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Grounding - Central Office and Remote Electronic Equipment Environments

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NOTICE

This publication presents Lumen's view of the generic requirements or guidelines that describe grounding methods for metallic frames and electrical power supplies associated with Central Office (CO) Switching Equipment, Remote Switch Units or Modules (RSV/RSV), Storage Program Control Switching Systems (SPECS) both analog and digital, or other telecommunications equipment that is installed within a building, normally referred to as Central Office buildings or Remote Equipment Enclosures.

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1. Introduction

1.1 General

This publication presents Lumen's requirements for electrical grounding methods for metallic frames, bays, and cabinets; and the electrical power supplies associated with a variety of Central Office Equipment (COE), or other telecommunications equipment that is installed within remote electronic equipment enclosures (EEEs), such as controlled environmental vaults (CEVs), remote huts, remote terminal (RT) cabinets, and customer premises equipment (CPE) installations (where the premise equipment is Lumen-owned).

NOTE: The requirements laid out in this publication are for both temporary and permanent installations.

General outside plant (OSP) bonding and grounding requirements (e.g., for buried and aerial cables, NIDs, etc.) are covered in applicable local and national Codes (such as the National Electrical Code® [NEC®] and National Electrical Safety Code® [NESC®]), as well as Lumen/ CenturyLink and Telcordia® OSP M&P's, practices and training documents.

Chassis grounds and other grounds internal to a relay rack or cabinet are fairly well covered in Chapters 5 and 8 of this document but also in Technical Publication 77350, Chapter 11; and in Telcordia® NEBS document GR-1089®.

1.2 Cross-Reference of Terminology

One of the most confusing parts of telecommunications grounding is the proliferation of terms (especially acronyms) that mean the same thing, but are used differently by various manufacturers, or are different in differing facilities. Because Lumen is an amalgamation of many historical companies, the same type of grounding equipment, bar, etc. may be called different things in different buildings depending on the history of ownership. Table 1-1 gives a cross-reference of some of the most common terms that may be found in this document or in various telecommunications facilities that mean essentially the same thing.

1.3 Requirement Applicability

The following applies:

SHALL	When this designation is used in a requirement, it denotes a binding requirement (not optional) due to fire, life, or safety reasons.
MUST	When this designation is used in a requirement, it denotes a binding requirement, but does not involve fire, life, or safety.
WILL or SHOULD	When this designation is used in a requirement, it denotes a condition that is a Lumen™ preference.

Table 1-1 Grounding Terminology Cross-Reference

Component	Names/ Acronyms	Place(s) Commonly Used
site principal ground point	OPGP MGB PANI bar TMGB MET PGP SPGP	RBOC COs telco sites built to RUS standards telco sites built to RUS standards Customer Prems Customer Prems OSP electronics sites OSP electronics sites
floor ground bar	COGB FGB	RBOC COs Telco COs built to RUS standards
Isolated Ground Zone	Isolated plane IGZ IBN SPG	RBOC COs telco sites built to RUS standards international term computer rooms
Integrated Ground system	Integrated plane	RBOC sites

	Non-IGZ CBN	telco sites built to RUS standards international term
Logic ground	LRE/G quiet ground signal ground	certain Class 5 switches copper loop testing equipment computer equipment
Ground Window Bus	MGB isolated-integrated bar SPCB	RBOC COs RBOC COs international term
isolated frame grounds bar	FGE/B GWB	certain Class 5 switches telco sites built to RUS standards
bar for metal < 6′ from IGZ	FOG ICB	certain Class 5 switches certain Class 5 switches
Surge Protective Device	SPD	newer term used throughout the industry
AC frame/equipment ground	ACEG green-wire ground bare copper wire PE	NEC® term NEC® term NEC® term international term

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2. General Requirements

2.1 Reasons for Proper AC and DC Grounding

For the safety of personnel and the protection of equipment, Central Offices and Remote Terminal locations shall meet the following requirements for both Alternating Current (AC) and Direct Current (DC) grounding environments.

2.1.1 Personnel Safety

All metallic parts within a ground plane and a grounding system shall be bonded such that voltage potentials cannot shock personnel. The grounding and bonding of metallic frames and raceways will minimize potential differences between these structures whenever the building or surroundings is struck by lightning, or whenever an electrical fault produces fault currents.

2.1.2 Equipment and Distribution Circuit Protection

If the grounding and bonding system is of sufficiently low impedance, overcurrent devices such as fuses and circuit breakers may interrupt/disconnect fault currents to prevent electrical fires and limit damage to equipment or circuit conductors.

2.1.3 Electrostatic Discharges (ESD)

The effects of ESD events are minimized by maintaining a bonded environment of low impedance paths between grounded points throughout the ground plane and grounding system. Many metallic parts of the ground plane are capable of storing electrostatic charges. Care must be taken during the installation and maintenance of ESD sensitive devices to ensure that static discharge from other devices and personnel (or even personnel wearing wrist straps) is properly transferred to well-grounded telecommunications equipment frames and chassis.

2.1.4 Reliability

The grounding system should resist deterioration and require minimal maintenance.

2.1.5 Equipment Operation

The grounding system should protect operating equipment and minimize the effect of disturbances originating outside the ground plane.

2.1.6 Noise Reduction

The grounding system should minimize electrical interference on operating equipment by maintaining a low impedance pathway (bonding) between ground points throughout the telecommunications system. Within isolated ground planes, the grounding will prevent or minimize the effect of noise currents and radio frequency (RF) energy.

2.2 Minimizing Grounding and Bonding Impedance

In a telecommunications environment, the most effective grounding and bonding system is the one with the least amount of impedance. In this document, wire sizes and connection methods are based on trying to provide a low impedance path at a reasonable economic cost.

Impedance (Z) is a combination of electrical resistance (R) to the flow of AC or DC current, and capacitive and inductive reactance (X) for AC behavior (note that reactance changes with the frequency of the AC signal). All of these values (R, X, and Z) are measured in Ohms (Ω). In a purely DC circuit, the resistance is the only factor. However, even in DC circuits, AC behavior can occur. Lightning currents, short circuits, impulses, etc. are all AC wave forms. All wire and connections have resistance. The smaller the wire, the greater the resistance. The smaller the metallic contact area in a connection (due to the physical size or shape of the connector; paint, oxide, excessive anti-oxidant compound, or other insulators; or a loose connection), the higher the resistance. In a telecommunications bonding and grounding system, inductance and capacitance are not purposefully added to the system; however, all wire has inductance, which is increased by turns/bends. For this reason, the minimum turn radius is 8 inches and any bend cannot exceed 90 degrees. (See Fig 2.1) Parallel conductors and some connections have capacitance.

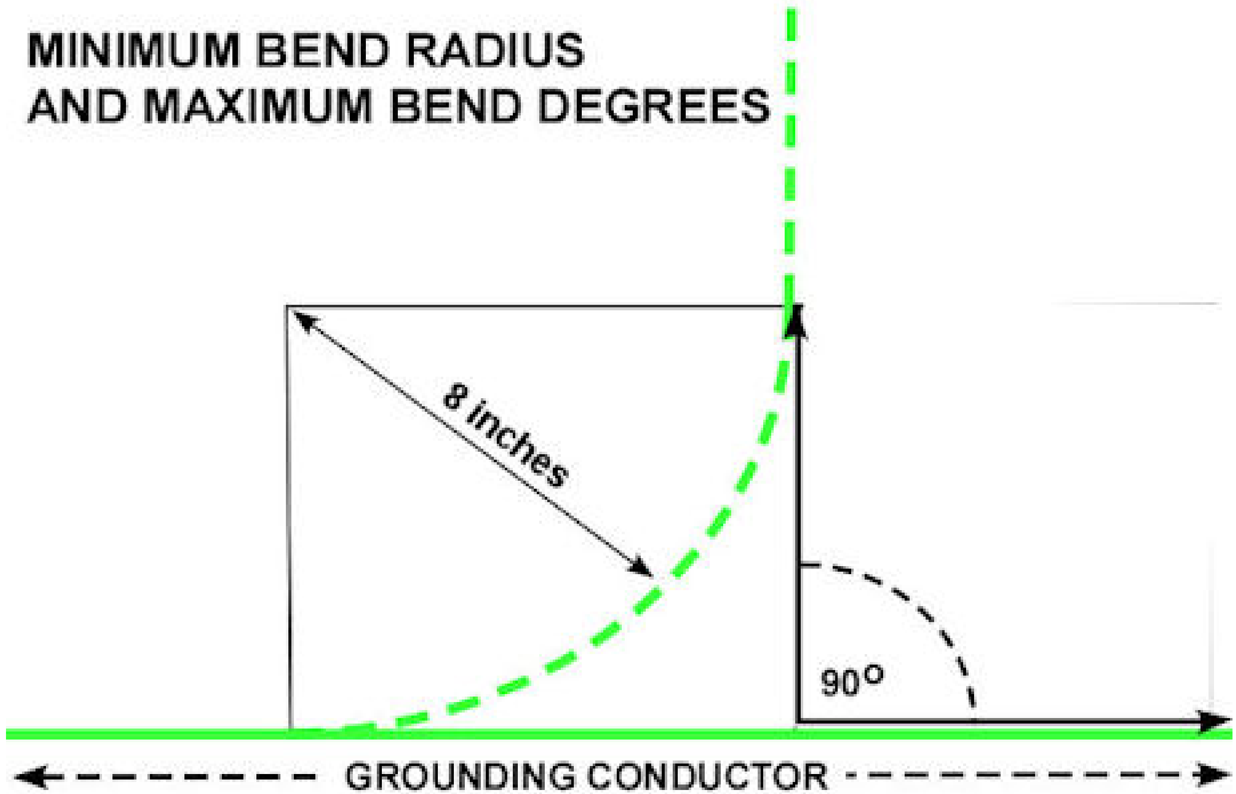
MINIMUM BEND RADIUS
AND MAXIMUM BEND DEGREES
8 inches
90°
GROUNDING CONDUCTOR

Figure 2-1

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3. Building Ground Requirements

3.1 Ground Electrodes

A ground electrode may be considered as a connector in a conductor path. An efficient connector is one that contributes insignificant impedance to the flow of current in the path. Generally, efficiency is ensured by provision of sufficient surface contact between a connector and the conductive components that it joins. A ground electrode joins metallic grounding electrode conductors to earth.

Note: Generally, the building grounding system is always considered as part of an Integrated Ground System. For additional information on Integrated Ground Systems, see Chapter 5 of this publication.

Earth surrounding an electrode must be considered as a conductor in series with a conductor path to some point in earth remote from the electrode. Earth resistivity is variable, dependent primarily on metallic mineral content, presence of electrolytic salts, acids, granular nature of the soil, soil compaction and moisture (see Table 3-1). The following factors that can affect the impedance to earth of a grounding electrode include:

- Temperature affects the resistivity. For example, resistivity increases drastically when the soil freezes, and for this reason, rod length below the frost line is all that can be considered effective. Current discharged into ground therefore will create a voltage differential between the electrode and remote earth that will be relative to the earth resistivity and the electrode - earth contact area.
- Over time, current flow may evaporate moisture around electrodes. This causes a condition known as soil potting. For this reason, rods should be located in an area where they can be watered, by natural rain, or artificially by a watering system.
- Grounding electrodes located adjacent to building foundations can affect the zone of influence required for proper electrode soil bonding. Where possible, placement of grounding electrodes must be equal to a minimum of one half of their length away from any structure or object that may impede the natural zone of influence.

A massive current discharge through a single electrode with modest surface contact with earth can create an extreme voltage differential between earth in the immediate vicinity and remote earth. Generally, this differential can be minimized by an increase in surface contact between electrode and earth, and by assuring that the electrode is in contact with permanently moist earth.

Since earth nearest the surface is more drastically affected by weather, an increase in the length of a vertical electrode will be more effective in decreasing the electrode to earth resistance than an increase in electrode diameter. A long electrode will penetrate further into permanently moist earth (where resistivity will be less). However, long single electrodes are not the most preferred grounding electrode in most situations. Ring (also known as buried halo) ground arrangements are usually best due to the multiplicity of interconnected electrode penetration points over a wide area.

Table 3-1 Typical Soil Resistivity Ranges

Soil Composition	Meter-Ohms
Sea water (reference)	1 - 2
Clay with no sand or gravel	3 - 160
Loam (sand, silt, and clay)	5 - 50
Limestone	5 - 10,000
Clay mixed with sand & gravel	10 - 1,350
Sandstone	20 - 2,000
Concrete (use 50 Ω-m for calculations when value unknown)	30 – 300
Chalk or Shale, or sandstone	60 - 800
Sand and gravel mixture	300 - 5,000
Quartzite, Granite rock	500 - 10,000
Slate	600 - 5,000

Before installing a grounding electrode at a CO or radio site, measure soil resistivity (with an earth resistivity tester, using the 4-point method; and preferably averaged at more than one location at the site) to determine the type and size of ground system to use. (There are computer programs to design a ground electrode system from an earth resistivity measurement, and some simpler equations are also given in this chapter.)

After installing the ground system, test it before and after connecting it. Impedance of the system measured with an earth resistance tester (often incorrectly referred to as a Megger™) using a 3-point fall-of-potential method with the middle (P) rod approximately 62% of the distance to the far (C) test rod (proper use of a meg-ohmmeter for measuring earth resistivity and impedance to earth, including that greater spacing between test rods, is described in IEEE 81®), should be (where economically practical) 5 ohms or less (3 ohms or less is preferred for NNS sites). In areas where the isokeraunic activity exceeds 30 lightning strikes per mi^2/yr., 1 ohm or less is the desired resistance to earth.

The use of clamp-on resistance meters (CORM) has been gaining popularity. CORM usage is described in Telcordia® BR 802-010-100; but there is easy potential for misapplication. Because "megger" measurements are generally more accurate, the use of CORMs for measuring resistance to earth is usually discouraged. If an existing ground electrode system cannot be disconnected to measure resistance to earth with the 3-point fall-of-potential method, a properly used CORM might prove useful. CORMs are especially useful for measuring continuity or isolation (see Sections 3.4, 6.3, and 8.21).

If a 5 ohm impedance cannot be obtained, contact a Lumen Electrical Protection Engineer for assistance. For (OSP) locations (e.g., CEVs, huts, cabinets, etc.) exceptions can be made to the requirements to measure soil resistivity and obtain 5 ohm resistance. Although 3-point fall-of-potential tests and 5 ohm resistance are desired, requirements for OSP locations are in Chapter 10 of this document. (the resistance of the ground electrode system shall not exceed the 25 ohms of NEC® Article 250.53A2 Exception).

Office ground electrodes commonly employed in Lumen installations are (1) the power utility's MGN (the connection between this and the site SPGP is known as the Bonding Conductor for Telecommunications, or BCT), (2) cold water metal pipes, (3) building steel, or (4) made grounding electrodes such as ground rings, etc. All of the aforementioned that exist shall be bonded together at the SPGP. The NEC® (250.104B) requires that gas piping be bonded only if it is likely to become energized, since we do not want to introduce electric ground current onto a potentially explosive system.

3.2 Acceptable Methods

The acceptable methods for establishing a made ground electrode (MGE) are listed below, in order of preference.

3.2.1 Ground Ring

Driven rods, which individually represent limited contact with earth, are used in multiple and bonded together with wire to create a common electrode. They are arranged in a pattern at or around the site to equalize earth potential in the area of the site. The primary conductor of a ground ring system often circles the building and is extended into the site by at least two conductors. These conductors should connect at opposite sides of the ring and terminate at the OPGPB (PANI- MGB) or interior ring/halo ground conductor. (Routing of these connections to the OPGP should cross as little interior building space as possible — if one of the routes is near the switch, it is better not to have the diversity.) Rods should be spaced 10-20 feet apart around the ring (greater spacing [up to double the rod length] should be used for longer/stacked rods). For the size of driven rods, see paragraph 3.3.

The advantage of a ring, as opposed to a straight line, is not to greatly decreased resistance to earth, but increased reliability in case the ring is cut in one location.

- The minimum length of ground rod(s) used in a driven ground, ring ground, or a supplemental ground system is 8 feet (2.44m). This minimum length is specified to ensure penetration to permanently moist earth.
- The depth of rod penetration is important. The rod should penetrate below the frost line and to a depth of permanent ground moisture for a most effective ground (it is preferable to get the entire rod below frost line if possible, including the ring conductor). The electrode must be installed at least 30 inches (76.2cm) below grade and at an approximate distance of 1/2 the rod length from the exterior wall (for RT cabinets, the electrodes need to be installed a minimum of 2 inches outside the perimeter of the concrete pad).
- Where rock bottom is encountered, the electrode may be driven at an oblique angle not to exceed 45 degrees from the vertical or buried in a trench that is at least 30 inches (762mm) deep. The upper end of the electrode shall be flush with or below ground level unless the above ground end and the grounding electrode conductor attachment are protected against physical damage (see NEC® 250.64B(1) and (2) and 250.70).
- At larger buildings (such as COs and radio sites), where future access to the ground ring may be necessary for additional external connections, rings must be installed with bottomless handholes for at least 2 of the rods (on differing sides of the building). Leads in the handholes should be tagged.
- The exterior ring must be connected to the top of the rods by an exothermic weld connection or an approved listed compression connection designed for solid wire.
- Metallic objects within 6 feet (of a ground ring should be bonded to it in order to minimize step/touch potential during a lightning strike.

If soil resistivity (in meter-ohms) is obtained by a 4-point measurement, ground field resistance to earth can be estimated in order to design a system to meet the max ohm requirement. The following equation gives the approximate value of resistance to earth when four 8 foot x ⅝ inch diameter rods are placed 16 feet apart in a ring/rectangle configuration buried 30 inches below grade (see Section 10.3 for more info on this configuration).

$$R_{e-4\mathrm{r}} \approx \frac{\rho}{20}$$

where:

ρ = average soil resistivity. Such values are obtained from a 4-terminal earth resistivity test (whose measurements typically have to be converted to ohm-meters by multiplying the test reading by 2ℓ, where ℓ is the distance in feet between any two of the four equidistant test rods, which are driven to a depth of $^{1}/_{20\text{th}}$ of the spacing, where the optimum spacing equals total depth [including cover] of the expected rod[s] to be used).

The next equation approximates the resistance to earth when three 8 foot x ⅝ inch diameter rods are placed 16 feet apart in a triangle configuration 30 inches below grade (this type of configuration is described in section 10.3 and shown in Figures 7-4 and 10-6).

$$R_{e-3\mathrm{t}} \approx \frac{\rho}{15}$$

The next set of equations are much more complicated but give the approximate resistance to earth when there are more than four 8 foot x ⅝ inch diameter rods placed 16 feet apart in a ring/square/rectangle configuration buried 30 inches below grade.

$$R_r \approx \frac{\rho}{n}\left(0.465 + 0.0655\left(\ln\frac{2n}{\pi}\right)\right)$$

where:

ln = the natural logarithm (base "e" [exp])

R_r = the estimated resistance to earth of the rods alone

n = the number of 8 foot long x ⅝ inch rods

$$R_w = \frac{\rho}{15.33n}\left(\ln(351n)\right)$$

where:

R_w = the estimated resistance to earth of the 2 AWG solid wire buried 30 inches below grade

$$R_m = \frac{\rho}{15.33n}(\ln(6.95n))$$

where:

R_m = the mutual resistance from interaction between the 30 inches deep buried 2 AWG wire and the ⅝ inch diameter by 8 foot ground rods

$$R_T = \frac{R_w R_r - R_m^2}{R_w + R_r}$$

where:

R_T = the total resistance of the ring

The calculated resistances in the formulas of these sections are at a frequency much lower than lightning. Due to soil ionization around the rods, wires, etc. at lightning frequency, the actual impedance may be twice as high as the calculated resistance. It may be wise to shoot for a resistance value of half the desired end result (e.g., if the user desires an impedance to earth of 5 ohms, design for a resistance of 2.5 ohms).

3.2.2 Deep Driven Rod

A minimum ⅝ inch (preferably ¾ inch) rod (stainless steel shouldn't be used in excessively alkaline soils — use copper-clad steel rods instead) should be driven down to a minimum of 40 feet and a reading of 5 ohms or less obtained (the 5 ohms pertains to CO type sites — see Chapter 10 for requirements for OSP types of sites). After 5 ohms is obtained, drive the rod 10 feet more if possible. Install a composite box around the top of the rod strong enough to withstand heavy loads. Connect the rod to the SPGP with a 2 AWG solid copper conductor. All connections to the rod must be treated with a conductive anti-oxidant/ corrosion prevention product. Make sure that all connections are pointed downward, with a minimum 8 inch bending radius.

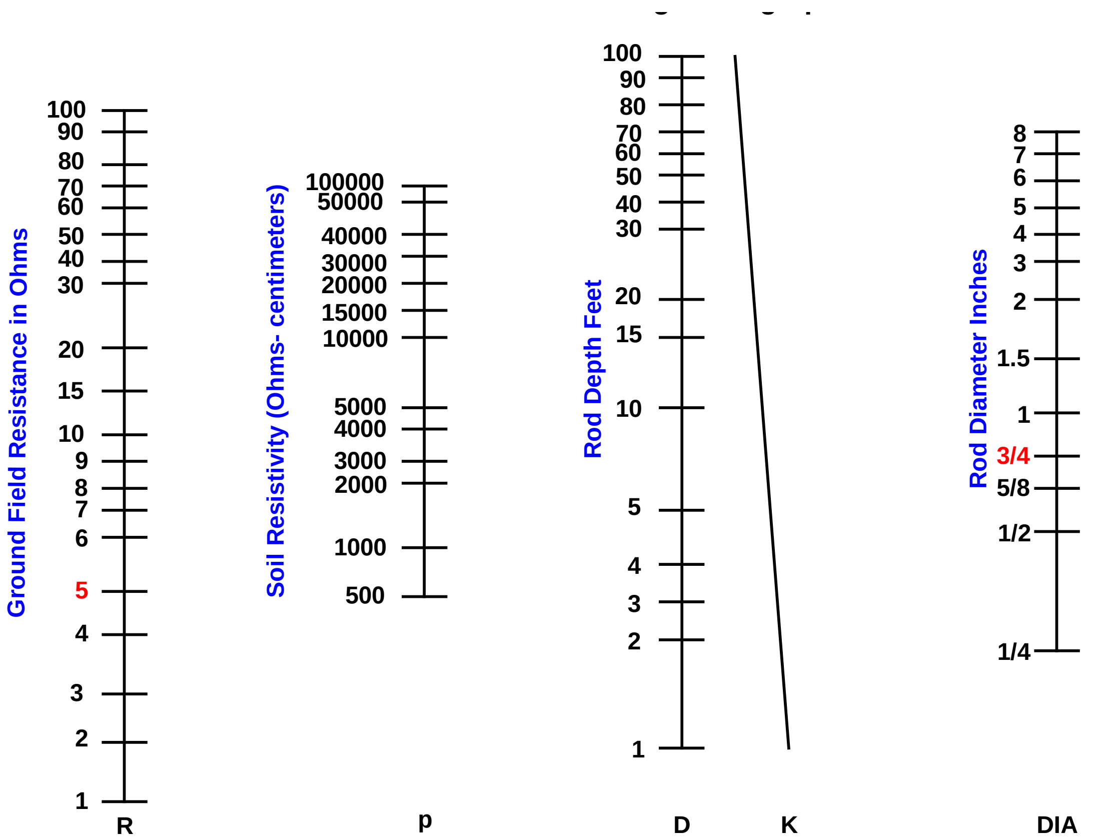
Note: Not all anti-corrosion compounds are conductive. Only products that are listed as conductive are acceptable to use where an anti-oxidant compound is required.

Figure 3-1 is a nomograph for determining the length of a deep driven rod if soil resistivity has been measured. Computer programs exist that will do the same thing as the nomograph. These same programs will also calculate the number of rods needed for a ground ring. The input to all these programs is a soil resistivity, obtained with an earth resistivity tester. Section 3.2.7 gives an equation for calculating the expected resistance to earth of a deep-driven (or any length) single rod, pipe or well, and section 3.3.1 gives simplified equations for multiple rods in a straight line (section 3.2.1 gives simplified equations for ground rings).

Generally, the effectiveness of a deep-driven rod or well is not linearly increasingly effective with length (as the nomograph shows), unless the soil resistivity continues to decrease as you go down (high resistivity soils on top and better ones below and/or a deep water table). This is why four vertical 8-10’ rods spaced 16-20’ apart typically provide a lower resistance to earth than a single 40’ rod (unless the water table is found between 11 and 40 feet of depth). However, a deep driven rod can be useful when multiple rods cannot be placed due to site considerations, or the water table will be contacted by the deep-driven rod when the traditional depth rods will not contact it.

3.2.3 Ground Grid or Array

A ground grid or ground rod array consists of a number of ground rods, between 10 feet and 20 feet apart. They are driven in a symmetrical pattern and interconnected with wire to form a grid or other such pattern such that each individual rod in the pattern is connected to at least two other individual rods in the pattern. The size of the grid may vary with the size of the facility protected. Ground grids are generally used to reduce step potentials (with even closer spacing than what is mentioned above) at electric generating stations, substations, and high voltage transmission towers. They offer little additional benefit to traditional ground rings for Lumen telecommunications sites but may still be used where they exist. The array is installed at least 30 inches below grade, and two conductors from opposing corners or sides are extended into the Central Office and connected to the OPGPB. If no OPGPB (or PANI- MGB) exists, one shall be established.



1. Select required resistance on "R" scale (2=Recommended and 5=Maximum)
2. Select measured or apparent resistivity on scale "P".
3. Lay a straightedge on "R" and "P" scale and intersect with "K" scale.
4. Lay straightedge on "K" scale intersect point and "DIA" scale 3/4 Inch and intersect "D" scale.
5. Point on "D" scan will be rod depth required for resistance on "R" scale.

Figure 3-1: Nomograph for a Deep-Driven Rod or Well

3.2.4 Counterpoise

Bedrock near the surface may prevent driving rods, or adverse soil conditions may limit the effectiveness of a conventional ground ring or grid system. A counterpoise ground electrode system may be necessary with, or in place of, the conventional rod electrode system. A counterpoise system may be less effective than a driven rod system in producing a low-impedance ground system. It serves primarily as a metallic path for the effective dissipation of lightning current. It is essential that as large an area around the building as practical be used as a field for the dissipation of current. A counterpoise system consists of a buried wire ringing the building, with rods if they can be driven (even if at an oblique angle), and buried uninsulated conductors extended from the four building corners in a straight line away from the building for no less than 25 feet. The ring and conductors are buried 30 inches below grade. The counterpoise system is sometimes called a radial system.

3.2.5 Lo-Ohm (Conductive) Concrete

Where the use of driven ground rods is not practical due to rock or soil conditions, Lo-ohm concrete may be used to form a large grounding electrode “plate”. A trench should be dug around the site at least 2 feet wide and 30 inches deep. 2AWG solid tinned copper wire is then placed into the trench and over-laid with the conductive concrete. The concrete can be used in its dry form and carefully placed along the trench so as to not cause wide dispersion of the concrete. The outer portion of the concrete should be compacted to form a concave shape with the 2 AWG wire pulled into the thickest (middle) part of the concrete. (See figure 3-3) At the point that the 2 AWG wire exits the concrete, it will need to be protected with tape or plastic tubing for 3 inches either side of the point of exit. (See Figure 3-2)

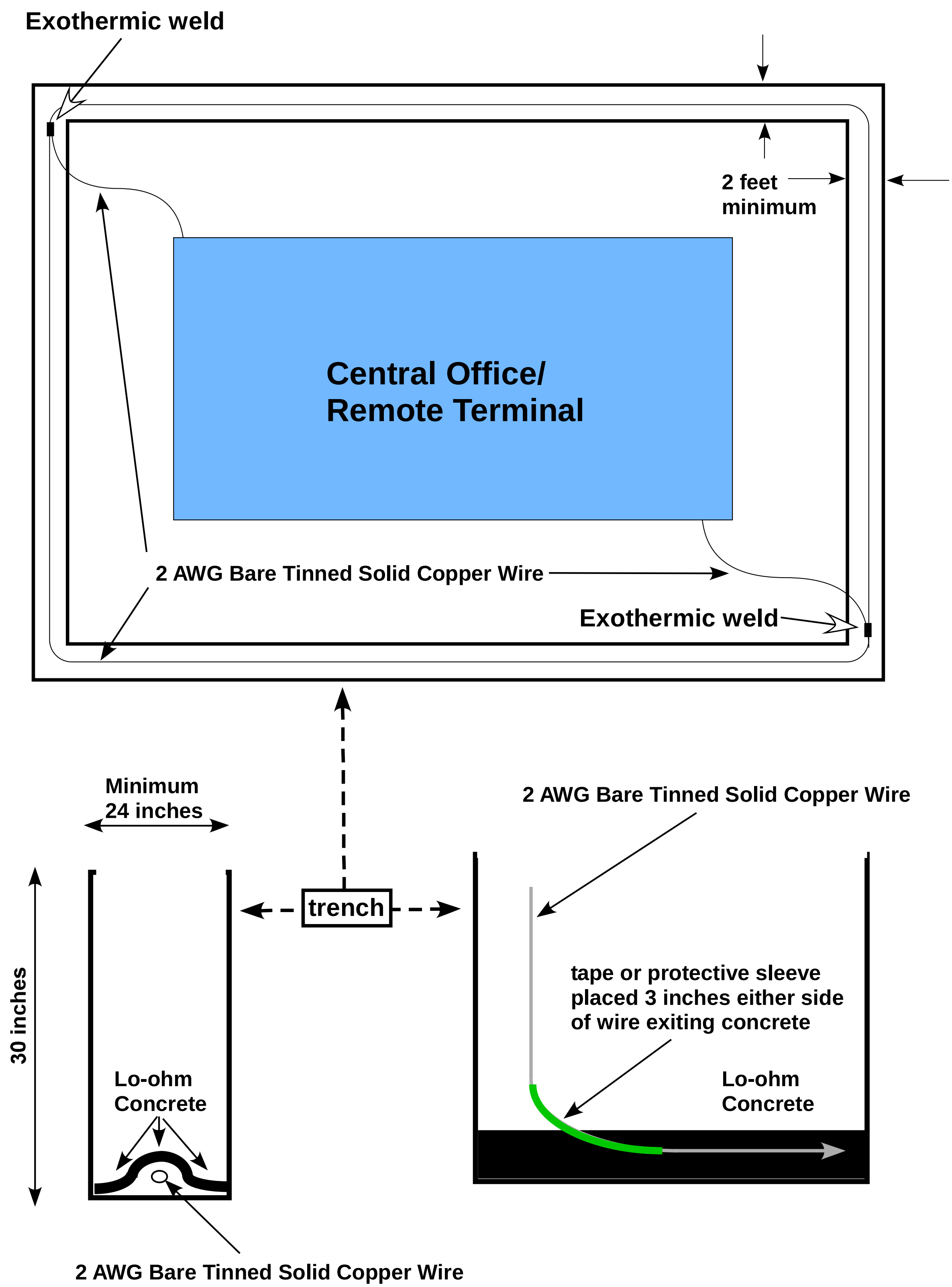


Figure 3-2 Lo-Ohm Concrete Diagram

Figure 3-3 Lo-Ohm Concrete Installation

Drag concrete bag along bottom of trench and spread concrete in a uniform thickness. Tamp down outer portion of concrete as shown in Figure 3-3.

3.2.6 Well Casings

Well casings, which generally penetrate earth to a considerable depth, constitute an excellent electrode with large current dissipating ability. It may be economical to install a well casing/pipe as a grounding electrode system rather than (or in addition to) a driven ground system. This may apply especially in areas where gravel or other earth conditions make effective grounding by means of driven rods impractical, or where a driven rod installation will cause considerable expense. While the National Electric Code® (Article 250.52A1) requires that the buried portion of the system be not less than 10 feet (3.05m), for Lumen applications, the buried piping should be electrically continuous for at least 40 feet (12.2m). The well may be located on the property outside the building or beneath the building.

The well need not be functional as a water supply to serve as an earth electrode. Generally, a driven supplemental ground field will be more economical than a well, supplied for grounding purpose only, unless special cost considerations are a factor.

3.2.7 Deep Well Ground

A steel well casing may be driven vertically into the earth at a point not less than 10 feet from the building foundation and capped not less than 30 inches below grade level. The grounding electrode conductors should be exothermically welded to the metal cap to maintain electrical continuity. The following formula may be used to calculate well size and resistance to earth (the same formula applies to a single deep-driven rod):

$$R_{e1} = \frac{\rho\left(\ln\frac{35L_r}{d}\right)}{2L_r}$$

where:

R_{e1} = the estimated ground resistance of a single rod (traditional length or deep-driven) or ground well casing.

L_r = the length of the rod or well casing in feet. A minimum of 20 feet must be used for any single well casing. The maximum casing length is limited to 250 feet.

d = the diameter of the well casing or rod in inches. A 2 inch minimum is required for well casings.

3.2.8 Backfilled Wells

In rocky areas, it may be almost impossible to find naturally occurring soils nearby that are good enough to obtain an adequate ground. In these cases, the only alternative may be a backfilled well.

The backfilled well typically consists of a rod(s), or a hollow section of metallic pipe (which may or may not have a rod inside of it), inserted in a drilled hole(s). This is then backfilled with water-absorptive bentonite clay, calcine petroleum coke, or low-ohm (conductive) concrete. Then the system is initially "watered".

Wells (or rods) backfilled with chemicals other than the more natural bentonite, coke, or concrete are prohibited in Lumen for environmental reasons.

3.2.9 Supplemental Grounding Electrodes

Many below-ground structures are used as supplemental grounding electrodes (supplemental means that at least one of the methods described in Sections 3.2.1 to 3.2.8 must be used as a primary grounding electrode, and supplemental electrodes must be tied to the primary electrodes). Some are listed in the rest of this subsection:

Public Water Systems - Public water pipes, though buried below frost lines, may not be a reliable grounding electrode due to the use of insulating couplings and nonmetallic pipes. If metallic water pipes in contact with the earth for more than 10 feet are available, they may be used as a supplemental electrode per NEC® 250.52A1.

Per NEC® 250.66(A) and 250.166(C), , the size of the conductor and meter jumper shall be at least 6 AWG (minimum resistance to the OPGP / PANI- MGB of 0.01 Ω) and sized based on the largest HSP entrance conductor (this is generally a 2/0 cable in PANI configured offices). Try to connect to the water pipe within 5 feet of its entrance (see NEC® 800.100(B)(2)). Interior metal water pipe must be bonded to the ground system per NEC® 250.104(A), regardless of whether it is a supplemental electrode. If the water utility does not permit grounding electrode conductor connections to their system, use a plastic section of piping between the interior and exterior water systems.

Building Steel – If no other bond exists to building rebar (see the paragraph later in this section on Ufer grounds) or to structural steel (as shown in Figure 3-5), a solid bond shall be made from the SPGP to the nearest appearance of building structural steel. The connection shall be no smaller than 2 AWG (in PANI configured offices, 2/0 AWG is preferred, with a cable resistance of less than 0.01 Ohms).

Central Offices with Basements - Figure 3-5 illustrates the following recommended methods of establishing a supplemental ground field for buildings with basements:

- Electrical continuity via structural steel columns or welded/strapped rebar.
- Since there are a large variety of construction methods, a supplemental ground field must be designed to fit the unique requirements of the building.
    - Figure 3-5, Plan "A" consists of ground rods at every column foot.
    - Figure 3-5, Plan "B" illustrates a typical configuration recommended for buildings that do not have vertical column continuity. The ground field conductors are run within 2 feet of the column footing but aren't bonded to it. Minimum requirement for ground rods, at columns on the peripheral conductor ring, is shown. Additional rods near interior columns may be employed. The ground field conductors, bonded either to steel columns or run near footings of reinforced concrete columns, provide a low impedance path for currents seeking earth through the columns. These bare conductors effectively disperse the current over a wide area to driven rods on the building periphery where permanently moist earth is more likely. Bare wire contact with earth adds to the surface afforded by rods, to reduce resistance to earth. The wire, which bonds the driven rods into a common electrode, also acts as an equalizer to minimize difference of potential in earth under the building. The ground field shall be connected to the building OPGP / PANI- MGB with at least two conductors from opposite sides of the field. These connections afford paths to the ground electrode for currents imposed on the equipment grounding system in the building and provide earth reference to the communication and electrical power systems. Generally, Plan "A" will provide a good ground electrode, but Plan "B", or any other similar plan may be used.

<u>Buildings without Basements</u> — Buildings without basements are assumed to be of medium or small size switching systems. For these buildings, an exterior driven ground system shall be employed as the primary ground electrode. The conductors entering the building shall terminate at the OPGPB/ PANI- MGB.

<u>Existing Building Additions</u> — A building addition abutted to an existing building may be provided with a separate water supply. This second water supply must be bonded to the OPGPB/ PANI- MGB

- When a common communication installation is housed in two closely adjacent buildings (i.e., separated by an alleyway) having individual grounds, the principal ground points shall be bonded together using a 750 kcmil conductor.

- Structural steel ground grids are provided in some types of building construction. They shall be bonded to the OPGPB/ PANI- MGB with a 2 AWG wire.

When it is suspected that operation of equipment is affected by a poor grounding system, earth resistivity measurements are recommended. A review of the ground electrode system should be done. Where it is proven that the resistance to ground is excessive, it may be possible to reduce it by adding additional rods, a counterpoise system, or by connecting the casing of a drilled well to the electrode system. Contact the Lumen Electrical Protection Engineer assigned to the region for assistance.

Other Ufer Grounds — Any concrete-encased metallic electrode (including rebar) can serve as a supplemental ground. These types of grounds are named after their principal investigator, Herb Ufer. The most common types include floor slabs on grade, including basements (already discussed in this section), tower footings, and buried concrete vaults without insulating coatings. Any of these can serve as a supplemental ground as long as an attachment can be made to the rebar. In fact, for all new buildings (and building additions), the NEC® requires that the rebar of the building foundation be bonded to the other grounding electrode(s). This can be done by bonding the rebar to an external ground electrode field (COGF) or to the SPGP. Ufer grounds are only more effective than direct-buried conductors when the resistivity of the concrete is lower than the surrounding soil (see Table 3-1).

3.3 Materials

3.3.1 Ground Rods

Stainless steel rods or copper-clad steel rods (with a minimum cladding thickness of 13 mils and an average cladding thickness of at least 15 mils) are allowable. They must be at least $^{5}/_{8}$ inch (15.87 mm) in diameter for lengths of 8 feet (2.44m) or more. Stainless steel rods must be of ANSI grade 32 or 34 alloy, which are resistant to corrosion. Copper is significantly more electropositive (cathodic) than iron or steel. Copper exposed to earth moisture near buried metal objects such as water pipes, fuel tanks, etc., can cause accelerated corrosion of iron or steel through electrolytic action.

Stainless steel is not significantly electropositive to iron or steel; therefore, it does not create the corrosive effect of copper (but is susceptible to corrosion in salty/alkaline soils; and thus, should not be used in those types of soils). However, stainless steel is more resistive than copper by several orders of magnitude. Because stainless steel rods are very costly, they only make economic sense at our more important CO, CDO, fiber backbone and Radio sites. However, the hundreds of thousands of OSP applications we have (CEVs, huts, RT cabinets, cable sheaths, homes, etc.) preclude the general use of these expensive rods. For OSP applications, copper-clad steel rods are the norm. Bare or galvanized steel rods, steel covered with stainless tubing, or hollow core pipes of any type must not be used as ground rods.

Nonferrous rods or their equivalent must be Listed and must not be less than ½ inch (12.7 mm) diameter (½ inch diameter rods are common when 5 foot rods are used in the OSP environment). Generally, solid copper rods are too soft to be utilized (will bend too much if driven in most soils).

The resistance to earth of ground rods driven in a straight line (as described for some site situations in section 10.3) can be estimated prior to installation if the earth resistivity (from a 4-pole test) in meter-ohms is known. For a simple 2-rod system (⅝ inch diameter x 8 foot rods), where the distance between the rods is 16 feet, and the connection is made with bare 2 AWG solid wire buried at approximately 30 inches, the equation is:

Note: *The values produced by all of the equations below are approximate, since no soil is homogeneous, and rounding and assumptions were made to simplify the calculations.*

$$R_{e2-\mathrm{L}} \approx \frac{\rho}{10}$$

For a 3 –rod (⅝ inch diameter x 8 foot rods) system in a straight line, where the rod separation is 16 feet, and the connection is made with bare 2 AWG solid wire buried at 30 inches, the approximate resistance to earth of the system is

$$R_{e3-\mathrm{L}} \approx \frac{\rho}{15}$$

For a 4 –rod (⅝ inch diameter x 8′ rods) system in a straight line, where the rod separation is 16 feet, and the connection is made with bare 2 AWG solid wire buried at 30 inches, the approximate resistance to earth of the system is

$$R_{e4-\mathrm{L}} \approx \frac{\rho}{19}$$

3.3.2 Exterior Ground Wire

Ground electrode systems employing driven rods or wire counterpoise are constructed by use of a 2 AWG solid tinned bare copper conductor buried in the earth. The wire should have smooth bends with a minimum bending radius (see Figure 3-6) of 8 inch (12 inch bend radii or greater are preferred if possible) no greater than 90^0. As the wire is subject to corrosion, solid tinned copper wire must be used exclusively at COs, CDOs, fiber huts, and Radio sites because it corrodes at a slower rate than any other economically acceptable wire.

NOTE: For locations that have an MGE that tests over 5 ohms and a braided/ stranded grounding electrode conductor was placed during the initial build, corrective action must be taken. The braided/ stranded grounding electrode conductor(s) must be replaced with solid tinned bare copper conductor(s).

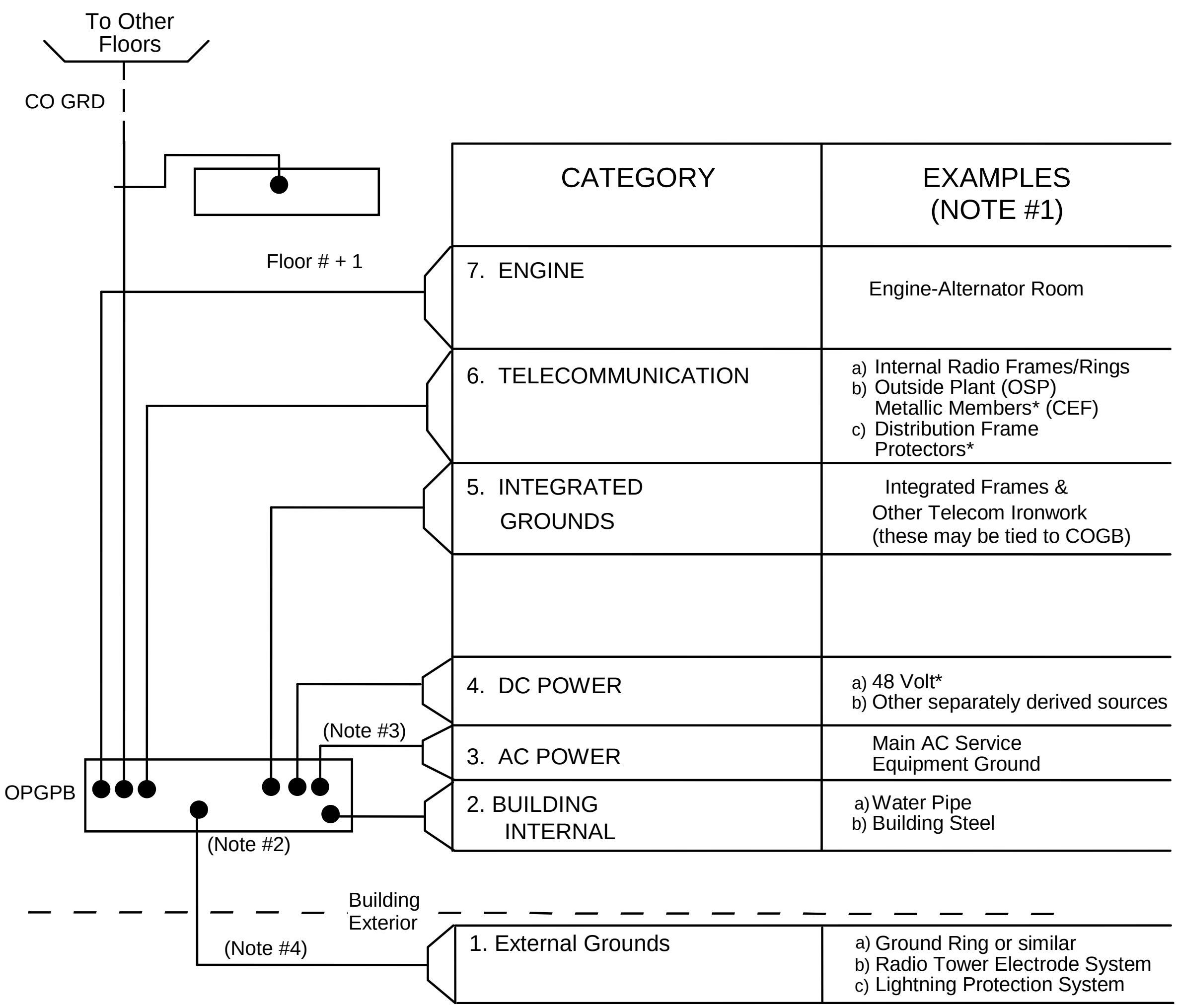
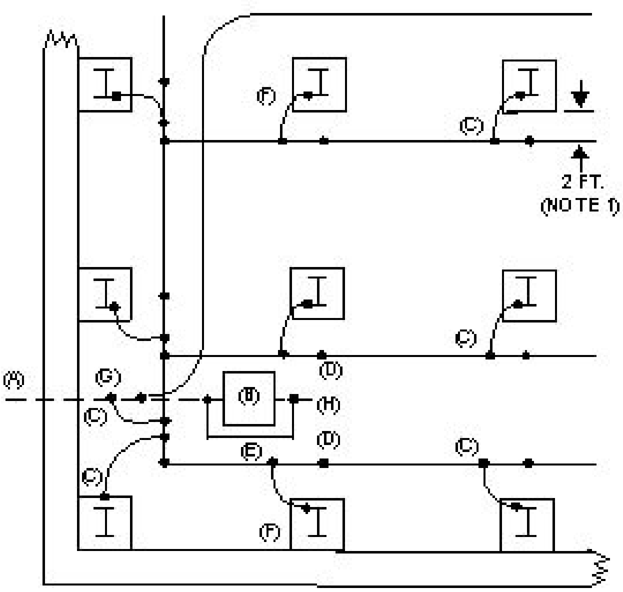


Figure 3-4: –Typical OPGP Connections

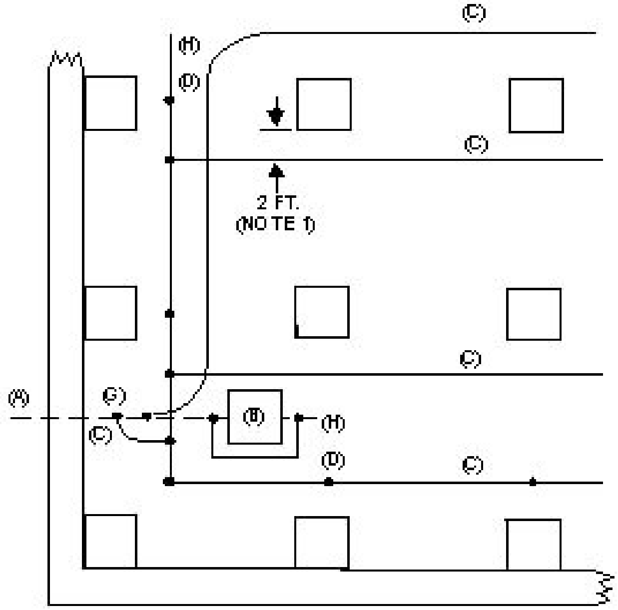
Notes:

1. Items marked with an asterisk may have ground bars associated with them.
2. The floor with the OPGP may also have a COGB depending on the area covered, and the number of holes needed.
3. AC neutral grounding electrode reference conductor size is determined by the NEC®.

4. Leads b) and c) should be tied to the external ground electrode (ring) outdoors if it can be accessed externally. If not, then those b) and c) leads should enter from outdoors as close as practical to the OPGP / PANI- MGB so as not to bring lightning too far into the building.
5. Where possible, the connections from internal building points will generally connect on the side on the bar opposite the connections from the grounding electrode points (no 180 degree bends should be used in any case).



BLDG PLAN A — Utilizes Rods at Every Column to Improve Grounding



BLDG PLAN B — Supplemental Ground Field for Buildings without Reliable Electrical Continuity through the Columns

LEGEND

(A) Water Pipe
(B) Water Meter
(C) 2 AWG Bare Tinned Copper Wire
(D) ⅝″ Stainless Steel Rod; 8 ft. (or 10 ft) long
(E) Denotes an Exothermic Weld of a. 2 AWG to a 2 AWG Wire
(F) Denotes an Exothermic Weld of a 2 AWG Wire to Column Steel
(G) Denotes an Exothermic Weld of a 2 AWG to Water Pipe or the OPGP
(H) Denotes an Exothermic Weld of a 2 AWG Wire to the Top of Rod (D)

NOTES

(1) Maintain a 2 ft separation between the grounding electrode wires and the columns for bending radius purposes

Figure 3-5: Various Methods of Establishing Supplemental Ground Fields in Buildings with Basements

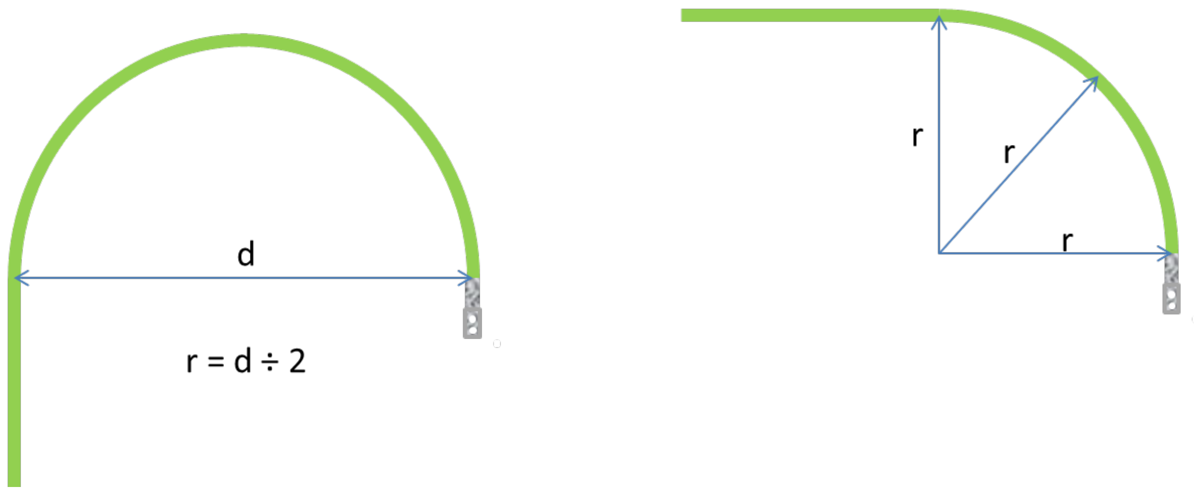


Figure 3-6: Measuring Cable Bend Radius

Note: Under no circumstances should a grounding conductor be looped or coiled. Excess conductor lengths should be removed to accommodate the required bend radius. Any single wire bend should never exceed 90^0.

The requirements for minimum wire size and type listed below are based on the relative significance of a number of factors: adequate conductivity, maximum longevity of the ground system, minimum galvanic effect on other buried objects, and physical resistance to damage. Other factors, such as the need to dissipate excessive RF energy in certain areas, may necessitate that larger wires be used. Types of wire for buried applications are:

- **Required — Minimum 2 AWG Bare Solid Tinned Copper Conductor**
  For general applications, this wire provides adequate conductivity, maximum longevity, minimum galvanic effect, and adequate strength. Wire should be soft (annealed) or semi-hard drawn commercial grade.

Tinned solid copper wire may not be stocked commercially and often cannot be purchased from commercial sources in specific quantity suitable for individual installations. It may be purchased through the purchasing arm of Lumen and may be made available to our contractors.

Pigtail leads are to connect individual rods to the 2 AWG wire only if exothermic welds or compression connections listed and approved for the application are employed to connect the pigtail to the top of the ground rod, and to the ring.

> **Note:** If the high strength copper compression ground rod method is used, drive the rod to the desired depth. Precrimp the ground rod before making the high compression ground rod tap connection. The reason for the precrimp is to increase rotational resistance by using the appropriate precrimp die. Do **not** pound the ground rod after the compression connection has been applied.

- **Restricted — Bare Solid Untinned Copper**
  Lack of tinning will increase the galvanic effect on buried steel or iron objects. Although bare solid tinned copper is required for exterior ground wire use in COs, CDOs, fiber backbone huts, and Radio sites, its limited availability and high cost make it somewhat impractical as a requirement for the hundreds of thousands of OSP applications (e.g., pedestal and NID grounding etc.) Although bare solid tinned copper is preferred, bare solid untinned copper is allowed in the OSP.
- **Prohibited — Insulated Conductors for general Bonding of Driven Grounds**
  Insulated conductors may be used only for connection of cathodic protection systems utilizing sacrificial anode rods and a DC current supply to render buried objects cathodic. They may also be used for connections between the OPGPB and the driven ground system. However, they are not to be used to connect the conductors together. The use of insulated conductors reduces efficiency of a driven ground system without adding equivalent benefits.
- **Prohibited — Buried Bare Stranded Copper Wire, Tinned or Untinned**
  This wire, generally acceptable for industrial systems' ground electrodes, is prohibited because of reduced life expectancy and increased galvanic effect. The life expectancy of the individual small strands exposed to corrosive conditions is significantly less than that of a single solid large diameter wire, and the galvanic effect on buried steel or iron is greater. However, stranded tinned copper conductors will be permitted as part of rooftop lightning protection systems.
- **Prohibited — Aluminum Grounding Wire** of all types shall not be used.

3.3.3 Interior Ground Wire

Wire employed in the equipment grounding system (which comprises the CO GRD system and extensions therefrom to frameworks, cabinets and other units requiring equipment grounding) shall be RHW type insulated commercial grade stranded copper wire (alternatively XHHW type copper conductor may be used, or TFFN wire may be used on wire sizes smaller than 14 AWG but must be protected at every tie point and point of impingement). Aluminum conductors shall not be used in the equipment grounding system. Note that there are two types of RHW insulation in use. One is a soft rubber that must be "fibered" at points of impingement or have a cotton braid outer covering. The other is a non-halogenated thermoset hard plastic, very similar to XHHW insulation. This newer RHW wire, when used for grounding, is green with yellow markings. Green insulation is required for interior ground wire unless it is "manufacturer wiring" for pre-wired bays, shelves, etc. THHN or THWN wire may be used for grounding in non-metallic conduits and in engine or AC electrical switchgear applications.

Interior grounding conductors of 1/0 AWG and larger size, whether run on walls, ceilings, cable rack hangers, or the sides of cable rack; and whether run horizontally or vertically, must be supported at least every 18 inches (passing between floors or walls, supports can be as far as 5 feet apart). For ACEG conductors run in conduit, per the NEC®, the conduit itself must be supported at least every 10 feet, and within 3 feet of every outlet, junction box, pull box, etc.

Types of wire for interior applications are:

- **Preferred — Stranded RHW (or XHHW) type Green-Insulated Copper Wire**
  In accordance with the NEC®, wires other than “grounding” conductors shall not be green. For example, the “grounded” -48 VDC battery return conductor[s] insulation shall be gray or black. The “green” requirement for DC grounding conductors is applicable as of Jan. 1, 1999 and applies to 6 AWG and larger conductors. It is recommended [but not required] for smaller wires, including chassis grounds.) Crimp connectors must be used with this wire. The insulation affords protection of the wire from paint and corrosion and eliminates strand separation at bends and incidental contacts of indeterminate impedance with metallic structures. It requires more frequent support than solid wire and requires stripping of insulation at bond points. Generally, RHW and XHHW wire is not made in sizes smaller than 14 AWG, so if smaller sizes are used due to manufacturer recommendation, they may be green-insulated TFFN if protected at all tie points and points of impingement.

  Note: Internal shelf grounding and shelf-to-rack/bay "chassis" grounding as well as engine and AC switchgear applications and wire run in non-metallic conduit may use THHN or THWN type wire. The green insulation applies to both frame grounding wires and reference/equalizing grounds/bonds. Because switch manufacturer's requirements inside isolated ground plane switch footprints supersede our requirements, they are not absolutely required to use green insulation.

- **Alternate — Stranded Bare Copper Wire**
  This wire must be connected with crimp connectors (unless it is a flat braid). It is easy to install and is commercially available. Special care must be employed to avoid separation of the strands at bends. Although separation of the strands does not reduce the wire's protection it does have a poorer appearance. Stranded wire requires more frequent support than solid wire. Bare stranded wire supported from walls must not be painted. Stranded bare copper wire is a grandfathered practice. Green-colored insulated wire should be used for all new installations of interior grounding wire outside the cable vault.
- **Alternate — Solid tinned or untinned bare copper wire**
  This wire can only be connected with an appropriate crimping tool with the properly sized die, lug, etc. designed for the size wire and connector, or by an exothermic weld. (An exception is made for solid flat ribbon conductor since there are no compression crimps designed for this type of wire.) Both solid and stranded braid flat conductors are limited to use in the cable entrance facility. Pressure type connectors are less reliable. The wire is somewhat more self-supporting than stranded wire, but difficult to install and straighten. It is not always available from commercial sources.
- **Prohibited — Peripheral Ground Rings Composed of lengths of Rigid Conductive Material**
  This would include UNISTRUT® channels, or steel pipe, bonded with straps or other conductive material around corners or other channel discontinuity points. Experience with this form of peripheral ring indicates that it is less reliable than a wire system. Dependence on continuity through numerous bolted joints increases the probability of high impedance in, or discontinuity of, the ring. Visual verification of ground continuity is often impossible. The cost is greater than that of a ring system using stranded wire and crimp connectors. It is recommended that any system of this type be replaced.
- **Prohibited — Aluminum Wire** of all types is prohibited.

3.3.4 Connectors

Thermal Welding — Thermal welding is approved for connections buried in earth, or for termination of copper conductors to copper, steel, or iron objects. Thermal welding includes both exothermic welds and brazing. After a thermal weld is made, it is advisable (especially for outdoor applications) to apply an anti-corrosion product to seal the weld and prevent the start of corrosion at the weld point.

- Exothermic Weld — The exothermic welding process utilizes graphite reusable or one-time ceramic molds to form welds. A crucible in the top of the mold holds a metallic powder which, when ignited, produces molten metal that flows into the form surrounding the joining point. The extreme heat melts the materials being welded too, forming a molecular bond. Each weld type requires a unique mold; and, because of limitations due to the gravitational flow requirement and heat generated by the process, there is some restriction of application. There are mold types designed with a cover and filter system (which eliminates smoke and sparks) for indoor use (a welding/cutting permit is still required). Reusable molds must be cleaned and dried between each use and cannot be used for more than 50 welds. Exothermic welds should never be pounded (to drive them further into the ground or to test them — tapping them to test them is acceptable).
- Brazing — Brazing may be used in place of exothermic welds in outdoor or cabinet installations. Brazing provides the same benefits derived from an exothermic weld. It requires the use of an external heat source (brazing torch) and brazing rod to provide the material for a molecular weld between parts to be joined. An exothermic weld is superior in some respects. Exothermic weld creates a uniform weld shape, and it produces heat so quickly that the weld is completed before dissipation of heat affects conductor insulation. It can also be used in areas where brazing might be prohibited because of nearby combustible material. Brazing is prohibited indoors.

Crimp — Crimp type connectors are required to maintain low resistance conductivity between wire and connectors. Crimp type bolted connectors are preferred for terminating stranded wire ground conductors to frames, cabinets, and other units requiring a bolted ground connection (bolts, nuts, washers, etc. used for crimp lugs must be stainless steel, copper-plated steel, zinc-plated steel, brass or bronze, or silicon-bronze and, when the mating surface and/or nut/bolt metals differ, it is even more imperative that a thin coating of conductive anti-oxidant compound between dissimilar metals is used). When exothermic weld connections are not employed, commercial crimp connectors may be employed, in accordance with restrictions outlined in the preceding paragraphs (see Crimp [Compression] Type Connectors illustrated in Figure 3-12). When crimps are made to solid wire or rods, hand crimps are not allowed (except for rare cases where the tool and die are Listed for that purpose). These crimps must be made with a hydraulic or electrical crimping tool. Crimp connectors must be made of copper or tin-plated copper. Coat outdoor irreversible crimps (and any mechanical connections made for purposes of being able to remove them for testing) with a conductive anti-oxidant compound.

- Two hole bolted tongue connectors are required for terminating grounding/ bonding conductors (except for manufacturer internal frame wiring and/or shelf chassis grounds, and grounding wires smaller than 14 AWG). One/single hole connectors are not acceptable except for the exceptions noted in the previous parenthetical. The contact area of metal to which the connectors are bolted must be prepared to a bare bright finish and coated with a conductive anti-oxidant compound before joining. When bolted tongue connectors are used outdoors, they should not have a skive (inspection hole), and they should be hermetically sealed (with shrink-wrap in a manner that provides a hermetic seal, or another method).

Clamp Type Pipe Connectors — Ground clamps may be utilized for termination of ground conductors at water pipes (if applicable), conduits, and fence posts (bonds to fence strands and support rails may also use mechanical clamps). Such clamps require periodic maintenance to ensure that a low impedance connection exists. For this reason, principally, they are deemed inferior to exothermic weld connections. There are a variety of designs available from prominent electrical connector manufacturers, which are adequate for such connections. Two clamps or a clamp designed for a two-hole connector are required when using a two-hole crimp connector. The clamps illustrated in Figure 3-11 are recommended for applications where pipe clamps are required.

Wedge Type Connectors — Impact driven wedge-activated compression connections may only be used in lieu of crimp type connection, when physical conditions warrant.

Solder Type Connectors — In conformance with NEC® Article 250.8(B), connections which depend solely on solder shall not be used for ground connections.

3.4 Connections

All connections of the 2 AWG wire to ground rods, building steel, or to other 2 AWG branch or bond runs must be exothermic weld or an approved compression connection designed and listed for the application to ensure a permanent low impedance connection. The exception to this rule is for connections between ground electrode fields where the OPGP/MGB of the site is not easily and closely accessed from outside the site. In those cases, 2-bolt mechanical connectors (or dual single-bolt mechanical connectors) are allowed so that a ground electrode field can be temporarily disconnected (after ensuring there is another ground reference) for testing. Or, place an external ground bar (that is connected back to the OPGP/MGB) on a wall or in a handhole, so that external connections can be made to it in all directions with 2-hole irreversible crimp compression connectors that can be unbolted from the bar to allow for testing of ground electrode fields. All connections buried or exposed to elements should be protected with an anti-corrosion compound.

Note: If the high strength copper compression ground rod method is used, drive the rod to the desired depth. Precrimp the ground rod before making the high compression ground rod tap connection. The reason for the precrimp is to increase rotational resistance by using the appropriate precrimp die. Do not pound the ground rod after the compression connection has been applied.

Continuity of connections (bonding) and conductors can be measured with a clamp-on resistance meter (CORM) (see Telcordia BR 802-010-100® or the CORM manufacturer's documentation for methods), a standard ohmmeter (less than 0.1 ohms for mechanical connections), or a continuity beeper with a standard digital multimeter (DMM).

3.5 Main Site Ground Bus (OPGP, SPGP or PANI- MGB)

- Establish an Office Principal Ground Point Bus on a standard bus bar located near the AC Service Entrance Switchgear (preferably on the inside of a building exterior wall, since this will limit lightning exposure of the equipment in the building). In PANI offices, this bus must be isolated from concrete or building steel.
- Bond the OPGPB (or Site Principal Ground Point Bus, or Master Ground Bar) to the Ground Electrode and to any supplemental electrodes which exist, as described in parts of 3.1, 3.2 and 3.3 of this document.
- Bond the OPGPB to the neutral bus of the AC Service Entrance Switchgear using a conductor sized per NEC® 250.66.
- The OPGPB becomes the source for the Office Vertical Equalizer system as described in part 3.7 of this document.
- In single-floor, single-room sites, the OPGPB should generally double as the COGB. If the OPGPB becomes too small to support all of the necessary connections, it can be extended to a COGB in accordance with the guidelines laid out in Section 3.8.
- Multiple OPGPs may exist in a building that has been expanded. This is allowed if an external connection of the ground electrode field for the added portion of the building back to the original ground electrode field was not possible, or if there is more than one AC entrance. In these cases, the OPGPs must be tied together with a 750 kcmil cable internal to the building. or by a 2 AWG solid, tinned copper conductor external to the building. Label them as OPGP 1, 2, etc.
- Grounding electrode connections (external ground fields, the connection to the HSP MGN, water pipe grounds, connections between separate OPGPs, etc.) to the OPGP (or MGB in PANI offices) should be routed as far away as possible from Network equipment areas (preferably outside the building, or against external walls of the building). If they are in a Network equipment area, it is preferable that they be routed at least 6 feet away from any Network equipment frames. They must be kept a minimum of 30 inches away from any Network equipment,

- The OPGP bar should be large enough to accept all of the connections shown in Figure 3-10, along with extra holes for future growth, dependent on office location and expectations. Generally, a ¼ inch thick by 4 inch high bar (of necessary length), with dual-hole lug holes of ⅜ inch dia., spaced on 1 inch centers, is acceptable. The bar should be set at least 3 inches off the wall or column. Drilling of existing bars is not generally recommended without the permission of the Design Engineer. Proper protection of nearby equipment and maintenance window guidelines must be followed if done.

3.6 Identification of Grounding Conductors

"DO NOT DISCONNECT" tags shall be provided at both ends on all grounding system conductors at water pipes, ground windows, power plant(s) or OPGPs when the connector is a lug or other disconnectible device. A tag identifying use and/or far end termination shall also be attached to grounding system conductors at the various points of attachment to grounding system components or equipment within the structure.

3.7 Design Parameters of Vertical Equalizer System

A Telecommunications Bonding Backbone (TBB) (more commonly called a vertical equalizer/riser [VGR]), is required in multifloored buildings to bond the floor COGBs/FGBs together and to provide earth potential reference to the CO GRD system. The vertical riser functions as a current path for ground current interchange between discharge ground circuits on various floors during periods of load imbalance, as a low impedance path to battery for fault current, and, through its low impedance connection to earth, effectively extends close to earth potential to each of the COGBs. Any floor COGB may be considered as an appearance of earth ground and any equipment requiring connection to an earth ground for proper operation and/or protection shall be connected to the COGB on the same floor as the equipment.

Figure 3-7 illustrates typical routing and connections of a CO GRD system vertical equalizer. A vertical riser must consist of a continuous length of 750 kcmil conductor. The vertical run must be as straight as practicable, preferably with only minor bends to avoid obstructions such as floor beams. Sharp bends are prohibited. A minimum bending radius of 8 inches is required for all grounding wires (12 inches is preferred for indoor wires) with a bend no greater than 90^0. Splicing of the vertical equalizer by any means other than smokeless exothermic weld or compression type in-line splice connections are prohibited.

The vertical equalizer must be located so that the horizontal portion of the run to the office principal point bus is as short as practical.

In some large structures, multiple vertical ground risers may be necessary (see Section 3.8). To avoid differences in potential between proximate equipment frames, bond vertical CO GRD risers together at every third floor to limit the difference of potential between the bond points (this horizontal equalizer bond is known as a Ground Equalizer, or GE). Horizontal 750 kcmil bonds (every third floor) between vertical CO GRD risers may be provided to serve as the conductive medium for nominal ground current return of older equipment that does not have the frame ground and return separated (such as some D4 channel banks, SLC-96™, and DISC*S®).

3.8 Design Parameters of Horizontal Equalizer System

A CO Ground bus (see 5.7 for design parameters) is required on every equipment floor of buildings utilizing the CO GRD system. The bus should be located on a column or wall or other accessible location that best serves the requirements of the physical design of the building. The location of the busbars will be such that:

- The maximum conductive run length between a bus and the furthest grounded equipment unit must not exceed 200 feet and must not extend beyond the perimeter of a square superimposed on a circle of 100 feet radius from the bus location. This restriction is based on the hypothesis that a single bus located in the exact center of a 200 X 200 foot building may serve all equipment located on the same floor (see Figure 3-9).
    - Figure 3-8 illustrates the maximum area that may normally be served by one CO GRD bus. It is recognized that physical design of buildings may exceed the parameters outlined above, in which case two or more CO ground bars per floor served by separate vertical equalizers individually terminated at the office principal ground point may be required. Specific design requirements are covered herein under paragraph 3.7, "Design Parameters of Vertical Equalizer System".

  - Sometimes, a COGB/FGB bar is too small to accommodate all the connections required by equipment growth. Generally, bonding main and individual aisle stringers (stringers are smaller grounding conductors running down the aisle) to horizontal equalizers (which are essentially, an extension of the COGB) can alleviate this overcrowding. In large buildings, as noted in Section 3.7, there may also be another COGB (from a separate vertical riser) on the floor, which can be used (as long as connections meet the distance limitations of the first bullet above). However, if additional COGB connection space is needed, the COGB can be extended with another bar. Preferably this bar should be located within 20 feet (it will usually be much closer) of the original COGB. However, it can realistically be placed anywhere within the 100 foot radius mentioned above. Any cable connected to this "COGB extension" must still meet the distance requirements noted in the first bullet above, with the distance measured back to the original COGB. The "COGB extension bar" must be connected to the original COGB (or to the vertical equalizer) with a 750 kcmil cable.

- The ideal location for the placement of buses on equipment floors is approximately in the center of the equipment, which should result in approximately equal run lengths of horizontal equalizers and conductors extended therefrom.
- The bond between the vertical equalizer and the COGB/FGB must be as short as practicable to minimize impedance, preferably less than 20 feet.
- All runs of CO GRD equalizer conductors must be routed so that loops (U shaped configurations) are avoided to minimize the length of such runs. All ground connections of the horizontal equalization system must be made with exothermic or crimp type connectors. All cable to cable or cable to busbar connections should be made with cables arranged to flow fault currents in the direction of the OPGPB or ground source (this is much more important for cables than it is for busbars — while flow towards the ground source should be attempted with busbars, in some cases, physical limitations may impede doing this).

- As indicated in Figures 3-8 and 3-9, horizontal equalizers that tie to discharge ground buses of older BDFBs or on horizontal ground equalizers of toll system discharge circuit conductors shall normally be extended into at least each quarter section of the building. These conductors shall bond BDFB return buses and ground equalizers to afford a path for the interchange of current as the increase and decrease of current flow occurs independently in each discharge circuit.

Note (see Figure 3-9) that older BDFB equalizers may also be horizontal equalizers, and that more than one BDFB can use the same equalizer. Note that newly-placed BDFBs that will serve only equipment that has return isolated from the frame ground [DC-I] (equipment with return bonded to the frame is known as DC-C, and includes D-4® channel banks, SLC®-96 and Series 5, and DISC*S®) are not required to have their return bus connected to a COGB (through a horizontal equalizer). If these newer BDFBs are fed from a DC plant with a remote ground window, they should not have their feed return conductors run by the ground window and bonded to it (as was commonly done in the past). New equipment should not have shared return and frame grounding (i.e., all new equipment should be DC-I instead of DC-C); however, if 2-wire DC equipment is used, it must follow the rules in Section 9.10.

- A reasonably direct equalization path should be established between discharge ground points because large equalizer current flow is expected whenever two or more power plant circuits feeding older BDFB or other toll equipment equalizers terminate on the same floor and the load is heavy on one or more and light on others. Wherever horizontal equalizers run within reasonable proximity to other such runs, they must be bonded together so as to form a direct conductive path, supplementing the path afforded by connection of CO GRD equalizers to the COGB. Such bonds are shown in the lower right of Figure 3-9, indicated by the BDFB and “duct bay” equalizer run closely together. They should be bonded with at least a 6 AWG. There is no formula for application of such bonding. As a rule of thumb, conductors in proximity are eligible for bonding if:
    - Points of proximity occur further than 35 conductor feet from the COGB.
    - Total conductor length via the COGB between proximate points is > 70 feet.
    - Direct bond between points of proximity will result in a path between discharge ground conductors of less than one-half the length of the “equalizer stringer” (see cable [B] in Figure 3-9 for an example).
        - Examination of a grounding schematic may reveal other conditions where supplementary bonds will significantly reduce the length of current paths between discharge ground conductor terminations.

-

3.9 CO GRD System Raceway Application

The use of raceways for support of equipment grounding conductors other than those associated with the AC equipment ground system is generally prohibited except for sleeves through floors and walls (see NEC® Article 300.11(C)), and for short pieces used as guards against damage, or where no other form of support is practical. When raceways are so employed, they shall be of insulating material, such as PVC plastic conduit or fiber duct (see NEC® Article 352). The equipment grounding conductors should always be run and supported so that as much of the runs as practicable may be visually inspected.

The only exception to the use of nonmetallic raceways shall be for installations where local electrical codes specifically prohibit the use of raceways of insulating material. Short runs of metallic raceway, principally rigid conduit (RMC), may then be used. These sleeves, guards, or short supporting runs must be short-circuited at each end by means of a 6 AWG cable bond between each end of the sleeve and the ground conductor(s) run therein. Connectors at conduit ends shall be clamp type "pipe" connectors; and at the conductor shall be crimp parallel cable connectors.

The bonding of metallic raceway to the enclosed ground conductor is important. A ring of magnetic material around a ground conductor creates an inductive impedance in the ground conductor during periods of fluctuating current flow. In addition to raceway, any magnetic material that forms a complete ring, such as U bolt supports, etc. should generally be avoided. Bonding of such rings to the ground conductor therein effectively short-circuits the ring to eliminate the inductive impedance and in addition provides equipment grounding for the metal enclosure. In the past, many such installations were inadvertently left unbonded. Therefore, use of plastic or other nonmetallic sleeves is recommended to ensure a reliable equipment grounding system. (See also Section 9.2.1 for further information on what types of “girdling” is allowable.)

In some cases, AC raceways (including conduit) may seem like a convenient support structure for DC grounding wires. However, NEC® Article 300.11 prohibits this practice. Per Lumen/ CenturyLink Technical Publication 77350 (Installation), DC grounding conductors can be secured to cable racks, hangers, or other suitable framework, but not on AC conduit or raceways. Refer to that publication (and specific section) for more detail.

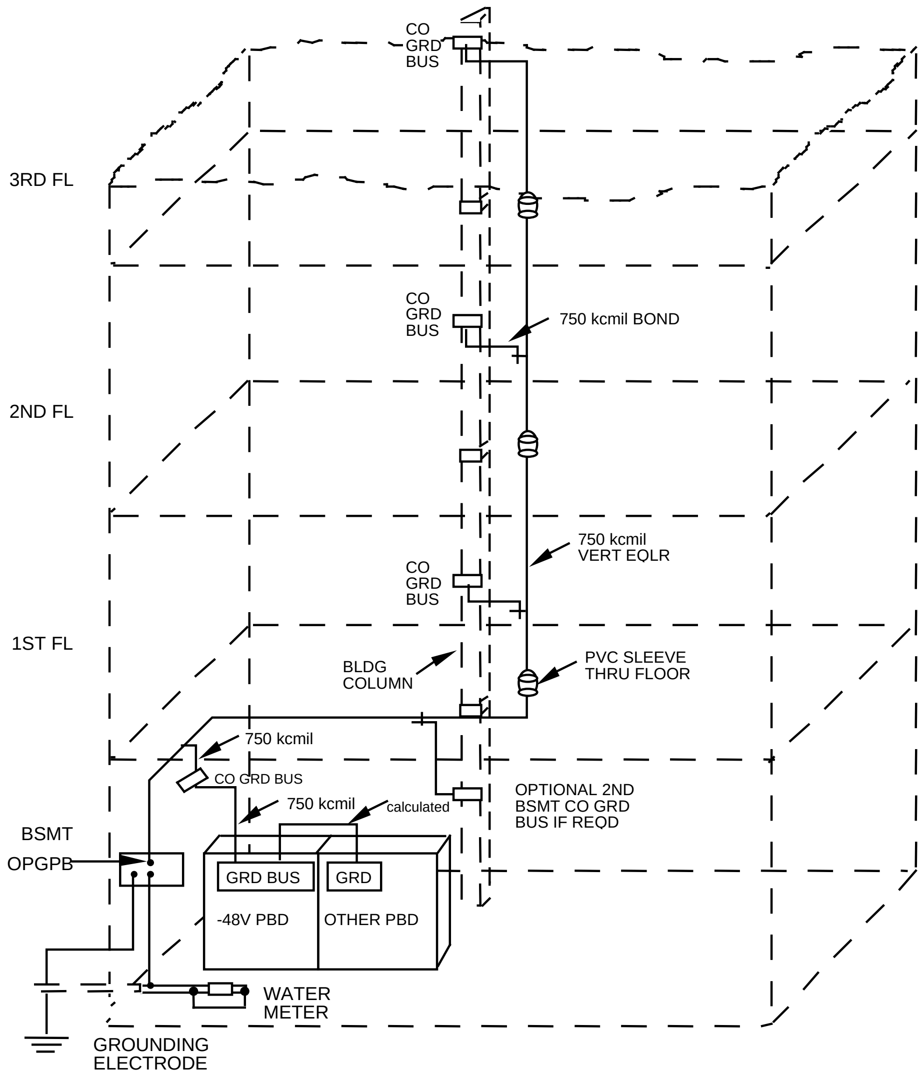
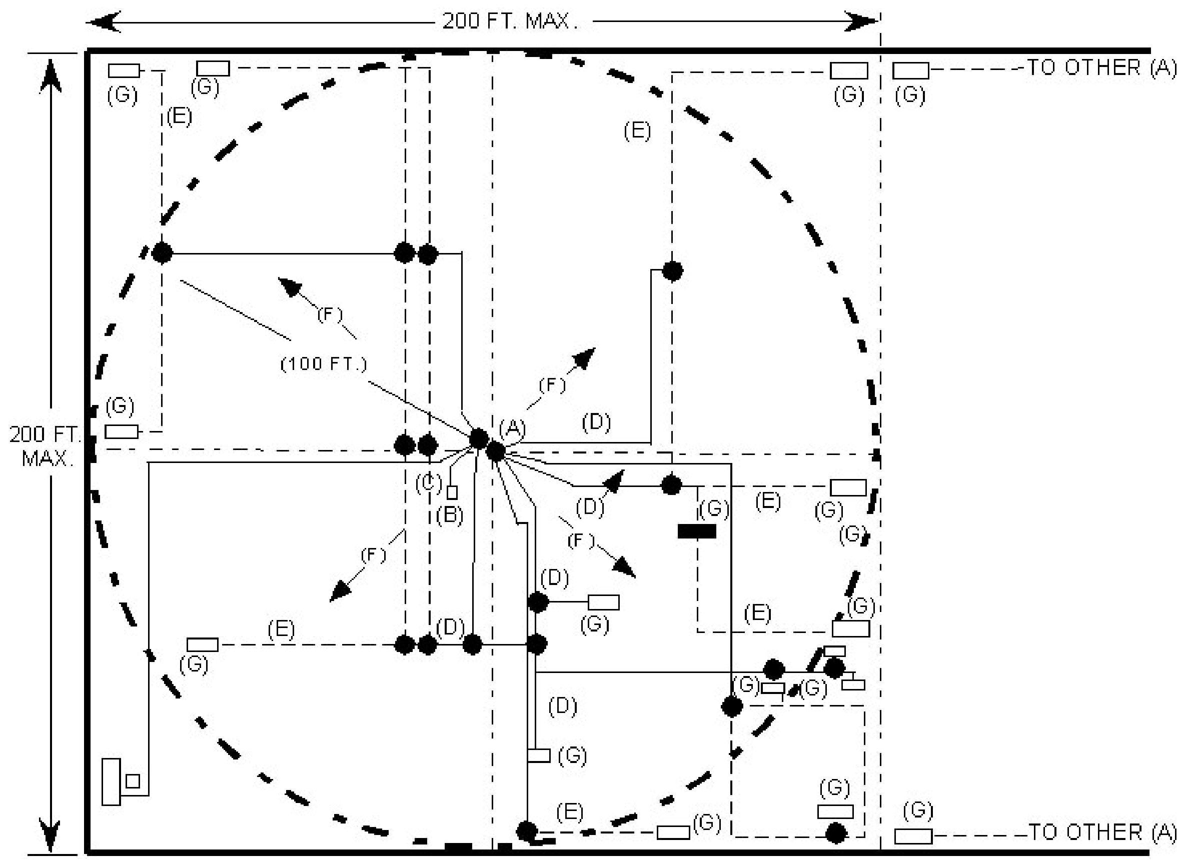


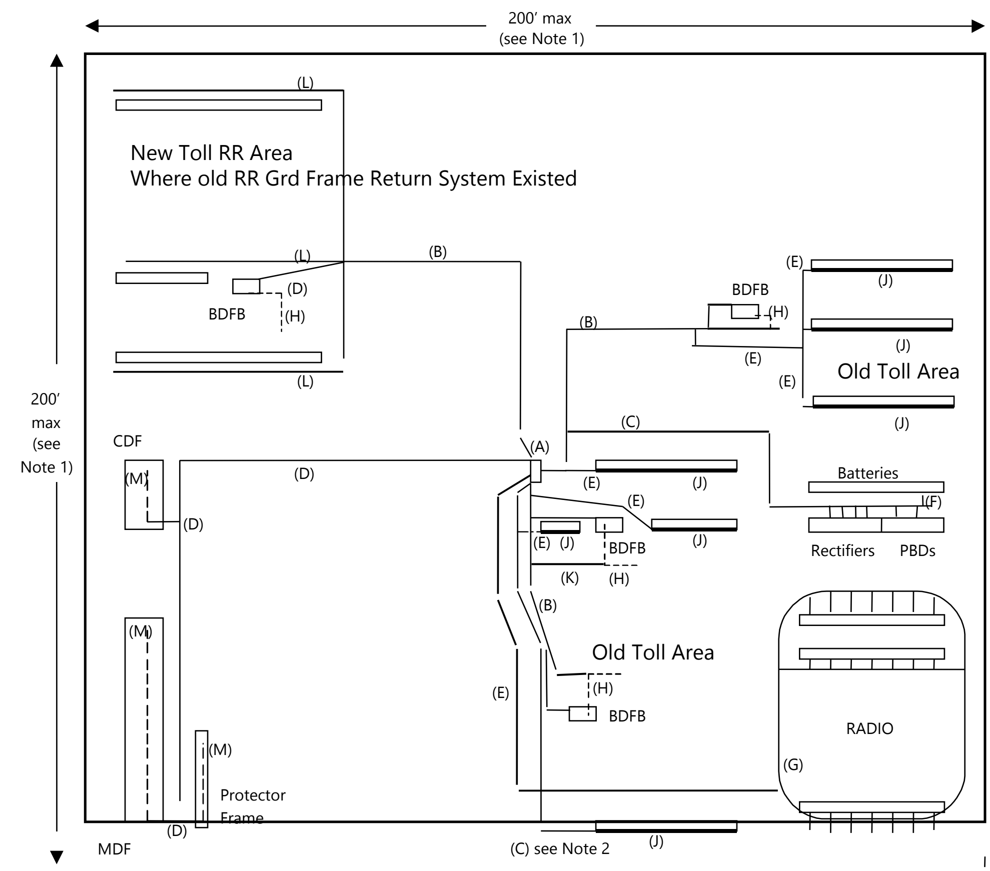
Figure 3-7: Typical Routing of a Vertical Equalizer and Placement of CO GRD Buses in a Multifloored Building with a Basement



LEGEND

(A) CO GRD Bus (COGB); aka FGB
(B) 750 kcmil Vertical Equalizer
(C) 750 kcmil bond
(D) 750 kcmil Horizontal Equalizer
(E) Conductive Ground Paths
(F) General Direction of the Horizontal Equalizers
(G) Unit Requiring Equipment Grounding

Figure 3-8: Representation of the Maximum Area to be Served by a Single COGB



LEGEND

(A)	Floor CO GRD Bus (COGB)	(G)	2 AWG Radio Ring Ground
(B)	750 kcmil CO GRD Equalizer	(H)	Return Conductor
(C)	350 kcmil CO GRD Equalizer	(J)	Duct Bay e/w 1" Pipe (can't use for new bays)
(D)	1/0 AWG CO GRD Equalizer to Frames	(K)	750 kcmil Ground Bond to old BDFB RTN bus (always accompanied with D frame GRD)
(E)	2 AWG CO GRD Equalizer	(L)	350 kcmil RR GRD Bond (older arrangement)
(F)	6 AWG minimum Frwk GRD Bond (for PBDs/Rects sizing see Sec. 5.4.1)	(M)	Distribution or Protector Frame GRD Bus

NOTES

(1) Max. run length to the furthest point must not exceed 200 ft from the COGB. The area served by a COGB must not exceed that bounded by a square superimposed on a 100 ft radius circle around the COGB. The Vertical Riser and Horizontal Equalizers must be run as directly as possible.

(2) Horizontal Equalizers (other than those used for grounding of radio ring or protectors) may be used as multipurpose CO GRD conductors (e.g., the equalizer for toll Relay Racks may be tapped to extend CO GRD to frameworks or cabinets or distributing frames in the vicinity).

Figure 3-9: Typical Horizontal Equalizer System on a Toll Equipment Floor

3.10 Grounding and AC Feeds for Separate Buildings

In some cases, multiple buildings (including temporary or permanent trailers housing working Network equipment) may be found on a Lumen property. Whether or not they should have their own ground electrode systems and whether they should be tied together is mainly dependent on three factors: size of the building in relation to the main building, its distance from the main building, and whether the buildings have their own AC Service Entrances.

Radio site buildings/towers/antennas are a wholly separate matter. They serve as lightning attachment points. Grounding guidelines for radio site buildings, towers, and antennas are in Chapter 7. The following guidelines are not as stringent as those for radio towers, but they do borrow heavily from those guidelines and Figures.

Per NEC® 250.32, buildings supplied from common AC service must have each building tied to at least one acceptable grounding electrode field. If the grounding electrode is a "ring" (or the field is within 100 ft of the supplementary building), and the new building is within 6 feet of the original building, the new building ground system must be tied to the ground electrode of the existing building in accordance with the aforementioned NEC® Article (see Figure 7-1 for an example). When the grounding electrode of the existing building is not nearby, it is permissible to establish a new ground electrode field, and it is always desirable to tie them together, but only required when the 6 foot rule is met.

When the supplementary building is made of metal, the metal of the building shall also be bonded to the ground electrode field.

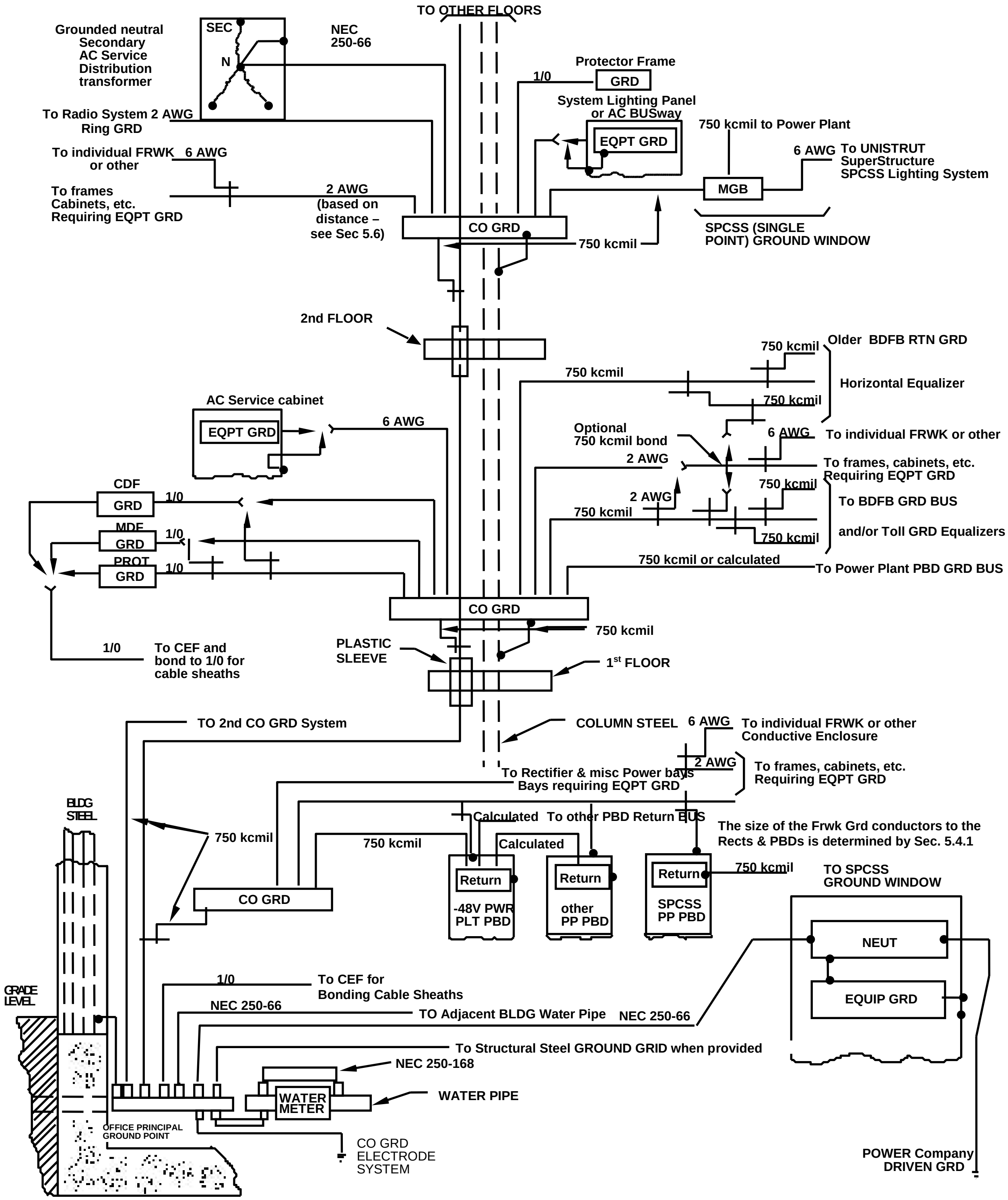


Figure 3-10: Typical Equipment Connected to a CO GRD System

The AC feeder from the main building to the separate building or structure (including standby engine outdoor enclosure structures) must comply with the requirements of NEC® Articles 225.30 through 225.34, and grounding requirements of 250.32. (Although exceptions in the Code sometimes allow for this AC feed to not have a disconnect at the "new" building, Lumen requires it. There must be a disconnect at the original "main" CO building — mounted on the exterior wall or just inside the CO). It is highly preferable that the AC feeder in this case be run in metallic conduit (whether buried, or above-ground).

Whenever a supplementary building or cabinet is fed from the same AC service as the primary building, and the supplementary building/cabinet is not completely under the lightning "zone of protection" (as defined for different geometries by NFPA 780®) of the main building, the potential is there for the AC feed to conduct lightning back into the primary building. In these cases (most of them), installation of a surge protective device (SPD), as well as the routing of the AC feed through the building becomes important. These same principles apply to outdoor engines.

Note: The NFPA 780® "zone of protection" only applies to buildings equipped with a lightning protection system. For buildings not equipped with a lightning protection system, generally, no "zone of protection" exists.

For a shared AC power distribution system (reference Figure 7-19 — although it references Wireless equipment, treat the Wireless equipment as if it were a separate building) SPD's need to be installed within 5 feet (typically at the Service Disconnect) of where the AC source enters the supplementary building. Both transverse and common mode SPD's should be provided. Even with an SPD at this point, if the feed from primary building to the supplementary building transverses a distance of 50 feet or more outside of the zone of influence, it may be advisable to install an additional SPD at the point the AC service leaves the primary building (and bond this SDP to the ground electrode field of the primary building). Because the most important Network equipment is DC-powered, it is never allowable to run -48 VDC out from a CO to feed an external building/enclosure (even when the outside structure is under the "zone of influence", and even if SPD's were to be installed on the DC feeds). (In the OSP world, feeding nearby RT cabinets from another RT cabinet is allowed because of the short distances and fewer number of circuits affected by the smaller power plant.)

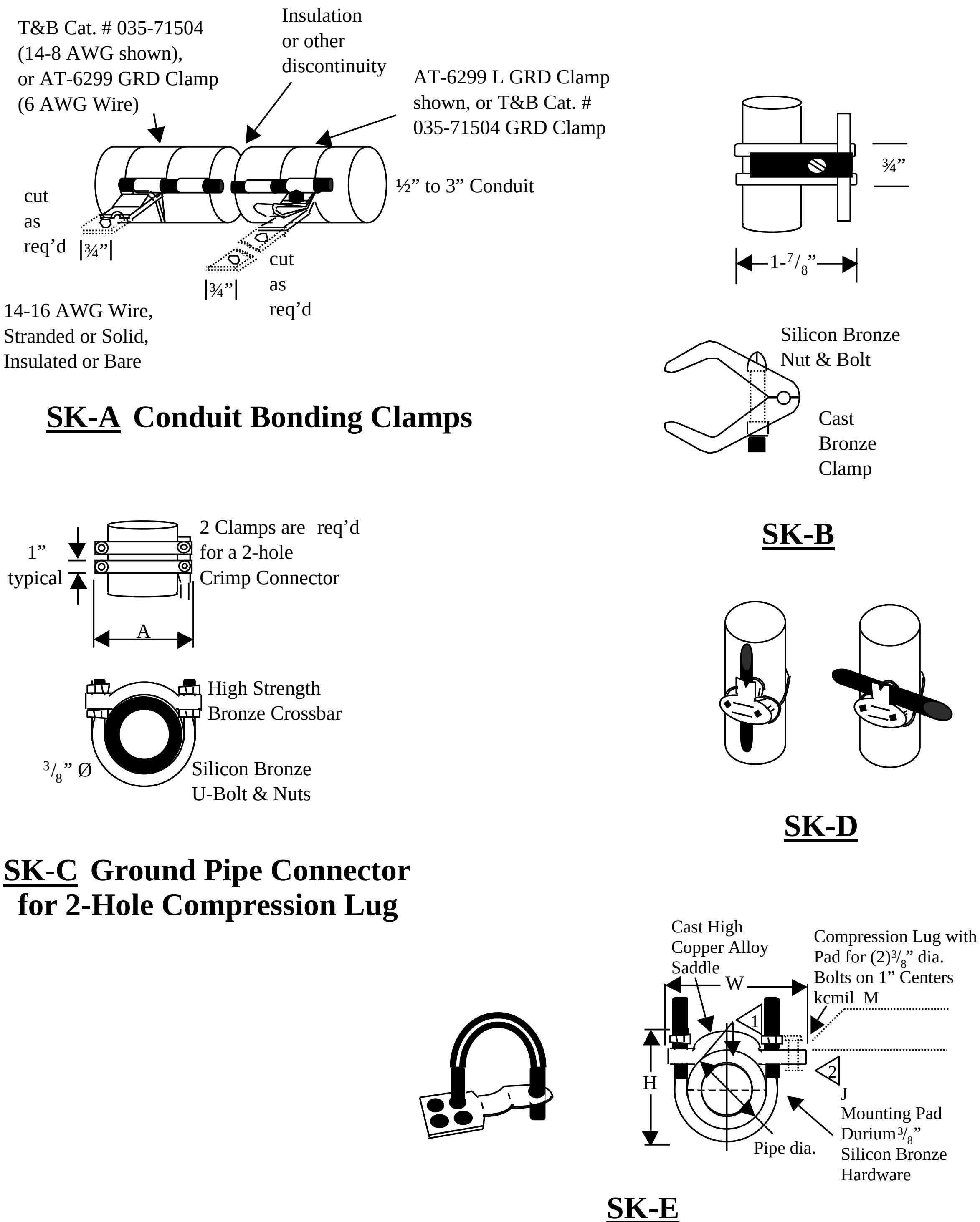
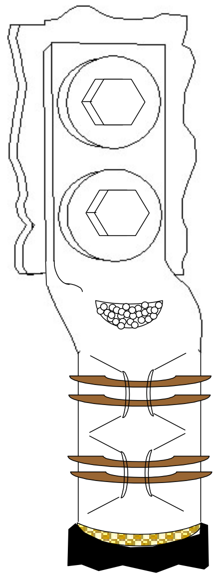
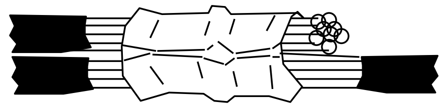


Figure 3-11: Pipe and Conduit Ground Clamps



2-hole bolted tongue
crimp (compression)
type connector
("color-keyed", typical)

SKETCH A



crimp (compression)
type parallel connector
("C"-tap, typical)
for use with 2 AWG
and small stranded wire

SKETCH B

Figure 3-12: Crimp (Compression) and Pressure-Type Connectors

Cable routing through the office is also a concern. If lightning enters the building on the AC feed going to a supplementary structure, sensitive equipment could be damaged if the lightning current "jumps off" the AC feed. If possible, The AC feed (and any ground conductors) leaving the building should take the path out of the building from the AC Service Entrance that passes the least amount of equipment, even if this means more of the AC is run outside the building than inside. Figures 7-19 and 7-24 are poor examples. It would have been better to bring the AC service directly from the HSP or other nearby AC panel (towards the upper right of Figure 7-25). Leave the building at that point, and then run the rest of the AC service outside. It is realized that this is not always possible but should be done whenever possible. If AC routing through the office cannot be avoided, attempt to run it away from sensitive electronic equipment, especially SPCSS switches (raceway passing within 6 feet of an isolated ground plane must be foreign object grounded, specific to the switch manufacturer's requirements — see Chapter 8 for additional information). If the AC service is being obtained from a sub-panel (as illustrated in Figure 7-25), try to choose a sub-panel whose feeder conduit (from the main House Service Panel) passes the least sensitive areas.

For separate buildings on the same property served by separate AC entrances, the requirements are not as stringent. A supplementary building with a separate AC service entrance may have its own ground electrode field or may choose to use the ground electrode field(s) of the main building (this will usually be determined by distance). The only time that a supplementary building with a separate AC entrance must use the ground electrode field of the primary building or have its ground electrode field bonded to that of the primary building, is when the secondary structure is within 6 feet of the primary structure. In the rare cases where a supplementary building/structure falls completely under the zone of protection of the primary structure, and the supplementary building does not contain sensitive electronic equipment (i.e., it is used for personnel space or storage), its ground electrode field does not need to meet the stringent requirements of this Section 3 (it may be held to the less-stringent requirements of the NEC® Article 250).

The existing grounding electrode system for the Lumen CO can be any of several types discussed earlier in this chapter. All are acceptable, although ground rings are preferred. When there are separate ground electrode fields, but points of interface (such as a shared AC service entrance/feed, or a T1 cabling interface, etc.) between the structures, the possibility exists that lightning hitting one structure may not choose the nearest ground electrode field. It may choose to take a path through the other building to get to the lower impedance ground electrode field. This poses a particular problem when the supplementary building, the OPGPB, the cable entrance and/or the AC service entrance are not located near to each other. Figure 7-22 represents the ideal situation (everything important to grounding is near each other). When this situation is not possible, the guidelines of this section and the other documents previously mentioned must be followed to avoid potential problems. In some cases, the Electrical Protection Engineer may specify upgrades to the Building Ground Electrode System in order to rectify potential interface problems.

Any cabling interfaces between separate structures must be protected. Data lines that use copper members (such as T1) must have electrical transient protection at the interconnect points between the structures. For copper facilities interconnecting a CO with an external building, there are basically 4 points of protection: outside the building, at the entrance to the supplementary structure, in the cable vault, and at the CO frame. Typically, all but the cable vault protection involves an SPD “gas tube” “5-pin” protectors (solid state “5 pin” protectors may also be used). Protectors integral to equipment (not 5-pin) are usually of the “gas tube” type.

Once again, these protection requirements for cabling interfaces are dependent on whether the supplemental structure is completely within the zone of protection of the primary structure (typically it is not).

Figure 7-19 illustrates that protectors must be installed on copper data circuits at a point before they enter the building. Even more preferable is for the protectors to be installed in an external manhole (typically known as MH-0, as shown in Figures 7-22 and 7-23), and bonded to that manhole's bonding ribbon. The bonding ribbon of a manhole is bonded to the rebar of the vault Ufer ground system, and out through the concrete of the vault to all the soil in contact with that vault. If the protectors are installed in an external protection pedestal (above ground), it must be grounded to a ground electrode field. If it is close enough to the CO ground electrode field, it may be connected to it. Or the “protection pedestal” may have its own ground electrode field, preferably made with three rods, similar to configurations shown in Figures 10-8 or 10-9, or Figure 7-24. If at all possible, this ground electrode field should be connected to another external grounding electrode field that is tied to the OPGP.

Just as with any other cable with copper members, cables entering the Cable Entrance Facility (CEF) or Vault must be shield grounded as specified in Section 6 (see also Figures 7-21 and 7-22).

After leaving the CEF, the copper facilities will have a point of presence on the MDF, DSX, or Cosmic Frame. At this point they will also be protected with a “5-pin” protector.

Oftentimes, outside cabling enters through conduit. Where possible, this conduit should be non-metallic and fire-retardant and comply with the requirements of NEC® Articles 362 and 800. Metallic conduit offers a path for transients to enter the building, and we do not want this, even if the conduit is properly grounded. Metallic facility must enter/leave through the cable entrance facility/vault, waveguide entry plates, or the AC service entrance.

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Chapter and Section **Page**

CONTENTS (Continued)

Figures

4. AC Service Distribution and Equipment Ground Requirements

This section summarizes rules found in the National Electrical Code® (NEC®) and clarifies and adds where needed. Note that this is only a summary. As a general rule, the NEC® is more widely applicable to all types of AC wiring. Lumen policy limits the entrance/exit of any metallic cable to the AC service entrance, the CEF (see Chapter 6), or a waveguide entry plate (see Chapter 7).

4.1 AC Neutral Conductor

The neutral is usually grounded at the service transformer by the serving utility and must always be grounded at the electric service disconnect. Neutral is <u>not</u> connected to grounded objects beyond this point (except for with separately derived sources per the following section). Neutrals are insulated current carrying conductors and connection to a grounded object creates a load current path through that object in parallel with the neutral. A neutral may only be used as a source of ground reference at the main panel. It cannot be emphasized too strongly that a neutral (grounded) conductor is **not** a grounding conductor. It is a single-point grounded current-carrying circuit conductor (see NEC® Article 250.142(B)). To maintain the single point concept, neutral bus bars installed in AC distribution facilities must be insulated from mounting framework. Special care must be exercised during installation to ensure that an inadvertent connection between neutral and grounded metal does not occur anywhere on the load side of the service equipment (one example of how this might happen occurs when a new main house service panel is installed, making the old one a distribution panel; and the electrical contractor fails to remove the neutral to ground bond in the old panel).

4.2 AC Service Grounding of Separately Derived AC Systems

AC systems powered from a transformer; or by means besides direct connection to a secondary system, are found in COs (note that where only an autotransformer is found, it does not create a separately derived source). These systems, with a neutral conductor, require ground reference. Per Code, to prevent ground current flow on grounding conductors, the neutral on the primary side of a transformer cannot be extended to provide ground reference to the secondary side. Therefore, a separate dedicated (see NEC® Article 250.121) grounding electrode conductor must be extended from the neutral of each such separately derived system to a ground reference source (see NEC® Article 250.30, and Figure 4-3 [which is located in the NEC® Handbook]).

A floor CO GRD or OPGP / PANI- MGB bus is an optimal point for obtaining ground reference (along with building steel). (The grounding electrode conductor shall be sized in accordance with NEC® Table 250.66.) In addition, the neutral and ACEG must be bonded at the output. This bond (which may be internal to the equipment) and the grounding electrode reference can be at the output terminals, or at the first distribution panel (unless that panel is more than 25 feet away — see NEC® 240.21(C)(3), and Figure 4-4, which is located in the NEC® Handbook).

Standby engine-alternators (see Figure 4-1, from the NEC® Handbook), and inverters with a maintenance bypass (see Figure 4-5), are not normally separately-derived sources, and are usually controlled through automatic or manual switching so that the standby supply is not adjoined to the commercial supply. In wire-connected services the neutral of the standby supply must be bonded to the neutral of the commercial secondary. The grounding electrode conductor of the secondary service suffices as a single point ground reference for both the standby and commercial systems, and such systems do not require a separate grounding electrode conductor. A few exceptions apply:

- When an engine is located in a separate building (or other enclosure) which has its own ground electrode, the standby system neutral shall also be bonded to the ground electrode in its own building. (Note that this does not require engines in outdoor enclosures to have their own ground electrode system; but if they do, there should be a neutral to ground electrode system connection.)
- UL 2201® requires portable engine-alternators below 15 kW to have the frame and neutral bonded at the set, making them "separately-derived" (most portables are not presently Listed to UL® 2201. However, they usually serve sites with a hard-wired neutral (non-separately-derived). This situation (easily identified using a clamp-on ammeter to look for significant current on the ACEG between engine and building) can be made safer by limiting the genset connecting cord distance to 15 feet and ensuring that the inlet is less than 10 feet from the HSP MGN-ACEG bond. This arrangement should only be used for backup power when AC is lost (not for long term temporary backup) and cannot be used if the site has a ground fault detection system. Driving a ground rod at the engine and bonding to it (see Figure 4-2, copied from the NEC® Handbook), can improve the situation. Some of these small portable gensets can be opened and have the bond removed.
- When standby engine-alternators have an output transformer (which is rare), they are considered separately derived sources (unless it is an autotransformer, since it has a direct primary to secondary connection in the transformer), and those NEC® rules referenced in the first paragraph of this section apply.

- DC-preferred -48 VDC-fed inverters are usually (see Figure 4-6) separately-derived sources (except where there is a hardwired/non-switched AC neutral), and the NEC® rules referenced in the first paragraph of this section apply (other than inverters/converters in the isolated ground plane, whose output grounding is to the nearest isolated frame or frame ground bar, as shown in Figure 8-5).
- Any UPS containing an input isolation transformer; or any other step-up or step-down transformer (other than an autotransformer) is considered a separately derived source (see Figure 4-7, which comes from IEEE 1657®, unless a maintenance bypass goes around the transformer(s), and those NEC® rules referenced at the beginning of this section apply.

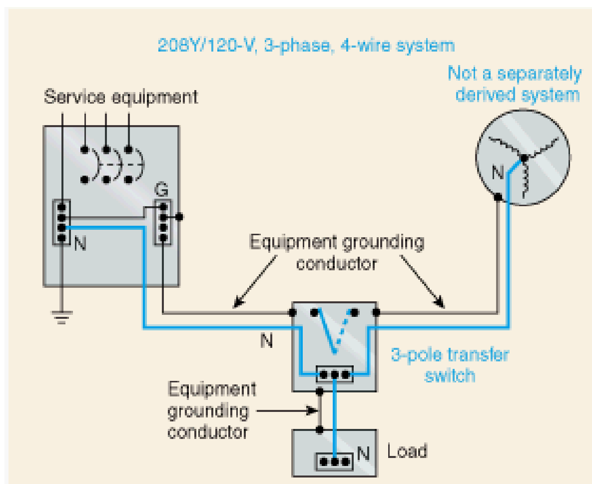

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Figure 4-1: Typical Engine-Alternator that is Not Separately-Derived (From the NEC® Handbook)

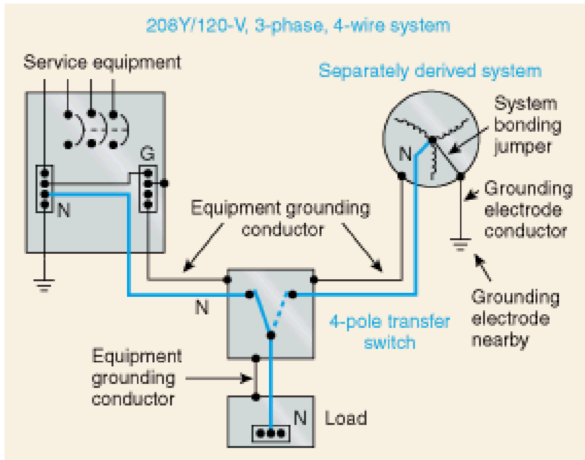

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Figure 4-2: Atypical Engine-Alternator that is Separately-Derived (From the NEC® Handbook)

4.3 NEC® Code Requirements

The preceding information summarizes basic National Electrical Code® requirements pertaining to grounding of neutral conductors for service of 600 volts or less. Individual installations must conform to all of the requirements expressed in the Code for the service furnished. Refer to Article 200 for requirements for neutral conductors and Article 250 for requirements for service grounding. In addition, refer to Article 702 for general engine-alternator (Optional Standby Systems) provisions. Where local Codes differ from the NEC®, installations shall conform to the local code requirement.

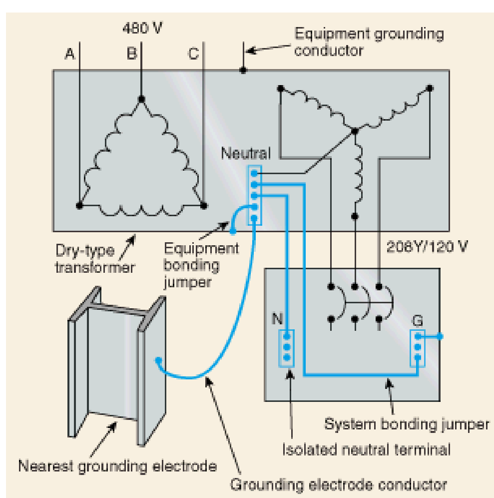

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Figure 4-3: Transformer with Separately-Derived Source Re-Grounding at Secondary (From the NEC® Handbook)

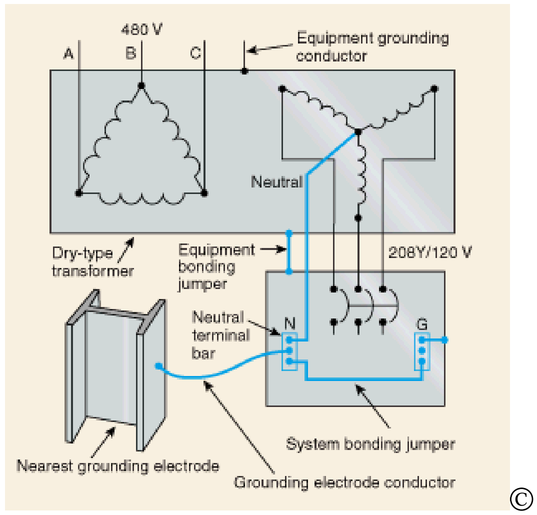


Figure 4-4: Transformer with Separately-Derived Source Re-Grounding at the First Disconnect
(From the NEC® Handbook)

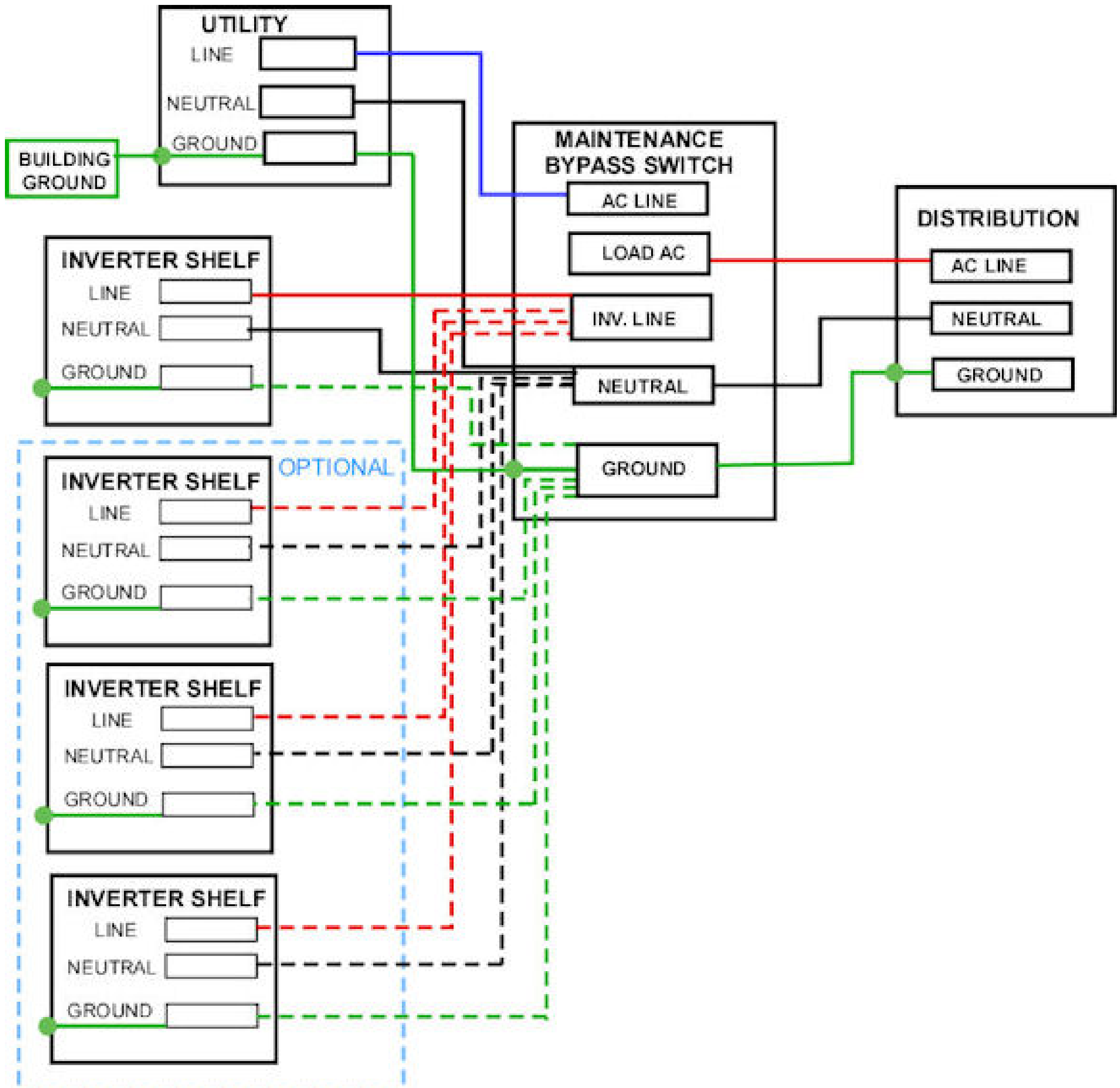


Figure 4-5: Grounding for Inverter with Maintenance Bypass (Not Separately-Derived)

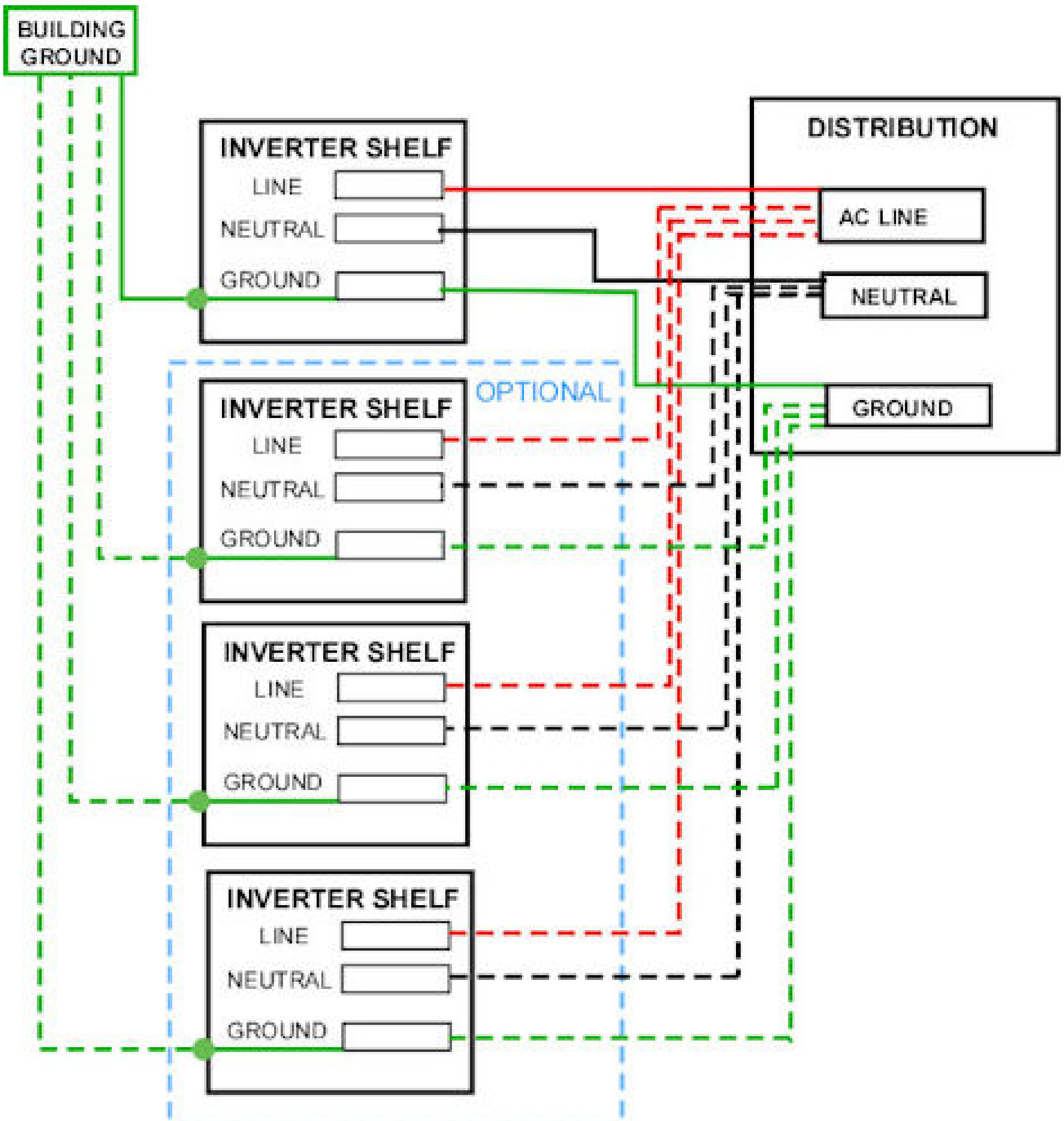


Figure 4-6: Grounding for Inverter without Maintenance Bypass (Separately-Derived)

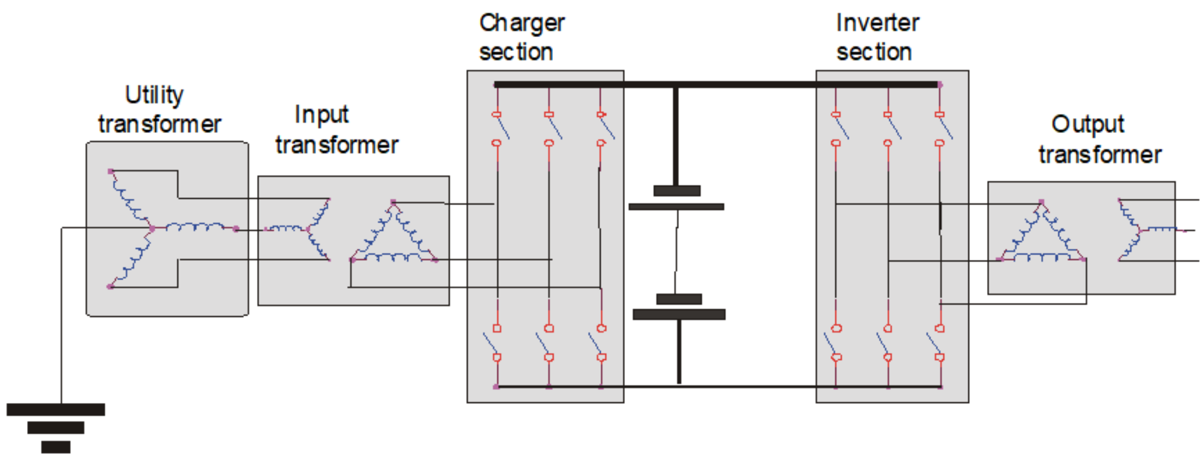


Figure 4-7: Typical Large UPS with an Input Isolation Transformer

The NEC® requires that the path to the ground from circuits (feeder and/or branch), equipment, and conductor enclosures shall:

- Be permanent and continuous.
- Have capacity to conduct safely any fault current to be imposed on it.
- Have sufficiently low impedance to limit the voltage to ground and to facilitate the operation of the circuit protective devices.

To ensure continuity and low impedance, and to provide additional insurance against noise generated in AC systems, all circuits shall include the ACEG "green-wire" sized per table 250.122 of the NEC® even when metallic conduit or other raceway is used.

4.4 AC Service Grounding Electrode Conductor

An AC service grounding electrode conductor is required for each secondary AC service circuit (per NEC® 250. Its method of termination differs if the AC is grounded or ungrounded. The conductor is normally provided by the electrical contractor at the time of installation of AC switching equipment. In a grounded AC system application, the grounding electrode conductor is terminated at one end to the neutral conductor of the AC system, generally at the location of the service disconnect equipment. It may be connected (bonded) to the neutral at any point on the supply side of the service disconnect equipment. *It must never be connected on the load side of the disconnect equipment.* At the point of termination, the AC service circuit neutral conductor is bonded to the metallic enclosure of the AC system equipment. This bond forms a path via the neutral to the transformer for fault currents that may be impressed on conduits, equipment ground wire or other metal forming the equipment ground plane.

- In an ungrounded AC system, a neutral is not employed and the grounding electrode wire is bonded to the enclosure of the service disconnect equipment. The other end of the grounding electrode wire is connected to a ground electrode. For typical bond and AC grounding electrode arrangements, see Figure 4-8.
- The AC service grounding electrode conductor and associated bonds at the service disconnect equipment and water meter are normally installed by the electrical contractor as directed by Lumen specifications. The conductor size shall be in accordance with NEC® Article 250.66.

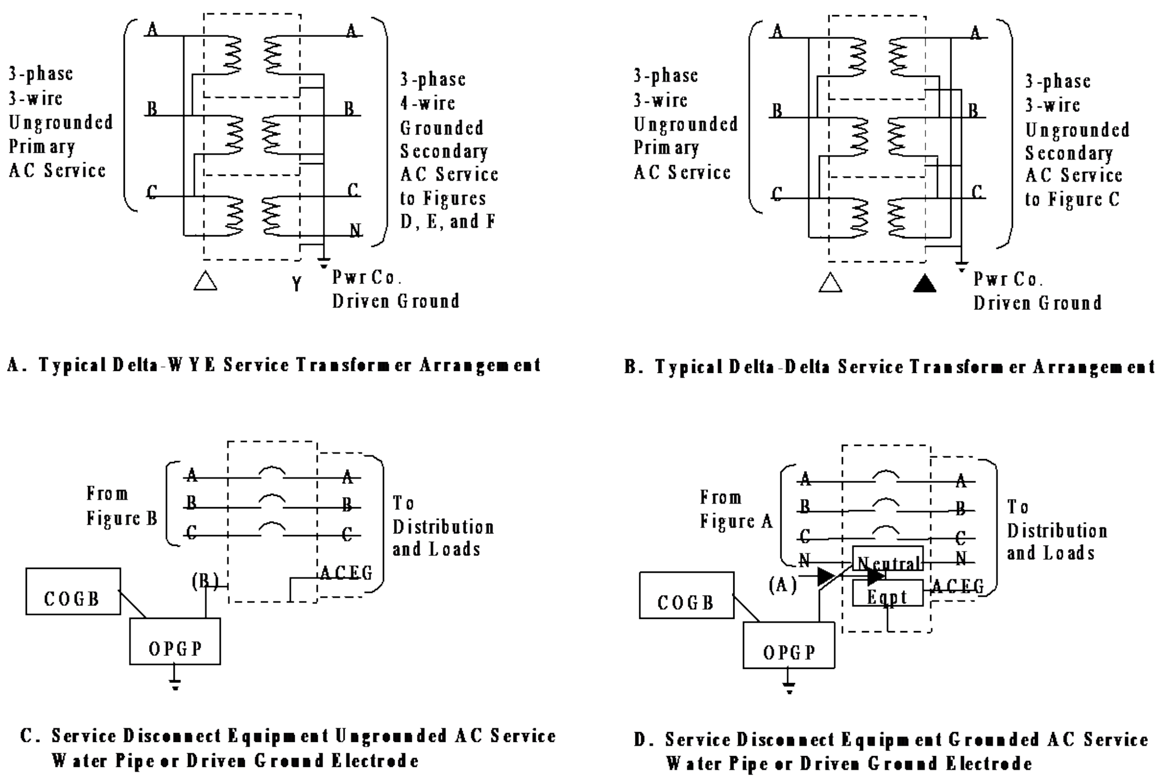


Figure 4-8: Typical AC Service Grounding Electrode Arrangements

Notes:

1. (A) and (B) Denotes wires sized Per NEC® 250.66
2. Figures A and B represent typical three-phase transformers wired to provide grounded or ungrounded service
3. Figures C and D show typical service grounding arrangements
   The figures illustrate that fault current impressed on the equipment system (ACEG) has a low impedance path to the current source (transformer) only in grounded AC systems

- It is preferable that the AC service grounding electrode conductor be insulated, stranded wire, run open or in a nonmetallic raceway; and installed per NEC®250.64. Preferably, it should be surface supported and visible for inspection. Where run through walls, partitions, etc., the wire should be routed through nonmetallic sleeves, if possible. It should not be routed through metal that forms a ring or in metallic conduit, where avoidable. If run in metallic raceway, the conductor must be bonded to any enclosing ring, and the raceway must have continuity with the terminating points of both ends of the grounding electrode wire. Suitable continuity is assumed when:
    - The raceway is terminated at the disconnect equipment enclosure with approved electrical raceway couplings or a bond conductor, and the enclosure is internally bonded to the AC system neutral (grounded AC Service).
    - The raceway is bonded to the OPGPB or other grounding electrode or bonded to the AC service grounding electrode conductor at the terminus of the raceway.
    - Intermediate points of the raceway discontinuity are bonded at every such point to the grounding electrode conductor run therein. Such bonds shall be of the same size as the grounding electrode conductor.
- It is preferable that the AC service grounding electrode conductor be tied to 1-2 ground rods driven by the electrician at the time of meter installation, and that those rods not to be connected directly (except through the MGN bus and OPGP / PANI- MGB) to the driven ground system for the site. This allows the site's driven ground electrode system to be disconnected for 3-point fall of potential testing without losing site ground reference.

4.5 AC Equipment Ground Conductor

An AC Equipment Ground (ACEG) conductor provided in the same raceway with phase conductors (and sized per NEC® table 250.122) ensures that minimal impedance to the flow of fault current will be encountered. The following requirement shall, therefore, be applied to the design of AC distribution systems in Lumen buildings. An ACEG conductor, enclosed in the same raceway with phase conductors, shall be provided for circuits distributing AC power from a commercial or locally derived power source.

The inclusion of an ACEG conductor in a raceway shall not be counted in determining the ampacity of conductors, in accordance with NEC® Article 310.15(B)(6). The ACEG conductor is not a current carrying conductor.

In a 3-phase grounded circuit, if the neutral carries only unbalanced current from other conductors in the same circuit, it is not counted. (If there are harmonic currents in the neutral, then it is considered current-carrying and must be counted. The neutral must be appropriately sized if harmonics are likely, per the NEC®. For sites with lots of switch-mode power supplies, such as computers, fluorescent lighting ballasts, and switch-mode rectifiers; harmonics are likely.) Therefore, a conduit containing three phases, a neutral and an ACEG may be, within limitations defined (in the NEC®), considered as not more than three conductors and need not be derated. The ACEG conductor shall be included in calculations of allowable percentage of conduit fill defined in Chapter 9 of the NEC®.

AC service phase conductors in sizes 1/0 AWG and larger may be run in multiple, provided the arrangement is such to assure equal division of total current among all conductors involved. When run in multiple raceways, separate equipment ground conductors shall be run in each raceway. All of the multiple equipment ground conductors shall be of the same length and size and terminated in the same manner. Size of the equipment ground conductors shall be determined as follows:

- Determine number and size of phase and neutral conductors required for load.
- Determine the number of raceways required to accommodate the phase and neutral conductors. Each raceway shall contain an equal number of same-sized conductors of each phase, a neutral conductor (if grounded service is provided), and an equipment ground conductor.
- Determine the ampacity rating (fuse or non-adjustable circuit breaker) of the overcurrent device protecting phase conductors.
- Determine the size of individual equipment ground conductors according to NEC® Table 250.122. Derating of these ACEGs is not permitted. Each raceway shall contain an ACEG sized per NEC® 250.122 to the protection device.

The AC equipment ground conductor in raceways or conduit shall be green-insulated, or bare wire (stranded or solid). AC distribution wire shall be THWN or THHN type.

When armored cable is used for AC service, the equipment ground conductor shall be the same size as phase leads. The entire exposed portion of the EG conductor shall be green color coded or made bare for purpose of identification.

When multiple AC circuits are run in a common raceway (see Figure 4-10), the ACEG conductor must be one or more single conductors of size required by the ampacity rating or setting of the largest overcurrent device of the associated circuits. The single ACEG conductor shall be tapped and branched, reduced and extended with each branch circuit emanating from the common raceway to each unit in which phase leads terminate. Reduction of the branch ACEGs shall be in accordance with requirements of the branch circuit overcurrent device ampacity or setting. The main ACEG conductor shall be bonded to the raceway at every point of emission of any branch circuit.

It is imperative that a continuous conductive path exists throughout both the ACEG conductor and any enclosing metallic material. Therefore, when the ACEG and phase leads emit from a conduit or other raceway into free air or a non-conductive fitting, the ACEG conductor and conduit must be bonded together so that the conduit maintains continuity to the termination point of the ACEG conductor. Similarly, any breaks in conduit or enclosure continuity must be bonded. Generally, the connection provisions of standard electrical fittings and enclosures utilizing bolts, screws, threads, pressure fittings and similar devices are considered adequate for electrical continuity, although bonding at each J-box (as shown in Figure 4-10) is recommended.

A floor mounted frame, cabinet or similar metallic structure provided for the support of an AC operated equipment unit, served by an AC equipment ground system that conforms to Lumen requirements (see paragraph 4.6), is considered to be adequately grounded via the AC equipment ground system. When such frames are mounted in floor areas also occupied by communication equipment grounded to a CO GRD system, it is required that these frames be bonded to the CO GRD system also. This is done by extending a 6 AWG framework ground bond from the frame to a suitable point on the CO GRD system. When the AC operated equipment is served from an AC service cabinet located on other than the same or an adjacent floor, a framework ground bond must be provided (see Figure 4-11). Provision of framework ground bonds ensures that low impedance exists between grounded objects in close proximity, which reduces the probability that a dangerous difference in potential can develop between the systems.

ACEG conductors shall never be connected (bonded) to the AC neutral termination point in any equipment enclosure.

4.6 Lumen AC Equipment Ground Requirements

Minimum safety requirements specified in the National Electrical Code® shall be met by forming the equipment ground system by means of both the metallic raceway and the green equipment grounding (wire) conductors. It has been recognized, however, that these forms of grounding are not always effective in shielding communication circuits from noise generated in AC systems. Supplementary requirements for a more effective AC equipment grounding system to be used in Lumen buildings housing communication equipment are listed below.

Supplementary requirements are as follows:

- AC conductors shall be run in metallic raceway exclusively, except for circuits run within equipment frameworks. (i.e. end guards or guard rails for AC outlets).
- When equipment is powered by an AC cord set, the cord shall not be longer than required (coiling excessive lengths can create mutual inductance).

4.7 AC Installation Requirements

The reliability of a grounding system is as dependent on careful and proper installation as it is on the proper choice of materials. Improper preparation of surfaces to be joined to make an electrical path, loose joints and corrosion can introduce impedance that will seriously impair the ability of the ground path to protect personnel and equipment and to absorb transients that can cause noise in communication circuits.

The following functions are particularly important to ensure a reliable ground system:

- Metallic surfaces to be joined must be prepared to a bare, bright finish (see NEC® Article 250.12).
- Current carrying metallic surfaces must be coated with corrosion preventive compound before joining. Raceway fittings must be made up tight to provide a permanent low impedance path for fault currents.

A conductive non-oxidizing agent must be applied to inhibit corrosion wherever the possibility of corrosion formation in ground conductor joints exist.

Note: Not all anti-corrosion compounds are conductive. Only products that are listed as conductive are acceptable to use where an anti-oxidant compound is required.

A "DO NOT DISCONNECT" tag should be placed on every non-welded ground conductor terminated to an OPGP (PANI- MGB) or COGB (PANI- FGB). In addition, a tag stamped with the location of the far end termination will be employed on each grounding conductor, to aid in conductor identification (this requirement is waived

when the grounding conductor is short in length, and both ends can be viewed from the same location).
Installation of metallic raceways must be in conformance with requirements outlined in the NEC®, Section 386; and local codes.

AC equipment ground conductors shall be provided in all raceways, such as:

- Buildings housing communication equipment
- In AC service, feeder and branch circuit raceways serving the following:
  - Communication equipment
  - Building service equipment

4.7.1 AC surge protection

The AC surge protective device (SPD) is designed to divert lightning and powerline surge current to ground and limit the surge voltage to an acceptable level.

The responsible Lumen employee (Real Estate) must determine the AC power configuration before selecting the appropriate SPD. The selection of the AC SPD should meet or exceed the following criteria listed below:

(A) Listed to the latest edition of UL® 1449, the ANSI/IEEE C62 series document, and comply with NEC® Articles 280 for surge arrestors over 1000 V, or 285 for SPDs 1000 Volts or Less.
Note: It is also preferable that SPDs be tested to NEMA® LS 1.

(B) A breakdown voltage of 600 Volts or less @ nominal 10kA of discharge current for sites served by 208 or 240 VAC. Any site served by nominal 480 V AC should have a breakdown typically from 800-1000 V.

(C) A maximum discharge capacity of at least 200kA (400 kA preferred) for sites with 5,000 subscriber lines or more; this includes data centers. A maximum discharge capacity of at least 100 kA (200kA preferred) is recommended for all other building sites.

(D) A minimum life of 1,000 operations @ 10kA

(E) Thermal Protection per U.L. 1449, Edition 2

(F) Self-restoring after power surge or fails “open” (never wire in series to the protected AC service)

(G) Equipped with visual failure indicator lamps

(H) Equipped with failure alarm circuitry

Building application(s) for the AC SPD's

- An SPD shall be placed on the load side of the building AC service main disconnect. (Type 2)

Note: Supply (line) side installations (type 1) are not permitted.

- In high lightning areas and where circumstances warrant, an SPD may also be placed on the load side of the automatic transfer switch (See Figure 4-9).

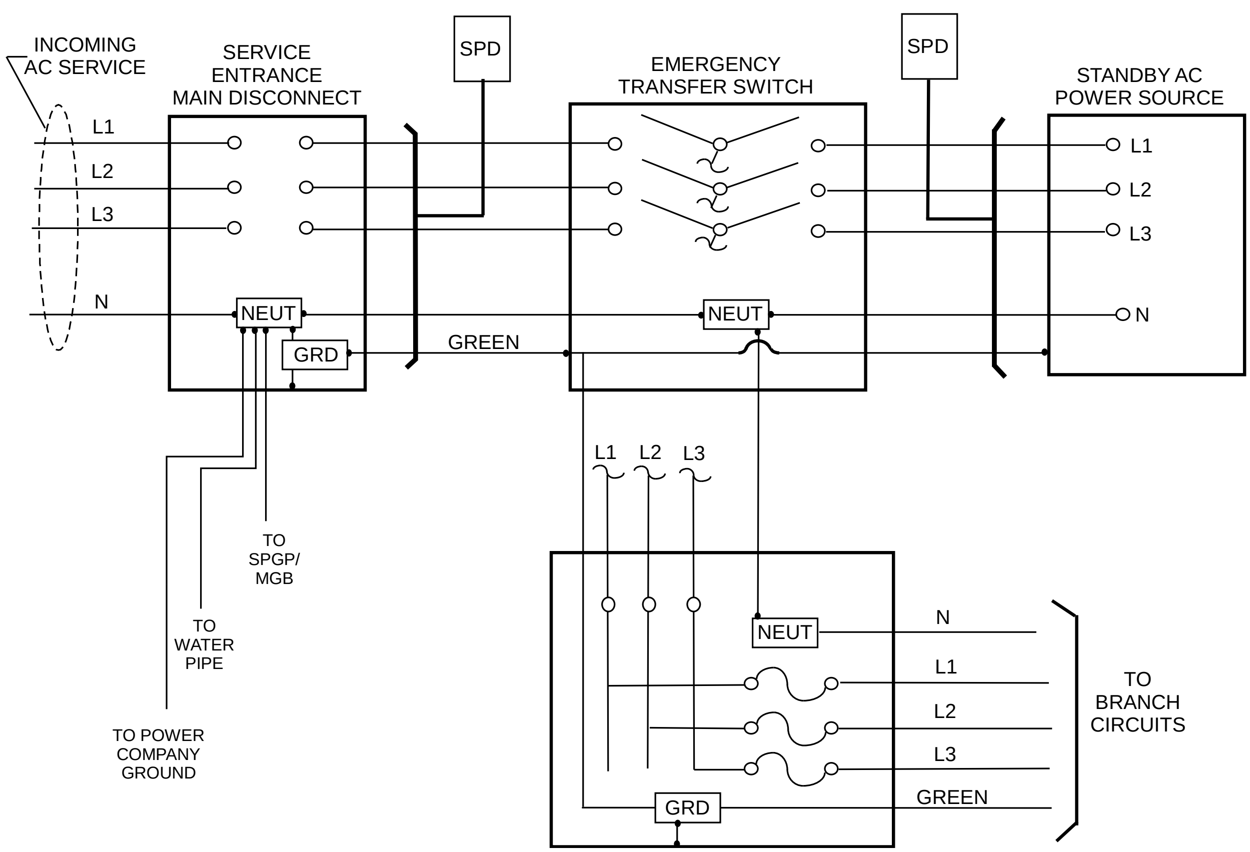


Figure 4-9
AC Surge Protection Placement

The following are recommendations for installing a power line AC surge arrestor:

- Mount the Surge Arrestor as close as physically possible to the main AC service entrance. The arrestor should be physically mounted in a location so that failure indicator lamps/alarms will be quickly noticed.

- Connect the arrestor to the load side of the main service disconnect using a minimum 6 AWG stranded, insulated, copper conductor. Connect SPD to a minimum 30 Amp fuse or circuit breaker (60 Amp preferred)
  NOTE: Disconnects are preferred because it allows replacement without de-energizing the site.

- The copper conductors connecting phase(s), neutral, and ground from the Surge Arrestor to the main service disconnect shall be as short as possible and follow the straightest route to the point of termination. The maximum lead length between the Surge Arrestor and AC service disconnect shall not exceed thirty- six inches. The practice of "Coiling" of conductor lead slack shall not be permitted. Sharp wiring bends and turns shall be avoided at all times.

- Use metallic conduit for the wiring connections between the Surge Arrestor and the AC service disconnect (unless otherwise specified and/or required).

- Connect the SPD alarm circuit(s) to the site alarm system (when required).

- Follow the manufacturer's installation instructions and ensure color-coding of conductors conforms to applicable NEC® requirements.

- A conductive non-oxidizing agent must be applied to inhibit corrosion on all electrical connections.

4.8 Engine-Alternator Set(s)

Engine-alternator sets always require an equipment ground conductor in the conduit or the metallic raceways that contain phase leads from the alternator. The equipment ground conductor(s) shall be furnished in accordance with paragraph 4.5.

The equipment ground conductor(s) shall terminate within the engine-alternator cabinet provided for termination of phase leads. Termination may be made on a bus bar or ground stud electrically bonded to the cabinet or directly to the cabinet interior with terminal lugs. The cabinet must be electrically bonded to the set frame by bolting or by a bonding strap or equivalent means to provide ground continuity between the entire set and the equipment ground conductors.

If phase and equipment ground conductors are enclosed in flexible conduit for vibration control (this would typically be done where the raceway interfaces to the alternator), the electrical continuity must be maintained by bonding, using an insulated, stranded 6 AWG conductor across the flexible section.

The neutral of the alternator shall not be bonded to the ACEG conductor or set frame when the set is located in the same building as the main AC service board. The neutral shall be bonded to the ACEG conductor only when the set is located in a separate building equipped with its own ground electrode.

4.9 Grounding for Engine-Alternators and their Rooms/Enclosures

The primary control cabinet for the engine shall be bonded to the metallic (steel) sub-base/chassis. These bonds should be made with bare, stranded, or ribbon conductors, designed and installed to withstand normal engine vibration. Figure 4-13 shows a grounding scheme for a standby engine room in a traditional isolated-integrated office. A minimum 2 AWG stranded insulated conductor shall be run from the OPGP / PANI-MGB (or to that floor's COGB/FGB) to the engine room. (It may be advisable to terminate this cable on an engine room ground bar and run all other cables to it for traceability.) Ground the engine with a 2 AWG, and all other components with 6 AWG stranded insulated conductors. If the fuel tank is located outside, then the metallic fuel lines must be bonded with a minimum of 2 AWG, since they constitute a ground source. If flexible piping is used on the fuel lines where they enter the building, there must be a bond around the flexible section using a minimum 6 AWG. The following must be bonded to the 2 AWG using a minimum 6 AWG insulated stranded copper grounding conductor:

- Metallic fuel tanks (day and main)
- Fuel piping (metallic)
- AC control panel or cabinet
- Start battery stand
- Exhaust pipe and radiator pipes
- Air dryer
- Battery charger
- Transfer switch cabinet

- Exhaust/intake fans that have a flexible connection to metal louvers
- Fuel monitors and/or gauges
- Other raceways to the exterior (i.e., metallic conduits to tank alarms, radiator fans, etc.)
- Metallic walls and metallic doors/frames for engines where there is an outdoor tank or exhaust stack "exposed" to lightning (i.e., not under "zone of protection").

Figure 4-14 shows a general grounding scheme for a standby engine room in a traditional PANI office. A 2/0 AWG stranded insulated conductor shall be run from the P section of the PANI- MGB (or alternatively to the PANI- FGB) to the standby engine room (routed as far away as possible from Network equipment areas). Ground the standby engine with a 2/0 AWG, and all other "producer" components (such as indoor fuel tanks, exhaust stacks, and intake air louvers) with outdoor exposure with minimum 6 AWG stranded insulated conductors. If the fuel tank is located outside, then the metallic fuel lines must be bonded with a minimum size of 2 AWG, since they constitute a ground source. If flexible piping is used on the fuel lines where they enter the building, there must be a bond around the flexible section using a minimum 6 AWG. A separate 2/0 AWG stranded insulated conductor shall be run from the N section of the PANI- MGB (or alternatively to the PANI- FGB) to the standby engine room to ground all other metallic components in the room (with minimum 6 AWG). Alternatively, if there is easy access to the existing exterior building ground electrode field near the engine room, all the metal of the engine room should be run directly outdoors to that field rather than crossing the office to get to the PANI- MGB or OPGP.

Note that when Engines are located in enclosures separate from the building, the transfer and AC switchgear and engine control cabinet located within the building do not have to be separately grounded to the DC grounding system unless they are not bonded to the ACEG.

Metallic fuel tanks (buried or above ground) located outside of the building enclosure shall be grounded to the driven ground system. Coordinate the grounding of the tanks with any tank corrosion protection system. Bond Metallic or metal-braided fuel lines to the CO ground system at building entry. Other incidental metallic items, like fuel tank ladders and remote radiators shall be bonded to the driven ground system. (In states where the PUC requires that the site be grounded to RUS standards, the outdoor engine frame must be grounded to the P section of the PANI- MGB.)

Standby engines outside the main building enclosure shall be grounded to the driven ground system. If these engines are in metal enclosures, that metal shall be grounded to the driven ground system (see Figure 4-14). If there is metallic within 6 feet of this enclosure, it too must be bonded (fences require a bond to at least one post [preferably two], then ensured continuity to other fence sections and gates). Roof-mounted engines should also be bonded to the lightning protection system if one exists (see Chapter 7).

To limit step/touch potentials, new above-ground outdoor metallic fuel tanks and metallic outdoor engine enclosures that are not within 6 feet of an existing ground electrode shall have a rod driven that is bonded to an existing ground electrode field.

When the exhaust stack is higher than the roof, it is an unintended lightning rod (it is permitted to be use as an intentional lightning rod if the metal thickness is $^{3}/_{16}$ inch or more). If a roof lightning protection system exists, bond the stack and thimble to it. If it does not exist, it is preferable to attach a 2 AWG conductor from the external stack, run it outside the building, and connect it to the ground electrode system (this helps direct lightning, which hits the stack, to ground outside the building). Try to bond the thimble (through which the stack exits the building) to this 2 AWG. When this cannot be done, bond the stack per Figure 4-13.

Standby sets whose nominal line-to-line voltage is greater than 480 V shall be treated as a separately derived system and shall have their neutral solidly grounded (Delta outputs with a corner-derived neutral can be resistance-grounded). A direct and continuous connection shall be made from the neutral to the nearest COGB with a grounding conductor sized per NEC® Table 250.66. A second independent connection shall be made between the neutral and the metal frame of the set.

When the standby AC neutral is not switched by an automatic transfer device (it is normally not switched), the following applies. For standby sets of 480 V or less, where a solidly grounded commercial power system is used, the neutral of the set shall not be grounded by connecting it to the ACEG of the set. An acceptable method of grounding the neutral of the set is to connect it to the neutral of the commercial power at the neutral bus of the transfer switch or wired through the transfer gear to the main AC entrance panel neutral bus, if such a bus is not provided in the transfer panel. In addition, the neutral and the phase lead(s) of the set should be the same wire gauge.

4.10 Ground Fault Detection/Protection

Where ground-fault detection and protection is required (although NEC® Articles 230.95, 210.13, 701.6D and 701.26 only require it on commercial entrances and main branch circuits rated at least 480 VAC and 1000 A, Tech Pubs 77385 and 77355 requires it for alternators and service entrances of 480 V or higher and/or 1000 A or greater), grounding the neutral at 2 points can lead to false operation of sensing devices, because part of the neutral current will flow in the frame ground paths (see NEC® Article 250.142). A net summing type of sensing device should be used. Ground fault detection devices may be adjusted to cause tripping of the AC service entrance and/or alternator output breaker up to 1200 Amps, but it is more typical to set them between 100 and 400 A. They should not be set too low, or nuisance tripping will occur. A study by a licensed electrical P.E. may be needed to determine the proper setting for the particular building and AC motors it contains that will cause the least amount of equipment damage while still avoiding nuisance tripping.)

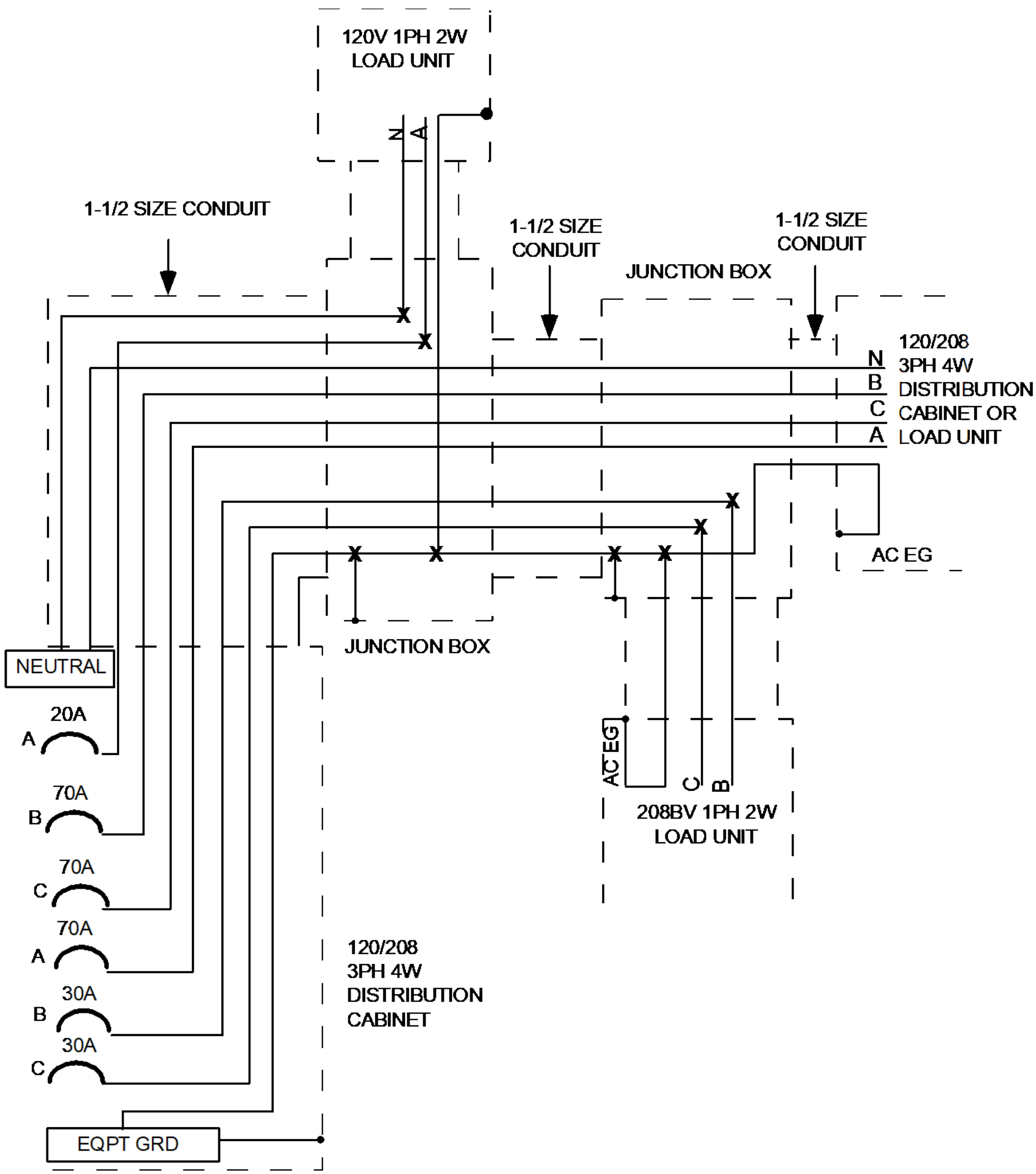


Figure 4-10: Single ACEG Conductor Serving Multiple AC Circuits in a Common Conduit Run

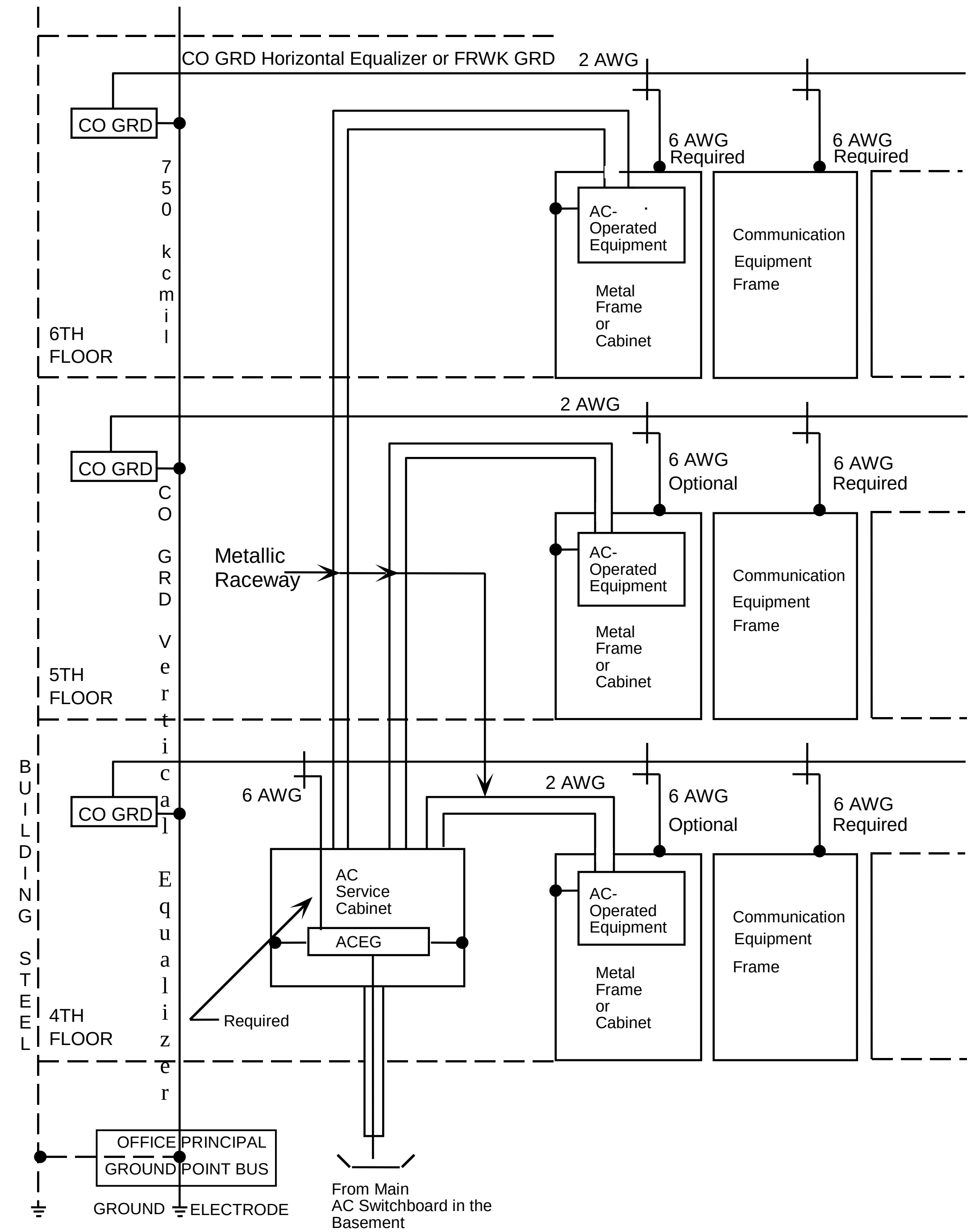


Figure 4-11: Requirement for Grounding Frames Mounting AC Operated Equipment Units

Notes:

1. Although not shown, each feed is run with an ACEG.
2. The required 6 AWG shown going from the AC cabinet ACEG bar to the CO Grd system is only for integrated (non-isolated) ground planes. For isolated ground planes, see Figures 8-5 and 8-7.

4.11 Busduct System

Busduct components used to supply floor mounted DC rectifiers in Central Office power plant installations are manufactured by outside suppliers to Lumen specification requirements. Equipment ground continuity is required throughout the busduct system. Each busduct section must have a connection between case and equipment ground conductor.

4.12 AC Power Distribution Service Cabinets

AC distribution cabinets always require an ACEG conductor in conduit or other metallic raceway(s) that contain phase feeder leads to the cabinet. The ACEG conductor provided with the feeder circuit is considered adequate for providing framework grounding for the AC distribution cabinet and connected AC operated equipment only when the ACEG conductor obtains ground reference on the same or adjacent floor to that on which the AC Service cabinet is located (in other words, if the AC service entrance or transformer that feeds this PDSC is tied to an OPGP or COGB within 1 floor of the PDSC). Otherwise, the cabinet shall be framework grounded to the floor CO GRD system, using a 6 AWG wire (see Figure 4-11). ACEG conductors shall terminate in the interior of the cabinet enclosure on an equipment ground bus bar electrically connected (bonded) to the cabinet enclosure, if provided. Otherwise, each ACEG conductor shall terminate, using terminal lugs bolted to the cabinet enclosure, near the raceway entry point.

The neutral bar provided in AC distribution cabinets must be insulated from the enclosure and the equipment ground bar. Extreme care must be exercised to ensure that the neutral does not have electrical continuity through mounting apparatus, terminal mounting bolts, or otherwise to the cabinet enclosure. Figure 4-17 illustrates typical AC circuits that terminate in an AC distribution cabinet. All raceway is metallic conduit that is electrically continuous between the AC distribution cabinet and load enclosures.

The AC distribution cabinets serving rectifiers are referred to by the special name of PDSC (Power Distribution Service Cabinet). In data center or computer room environments, they are often referred to as PDUs (Power Distribution Units).

4.13 AC Equipment Ground Busbars

Certain equipment bays and cabinets provided for distribution of AC service are equipped with equipment ground bus bars by the manufacturer for the purpose of providing a convenient terminating point for AC equipment ground (green-wire) conductors. Other AC service equipment units may not have this facility furnished. Units in which such terminating facilities may be found include house service boards, power service cabinets, lighting distribution cabinets and other units that may be employed as a distribution point for AC service circuits.

When an equipment ground bus is provided, it is mounted within the equipment enclosure so that it is electrically bonded to the enclosure, and all AC equipment ground conductors shall be terminated thereon. When no ground bus is furnished by the manufacturer, a ground bus shall be provided by the service (installation) supplier.

4.14 Raceways

The AC equipment ground system is composed of two components: metallic raceways (typically EMT conduit), and a network of green insulated conductors. The conductors are extended through the raceways that carry the phase conductors and bonded to the framework of the apparatus associated with the system. The purpose is:

- To enhance the raceway conductivity so as to ensure a low impedance path for fault current from a point of fault to an overcurrent protective device
- To bond across inadvertent discontinuities in raceway conductance
- To short out noise producing high impedance joints in raceways.

In PANI sites with fire suppression systems (whether water or chemical-based), all types of non-metallic conduit are allowed and encouraged (to prevent violation of the isolated ground planes, of which there are a greater number in PANI offices). In sites without fire-suppression systems (typically NEBS-compliant equipment sites), only fire-rated non-metallic conduit (such as ENT or treated rigid plastic) is allowed when non-metallic conduit is used. For MDF frames in PANI sites, AC conduit must either be non-metallic, or insulated completely from the frame. In sum, offices using primarily PVC conduit should continue to do so, and offices using primarily EMT conduit should continue that practice.

4.15 Lighting Distribution Systems

AC feeder circuits serving AC distribution panels provided for branch circuit distribution of AC service to lighting fixtures and AC appliance outlets shall include an ACEG conductor. An ACEG conductor shall be provided as described in paragraph 4.5 in each raceway emanating from such panels that contain branch circuits serving switchroom fluorescent lighting fixtures. The ACEG conductor shall be branched and extended so as to terminate at one of the screws that secure the lamp ballast on the interior of every fluorescent lighting fixture. This ballast grounding system is required to ensure a reliable ground path from ballasts for the purpose of suppressing transient voltages emanating from ballast and other components of the lighting system.

4.16 Cord Connected AC Operated Equipment

Parallel polarized U ground slot receptacles are standard for frame base appliance outlets and other miscellaneous 15 Amp 120V AC branch circuit applications serving cord connected equipment. Such equipment, whether portable or permanently mounted, shall be equipped with a three wire cord and a three wire grounding attachment plug (cap). Two wires of the cord must serve as circuit conductors. The third wire shall serve as a grounding conductor, connected at the cap to the U blade, and to the equipment structural metal, so that ground continuity is established from the receptacle to the equipment structure.

The U ground slots of such receptacles are permanently bonded to the metallic parts utilized for mounting the receptacle to a box or frame and mounting thereto establishes a ground path to the box or frame metal, a bonding jumper is also required. Armored cable, conduit or other raceway metal utilized as enclosures for branch circuit conductors serving the receptacle must be electrically connected/bonded (conduit locknuts or equivalent) to the box or frame.

Permanent cord-connected equipment shall use cords without excessive extra length. Extra length shall not be coiled and stored.

When branch circuit conductors are not run in electrically continuous metallic raceway, an ACEG conductor must be provided from the panelboard to the receptacle. Ground continuity is provided to the U ground slot via the receptacle mounting members (see NEC® 250.148). Bonding Jumpers are required.

For branch circuits of other than 120V and/or 15 Amp maximum, suitable receptacles, cord and caps for the required service shall be provided to furnish equivalent grounding facility.

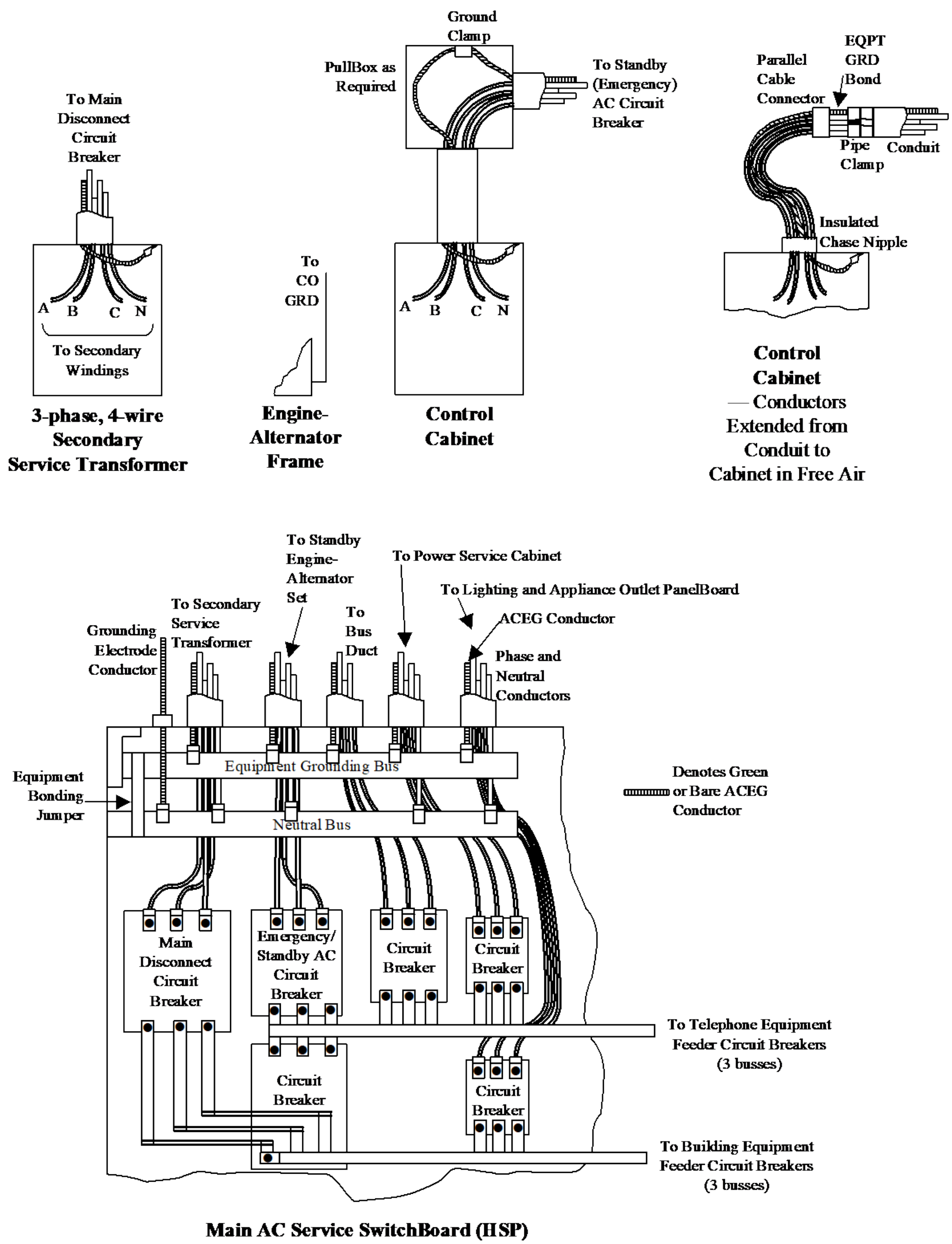


Figure 4-12: Typical Arrangement of ACEG Conductors at the Service Entrance and Standby Equipment

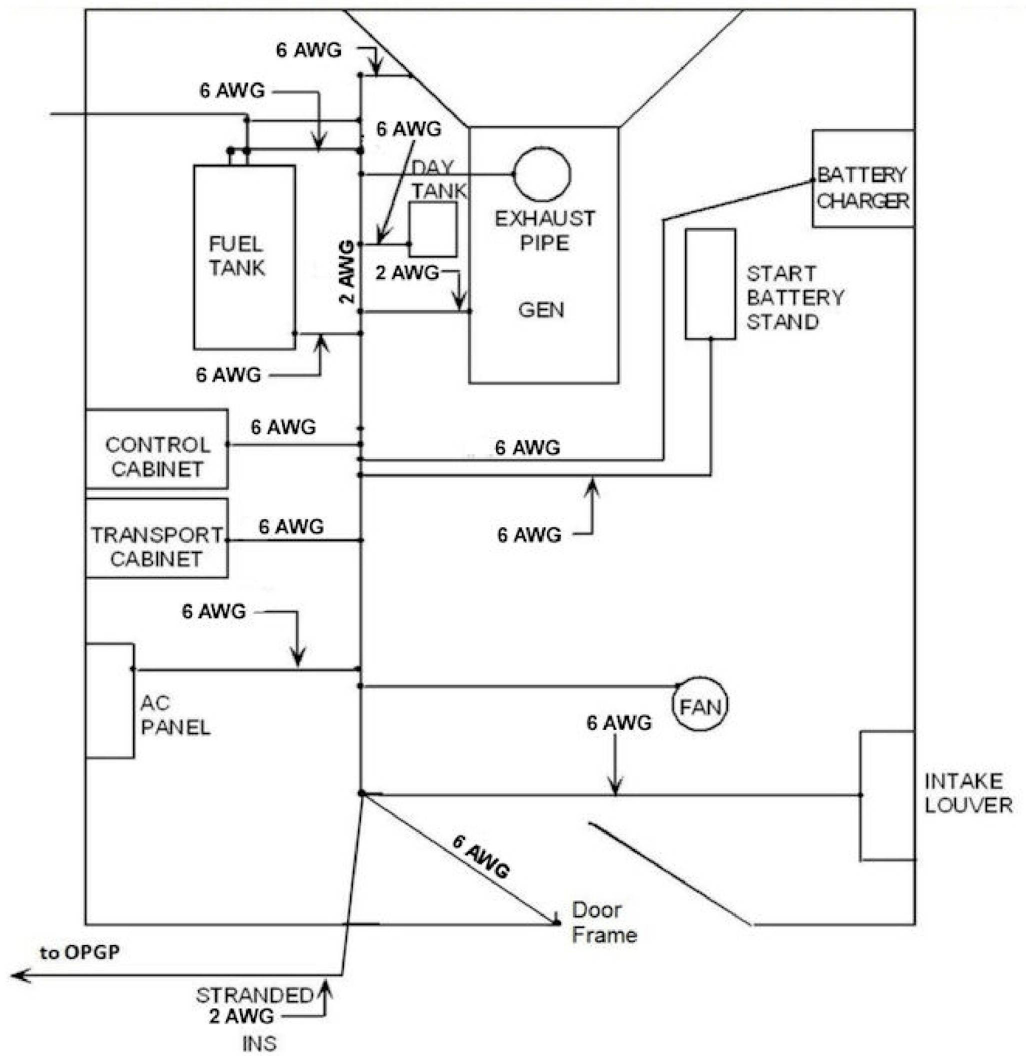


Figure 4-13: Typical Standby Engine Room Grounding Scheme for an OPGP Office

Notes:

1. All connections to the. 2 AWG will be crimped type connections (C /H- tap connectors).
2. All Connections to equipment will be 2-hole crimp connectors and connected on bare metal.
3. All conductors will be run exposed and attached with cord or plastic ties.
4. <u>No</u> mechanical connections will be accepted
5. RHW (or XHHW) type wire only - bond around flex conduits (feeders only)
6. All splices must point towards the ground source if possible (i.e., towards the source of the 2 AWG coming from the COGB or OPGPB)

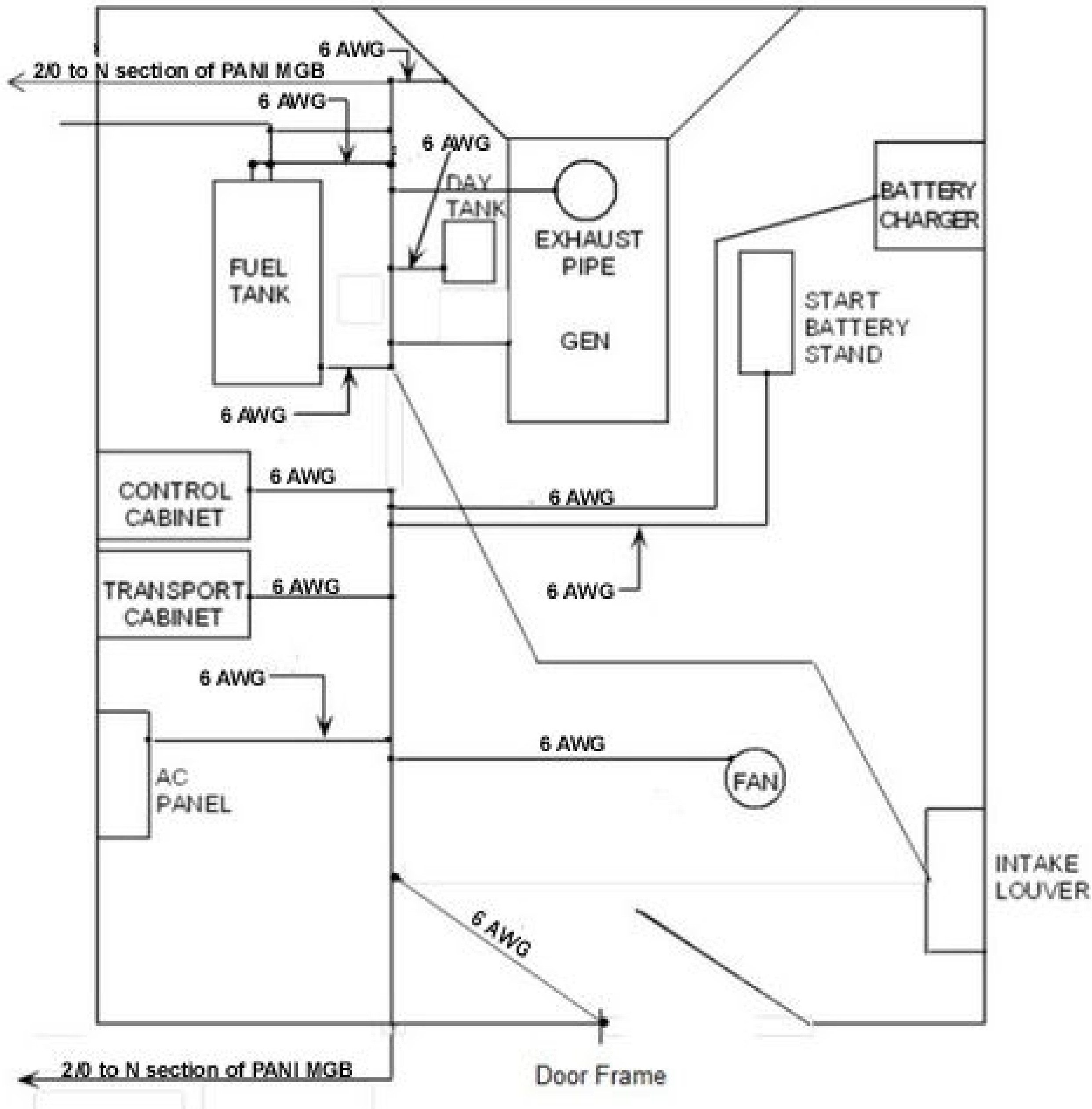
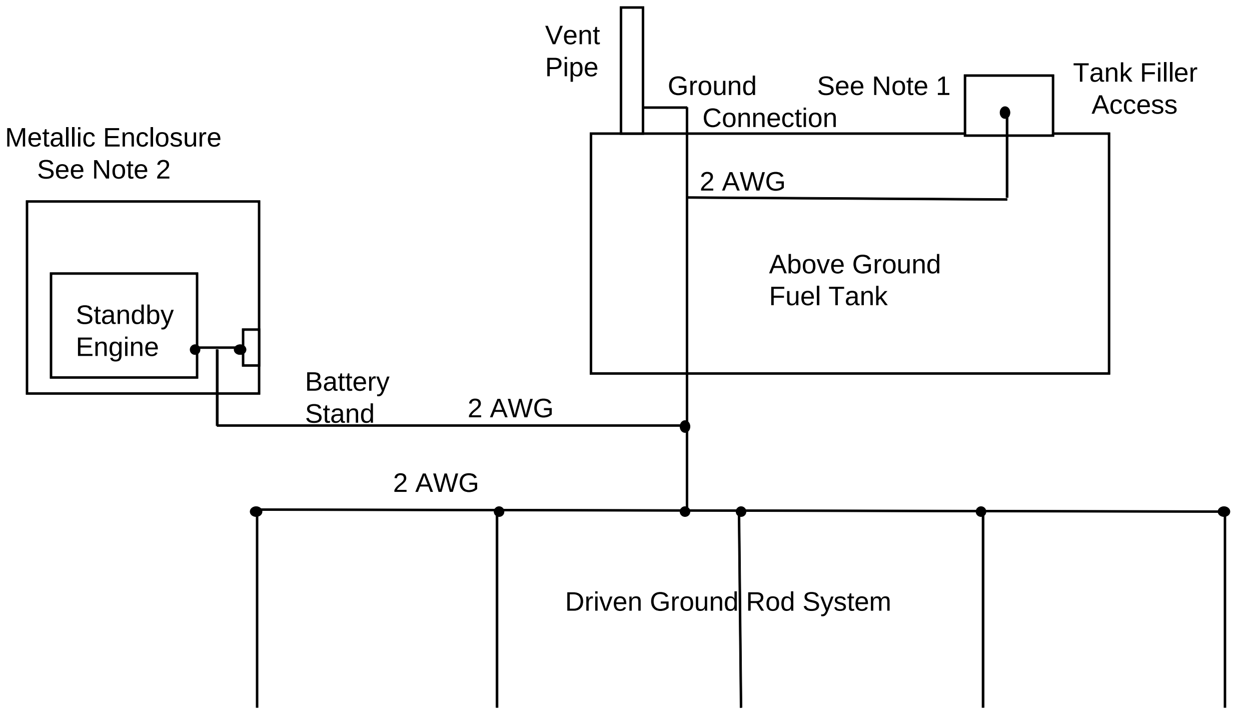


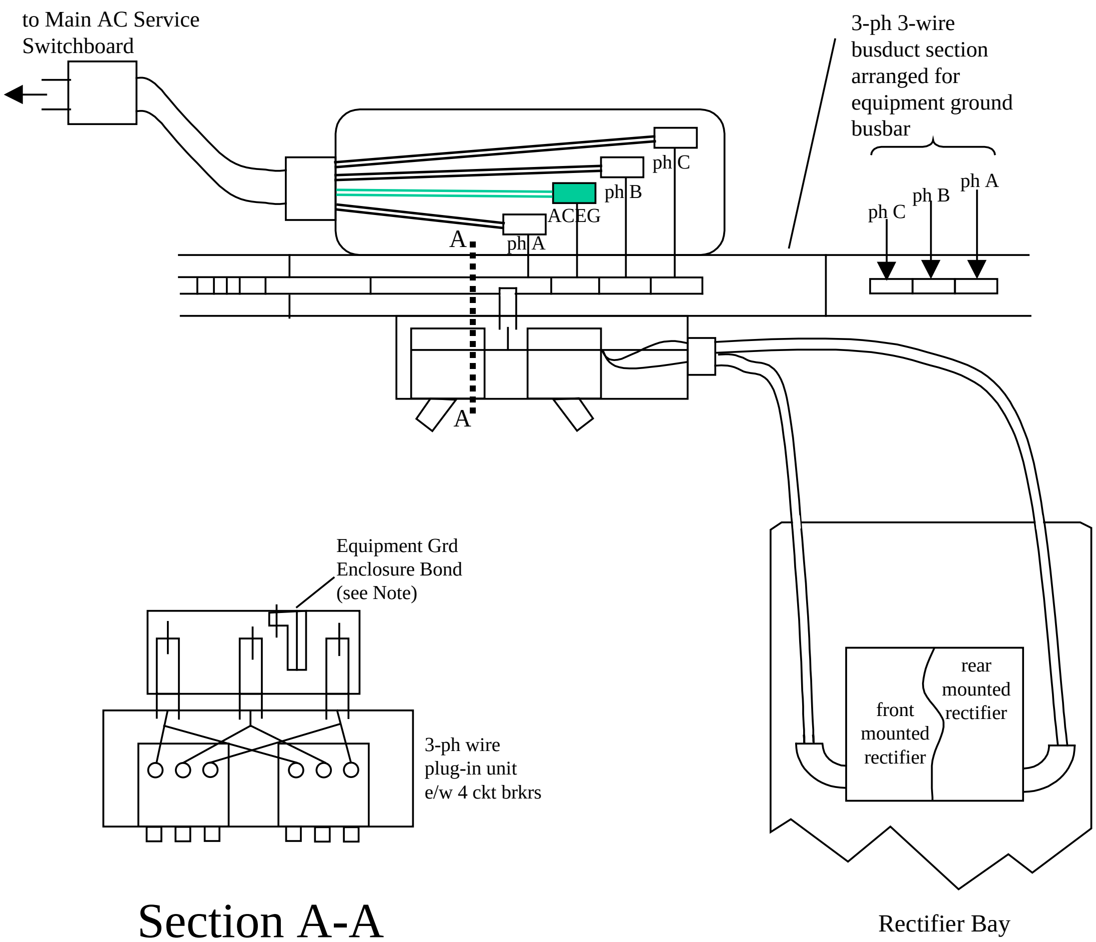
Figure 4-14: Typical Standby Engine Room Grounding Scheme for a PANI Office



Notes:

1. It is not necessary to ground tank vent/access points if the tank has other ground point(s) and continuity of less than 0.1 Ohms can be established/verified between the vent/access points and the ground point(s). If such continuity between the tank ground and the vent/access pipes/points cannot be verified, and the vent/access pipes do not have ground tabs available use a pipe clamp (see Figure 3-11, sketch E)
2. If the standby engine is located outside the building in a metallic enclosure, the metallic enclosure, standby engine and battery stand must be grounded to the driven ground system.
3. All connections must be made with copper two-hole crimp type connectors. Paint must be removed on painted surfaces and coated with an anti-oxidant compound before making connections.
4. When the primary driven ground system cannot be accessed, bring a 2 AWG solid tinned bare copper conductor from the external tank and/or engine, and run it outside the building to the OPGP. If an exterior run is not feasible, it may be run inside the building (in this case, it can be a minimum 2 AWG insulated or bare conductor), but as far away from equipment as possible, and as near as possible to the building's outer walls.
5. See Figure 7-1 for proper grounding of a direct-buried tank.

Figure 4-15: Typical Above-Ground Fuel Tank/Steel Containment Tank and Outside Standby Engine Grounding Scheme



Note: Equipment ground bar-enclosure bond (bus or cable) is required in each busduct section.

Figure 4-16: Typical Busduct System Equipment Grounding Arrangement For a 3-Phase, 3-Wire System

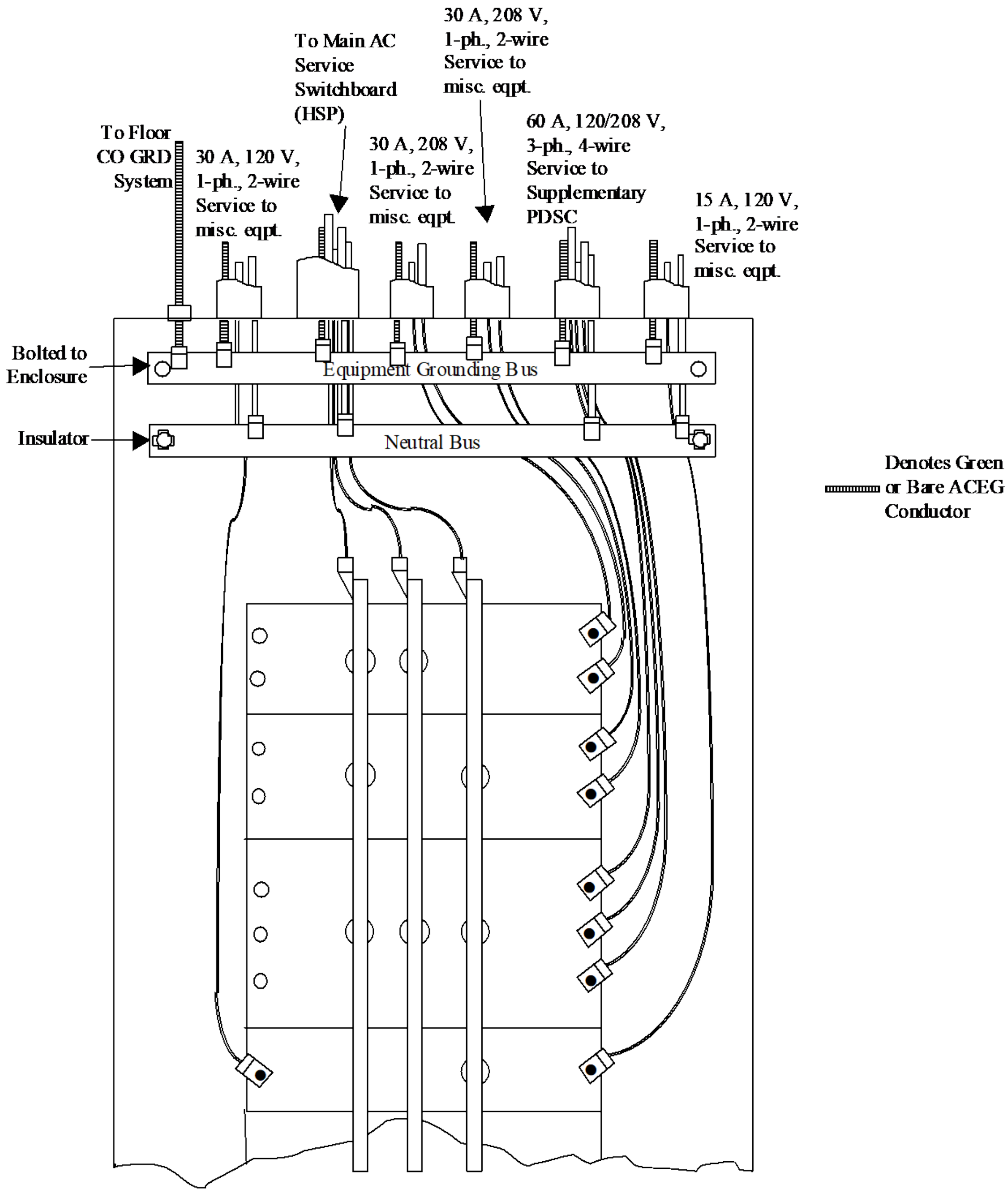


Figure 4-17: Typical Power Distribution Cabinet Equipment Grounding Arrangement

Older central office installations may be equipped with 2-pole, 3-wire grounded receptacles of other designs (e.g., Crowfoot, or other). These receptacles should be replaced with parallel polarized U ground units. Some offices may employ 2-pole, parallel, ungrounded receptacles. These units must be replaced.

Certain portable equipment now in use may be equipped with 2-pole ungrounded caps and 2-wire cords. Unless protected by an approved system of double insulation, such units are potentially hazardous. These cord and caps shall be replaced with 3-wire cords and 2-pole, 3-wire grounded caps.

Generally, all new manufacture AC operated portable or permanently mounted equipment units utilizing cord and cap for AC supply shall be supplied with 3-wire cords and 2-pole, 3-wire grounded caps that function to ground the unit structure. The only exceptions should be for tools such as soldering irons that must be employed on or near circuit connection points that may have DC potential, where contact with the tool would constitute a short to ground, or for other specialized requirements of similar nature.

AC cord may be used to power equipment within a bay or cabinet but shall not be used for permanent powering of equipment extending out of an enclosure or frame unless it is to a NEMA locking receptacle.

4.17 Frame Base Appliance Outlets

Convenient appliance outlets are provided throughout a communication equipment area to make 120 volt single phase grounded AC service available to operate cord connected appliances (i.e., test sets, soldering irons, floor maintenance equipment, etc.). Appliance outlets are established by mounting duplex parallel polarized U ground slot receptacle units in the base of communication equipment frames, with the U ground slot in contact with the frame metal. Normally (but not always), a base receptacle is provided every third frame. The NEC® (see Article 220.14 Exception) does not limit the number of outlets on the circuit for circuits dedicated to these duplex receptacles. However, good engineering practice would limit the outlets to 12 per 20 Amp circuit or 8 per 15 Amp circuit. Although it is not generally recommended to put these outlets on lighting circuits, when this is done, each duplex outlet is computed as a 180 VA load.

The AC circuits are generally extended to the frame area by means of metallic raceway (i.e., conduit, wiremold, etc.). They are alternatively tapped and extended to the ends of frame lines in armored cable or conduit. The metallic raceway is usually terminated in a conduit hole provided in an end guard mounted on an end frame of the frame line, with a fitting approved for use as an equipment grounding fitting (see NEC® Article 250.118). When so arranged, equipment ground continuity exists between the unit containing the circuit overcurrent device (usually a 20 Amp circuit breaker mounted in a lighting and appliance branch circuit panelboard) and the frame end guard via the raceway metal and the ACEG conductor. An ACEG conductor must be provided in the raceway and terminated in the box where the raceway terminates.

Usually, the circuit conductors are extended from the raceway terminal point as loose wires routed in end guard and frame bases. They may, however, be extended in the raceway if protection from physical damage or shielding from personnel is desirable. Where gaps occur in the frame line, the portion of the circuit run that bridges the gap must be routed in the raceway terminated at frames with fittings that provide equipment grounding continuity via the raceway between the separated frames.

4.18 Trolley Type Busduct

Trolley type busduct provides 15 Amp 120 V AC power for portable appliances. Generally, installations are made at distributing frames where personnel working on rolling maintenance ladders require a power supply for soldering irons. The busduct consists of a U-shaped steel rail enclosure mounted to superstructure with the mouth of the U facing down. Copper strap conductors are mounted in left and right sides of the U, insulated from the enclosure. Couplings and end connectors are provided to form a continuous circuit that runs the length of the equipment frame line.

The trolley type device, with contacts on either side that maintain sliding contact with the copper straps and four wheels that ride in grooves formed for the purpose in the open side of the enclosure, travels inside the duct and provides a connecting means of extending AC via a three-conductor cable to a receptacle mounted in a conduit box on the rolling ladder. AC service is thereby made available to the trolley duct end closure, through the duct via the trolley and cable.

Other installations are made in equipment aisles, generally in Maintenance Test Centers where rolling ladders are not used. In these applications, the cord is terminated in a parallel-polarized U ground slot plug that hangs within reach above personnel. AC power available therefrom is used to power test sets and various other applications.

Equipment grounding is provided through the AC conduit, the duct metal, metallic parts of the trolley, and the equipment ground conductor provided in the three-conductor cord. An ACEG conductor is required in the conduit that carries branch circuit conductors from the panelboard (or another device) to the busduct end connector.

Prior to the introduction of trolleys, equipment grounding continuity between duct enclosure and cord ACEG conductor depended on contact of duct metal with trolley wheels, which was not always dependable while the trolley was in motion. The latest trolleys provide improved contact by means of spring type contacts. It is recommended that earlier type trolleys be replaced with the spring type contacts.

4.19 Armored Cable

Refer to NEC® Article 320 for conductor sizes, quantity, and color normally available. Armored cable (also known as BX cable) containing. 14 AWG to 1/0 AWG wire contains a bare bonding strap to decrease sheath resistance. This strap shall be cut at the ends of the sheath. It shall never be used as an AC equipment ground conductor. An AC equipment ground conductor is required in all armored cable used for AC distribution; therefore, one additional insulated conductor must be provided. Insulation must be stripped from point of egress from armor or insulation must be colored green for identification. The maximum number of conductors available in an armored cable is limited to three in certain sizes and not more than four. Commercial types of armored cable cannot be used for 3-phase, 4-wire AC circuits requiring an AC equipment ground conductor, or certain single-phase 3-wire circuits (but MC cable can). Lumen has a standard that armored power cable shall be no longer than three feet in length, except for vertical runs in manufacturer's equipment. Armored power cable and flexible metal conduit shall never be used in any length in battery rooms per NEC® 320.12, and 348.12, but flexible MI or MC (metal-clad) cable can be used in battery rooms. Insulation-coated (liquidtight) armored power cable can be longer than three feet.

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5. Integrated Ground Systems

5.1 Integrated Ground Plane

An integrated ground plane (also known as a common bonding network or CBN) is one where the various communication system circuit ground points, and the DC discharge ground (battery return) conductors are not deliberately isolated from framework; and/or the framework is not deliberately isolated from contact via building steel, or other incidental conductive paths, to foreign communication system ground planes or to earth. Current imposed on an integrated plane is free to flow through any member of the plane in seeking a path to earth or to its point of origin in the building.

Miscellaneous metalwork (such as HVAC ducting, chilled water piping, metallic door and window frames, etc.) in a building is generally not required (although it is recommended to bond it to the CO GRD system in integrated/non-isolated areas at a minimum of one point) to be intentionally bonded to the integrated ground plane (it is required within the isolated ground plane and for engine room doors and metal near "producers" such as cable vaults and MDF protector frames), except in PANI offices with isolated ground planes (where door frames should be bonded at a minimum). It is often unintentionally bonded. It is becoming more common to intentionally bond HVAC and chilled water systems for building mechanic safety reasons. Where HVAC ducting comes from outside the building (especially if it is continuous metallic structure from the roof, or from outside where the components are not under a lightning zone of protection per NFPA 780®), it is desirable to isolate the exterior metal from the interior metal ductwork by use of a fiber-insulating section.

5.2 Buried Objects

Buried fuel tanks, gas piping that has the potential to become energized (see NEC® Article 250.104B; although attempts should be made to route electrical and gas piping such that gas piping never needs to be grounded), sewer piping, and other buried objects having entry to the building via metal pipes or other conductive material may act as unintentional earth electrodes. These electrodes must be made common with the intentional electrode (e.g., ground ring, etc.) by bonding them at their entry point with a 2 AWG wire to the OPGPB.

Bond together the telephone cable sheaths that enter the building and connect them to the ground bus on the Main Distributing Frame (MDF) and to the OPGPB (see Figure 6-1). If the MDF and the ground window are on the same floor, bond the ground bus on the MDF to both the CO GRD and the MGB in the ground window.

5.3 Frame Grounding Methods

Multi-ground the main distribution frame (treat it as an integrated ground plane) for personnel safety. Generally, it is bonded to the cable sheaths, CO GRD, and the ground window main bus (only required to be bonded to MGB when on the same floor).

5.4 Integrated Ground Plane Loads

5.4.1 Frame Grounding and Return Bus Reference for DC Power Supplies

DC power supplies in a non-isolated ground plane shall be grounded to the SPGP/ PANI-MGB. The return side of the principal power source (normally the positive buss) shall be grounded with a separate grounding conductor to the site ground system at the SPGP/ PANI-MGB. Where the power plant serves both isolated and integrated ground planes, the grounding conductor is connected to the ground window/MGB. The principal power source is classified as an external power source.

The minimum and typical sizes for the DC Grounding conductor (DCG) that references the return bus of DC plants is given in Table 5-1.

Table 5-1 Minimum and Typical Grounding Conductors for DC Plants

Power Plant Type	Minimum Grounding Conductor Size
All	≤ 0.01 Ω
CO Plants > 600 A	750 kcmil
CO Plants ≤ 600 A	1/0 AWG
Radio Sites	2 AWG (1/0 recommended)
CEV, CEC™, UE™, hut	2 AWG
RT Cabinet	2 AWG
Commercial Customer Premises	6 AWG (2 AWG recommended)

Rectifier, PBD (power distribution bays), and BDFBs should be frame grounded based on the largest protector (DC fuse or breaker) in them (this would also apply to battery stands/trays with disconnect breakers) or feeding them (could be an AC or a DC breaker or fuse). The size of the reference conductor is derived from NEC® Table 250.122. The minimum sizes are as shown in Table 5-2.

Table 5-2 Minimum Frame Grounds for DC Plants and Distribution

Maximum Possible Fuse/Breaker Size Feeding To/From/Within Bay/Rack	Minimum Frame Ground Conductor Size
≤ 200 A	6 AWG
225 - 300 A	4 AWG
350 - 500 A	2 AWG
600 - 800 A	1/0 AWG (2/0 if in PANI office)
1,000 A	2/0 AWG
1,200 - 1,600 A	4/0 AWG
2,000 - 2,500 A	350 kcmil
3,000 - 4,000 A	500 kcmil
un-“fused” battery racks	6 AWG (10 AWG if ≤ 13 Ah)

Batteries with disconnects should use the frame ground sizing rules of Table 5-2. But, if the cables to the batteries are "unfused", a simple 6 AWG (or a 10 AWG for 13 Ah and smaller batteries) is provided primarily for static discharge because the frame ground cannot be sized large enough to handle the potential short circuit current.

5.4.2 Loads Fed from the Principal DC Source

When integrated ground plane loads are fed from the same principal DC power source that supplies the isolated ground plane, the return conductors must be routed via the ground window and bonded to the main ground bus in the ground window before they are extended to the equipment being powered.

The frames of all DC-powered equipment shall be bonded as specified principally in this chapter and Chapter 3 for integrated ground plane equipment; and as specified in Chapters 8 and 9 for isolated ground plane equipment. This includes DC lighting.

Note, Only one DC fixture per circuit needs to be grounded with a 6 AWG because the other fixtures in that circuit are bonded by conduit.

5.4.3 Loads Fed from Internal Power Sources

When integrated ground plane loads are fed from power sources internal to an isolated plane, their return conductors must be routed through and bonded to the MGB within the ground window before they are connected to the power source return bus. (It is discouraged to feed integrated ground plane loads from isolated ground plane power sources.)

5.5 Grounding for Separately Derived DC and AC Power Supplies

Frames containing separately derived AC and DC power sources (e.g., transformers, ring plants, and some inverters [see Figures 4-5 and 4-6] and converters) shall be equipped with a frame grounding point that is referenced to the ground via the frame-grounding conductors.

5.5.1 Referencing Internal DC and AC Power Supplies

Separately derived large power supplies shall be single-point grounded by connecting the return bus to the nearest COGB/FGB or OPGP / PANI- MGB / MGB in the ground window. This ground reference conductor shall not be used to conduct normal load current nor should it be used for frame grounding (see NEC® Article 250.121). The grounding location should be at the immediate output of the power supply, and not at the load. Loads shall be powered with separate pairs of conductors and the frames containing the loads shall be grounded. Table 5-3 gives typical minimum grounding electrode conductor sizes for separately-derived sources fed from a DC battery plant.

Table 5-3 Minimum and Typical Grounding Conductors for Separately-Derived Sources Fed from a DC Battery Plant

Plant Type	Minimum Frame Ground Conductor Size
DC-DC Converters (with output isolated from input)	6 AWG
Residual Ring Plant	14 AWG
Inverter(s) ≤ 60 kVA without a maintenance bypass	6 AWG
Inverter(s) 61-80 kVA without a maintenance bypass	4 AWG
Inverter(s) 81-120 kVA without a maintenance bypass	2 AWG

The residual ring plant grounding conductor is sized per manufacturer recommendation, and NEC® Article 250.30(A)(1) Exception 3. NEC® Article 250.30(A)(5) Exception 3 even allows a ring plant to not need a grounding conductor if the manufacturer design is proper (non-isolated non-separately-derived) and the manufacturer permits lack of such a conductor. Depending on the connections available on the ring plant output return bus, 2-hole connector requirements for this reference ground may be waived. Inverter ground reference conductor size is based on output conductor(s) sized per NEC® Table 250.66 but using 6 AWG minimum.

5.5.2 Two or More Power Sources

When two or more power sources supply power to circuits that have a common return conductor, there shall be a single-point grounded reference. This will be accomplished by making a single connection from the common return conductor to the nearest ground reference bus.

Note: The grounded conductor of the input power to a separately-derived source must not be connected to a frame (this violates single-point grounding).

5.6 Central Office (CO GRD) System

The basis of an integrated ground plane is the CO GRD system as described in Section 3:

- The ground system starts at the OPGP or PANI- MGB and is extended to the floors via (a) vertical riser(s) (see Section 3.5 and Figure 3-8 and Section 3.7 and Figures 3-5 and 3-8);
- COGB/FGBs connect to the vertical riser whose ground potential is extended with horizontal equalizers (see Section 3.8, and Figures 3-5 , 3-6 to 3-8). Additional information for COGB's can be found in section 5.7
- Main aisle feeders (sized from 2 AWG to 350 kcmil) may branch off from these horizontal equalizers (see Section 3.8, and Figures 3-6 to 3-8).
- Individual aisle stringers are sized from 2 AWG to 2/0, and individual relay rack bonding is usually 6 AWG (see Sections 3.9, 5.8, 5.10, and 9.1; as well as Figures 3-6 to 3-8).
- When adding a new aisle/lineup or adding to an existing one with no overhead stringer, a new stringer should be extended the entire aisle length to avoid future splices of the grounding conductor.

Ultimately it is most desirable to keep impedance as low as possible among internal grounding cables to facilitate the flow of electrons back to ground and limit voltage differentials during a lightning strike or power fault to ground. The desirable limit for any internal fault current grounding path back to the building SPGP is 0.03 DC ohms (up to 0.01 ohms on any one branch). Table 5-4 gives the approximate 0.01 DC ohm limit at expected cable rack temperatures for the given typical grounding cable sizes.

Table 5-4 DC 0.01 Ohm Resistance Distances at Cable Rack Temperatures

Grounding Cable Size	0.01 Ω DC Resistance Distance
6 AWG	25 ft
2 AWG	60 ft
1/0 AWG	90 ft
2/0 AWG	120 ft
4/0 AWG	190 ft
350 kcmil	300 ft
750 kcmil	650 ft

Some other standards (such as ATIS-0600333) require certain grounding conductors to have 2000 circular mils of cable size per linear foot. This corresponds to approximately a resistance of 0.005 DC ohms (half the distances shown in the table above), which is also the resistance required for certain key grounding conductors in RUS standards.

5.7 Design Parameters of a COGB

The CO GRD bars are used to facilitate distribution of horizontal ground conductors on various floors of a CO. The bars are generally mounted on a building column. If the CO GRD busbars are wall-mounted, try to use an internal wall instead of an external wall or column, since lightning will hit the outside of a building. The busbars do not need to be insulated from the column (they do need to be insulated from cable racks, if they are attached to those), but they do need to be kept a minimum of 3 inches from the surface to allow for workspace. If the main COGB(s) for a specific floor (not including supplemental COGBs on the floor fed from the main bar or the same vertical riser; but including COGBs on the floor fed from a different vertical riser) is insulated from building steel/concrete, it must be bonded (with a minimum 6 AWG) to accessible building steel (can be rebar or concrete or I-beams, etc.), and water piping on that floor (this requirement is per NEC® Articles 250.30(A)(4), 250.104(B), and 250.52(A)(1) and (A)(2)). Preferably, place the COGBs so that the grounding conductors coming from the equipment on the floor may terminate opposite from the vertical riser connection. Ground is established by bonding the busbars to the vertical riser.

The floor COGBs are made of copper and are usually at least ¼ inch thick, 4 inches high and 16-24 inches long. Aluminum buses in DC ground systems are prohibited (except where they are pre-existing). All connections to the COGB must be with 2-hole crimp connectors.

Each COGB or OPGP should be pre-drilled with a minimum of 16 sets of holes on 1 inch centers, and 6 sets of holes on ⅝ inch centers (floors with more equipment may require larger bars and more holes). Drilling of existing bars is not recommended, and if done, must have the written permission of the Design Engineer, protection for nearby equipment and buses, and must be done in the Maintenance Window.

5.8 Equipment Frame Grounding

All switch frames, fuse bays, relay racks, miscellaneous bays, and cabinets (PICS storage cabinet static discharge grounds are exempt from the size and distance requirements of Table 5-4, and the "choke" requirements of Section 9.2.1) must be grounded with a minimum 6 AWG (bays that have no power running to them, no metallic cables in them, nor any circuit packs in them, and that are not within 6 feet of an isolated ground plane, are not required to be grounded) from the DC grounding system (DCEG). Normally, a 2 AWG insulated stranded wire is run on top of the lineup (2/0 in PANI CO's), with 6 AWG branches to ground individual frames (this is sometimes referred to as a Telecommunications Equipment Bonding Conductor, TEBC). All painted contact surfaces shall be cleaned so that metal-metal contact is made. A conductive non-oxidizing agent must be applied to inhibit corrosion. The connection to the frame must be made with a two-hole copper crimp connector. Connections to grounding conductors should be made so that the conductor flows toward the ground source. In the past, a steel pipe used to support the bay framework was used as a frame ground. This support pipe is no longer acceptable for grounding newly added frames.

Guidelines such as Tech Pub 77350 and Telcordia NEBS GR-1089 are to be followed for grounding individual shelves within a relay rack (chassis grounding). Terminating a lug on top of another one on the same side of a frame or bus bar (known as "double-lugging") or placing multiple grounding conductors in a single lug is prohibited. Chassis grounding conductors should be bare or have green insulation. The Unit Bonding Conductor (UBC) method must be followed by placing grounding conductors between chassis' and the relay rack. The manufacturer should specify the wire size and type. Lacking manufacturer guidelines, the intent of NEC® Table 250.122 should be followed. The minimum copper wire sizes shown in Table 5-5 shall apply.

Resistance between chassis and frame ground must measure less than 0.01 ohms (0.001 ohms for NNS). Single-hole grounding lugs are allowed for smaller (2RU or less) shelf/chassis grounds. An approved anti-rotational lock washer must be used on all single hole lugs. All grounding connections to chassis' larger than 2RU and all frame grounding connections must be two hole lugs. If the shelf provides a two-hole connection, it is required that a 2 hole lug be utilized.

Table 5-5 Chassis Ground Sizes When Required and Not Specified

Feeding Fuse/Breaker Size	Minimum Chassis Ground Wire Size
≤ 4 A	19 AWG
5 A	18 AWG
6 - 10 A	16 AWG
12 - 15 A	14 AWG
20 A	12 AWG
25 - 60 A	10 AWG
70 - 100 A	8 AWG
110 - 200 A	6 AWG
225-300 A	4 AWG

Certain older switching systems, and various other older equipment frames, are equipped with frame ground busbars. These ground bars are mounted in electrical contact with the frame metal. These ground bars thereby form a part of an integrated (or isolated in the case of the Ericsson switch) ground plane in common with frame metal and any other metallic components that are electrically bonded. The integrated ground plane for these types of toll transport systems is a single plane extending throughout the building with multiple points of interface between building and discharge ground system through the equipment frame ground bars. More information is contained the sections 5.9 and 5.10 on these and similar types of systems.

Frame ground bars, when provided, normally function as a common ground point for circuit ground conductors from equipment units mounted on the frame. The ground current must return to the DC plant batteries. A current return path, dependent on the ground system design of individual communication systems, may be afforded by:

- Discharge ground conductors run from individual frames.
- Interjunctioning ground bars in a frame line into a common conductor and extending the run with wire to discharge ground paths that terminate at the ground terminal of the battery.
- Various combinations of the methods just mentioned.

5.9 Equipment Frame Busbar Functions as a Combination Discharge-Framework Ground Busbar

Ground busbars that mount directly on framework may function as combination paths for current return to battery and for framework grounding. Most modern equipment does not use this method for ground and battery return; however, its use in existing installed equipment is not totally obsolete. Equipment units mounted on frames sometimes were circuit-grounded at frame ground busbars in electrical contact with frame metal. Busbars mounted in a frame lineup were junctioned to form a continuous conductive path. The continuous run was connected at the head of the lineup to a main aisle ground equalizer extending along the main aisle to allow connection thereto from each lineup in the system. This equalizer is connected to the discharge ground conductor of the battery discharge circuit feeding the system to provide a current return path and to the floor CO GRD system to safety-ground the frames. This arrangement (including the frame busbars, aka Equipment Frame or Relay Rack Ground Busbars) is referred to as a Combination Discharge-Framework Ground System. These systems use standard frame and aisle stringer cable sizes, as per Section 5.8, and Figure 3-7.

5.10 Relay Rack "Frame Return" Ground Busbars

The term "RR GRD" is used extensively on some older communication systems circuit schematic drawings to denote that equipment units mounted on an equipment frame should be circuit grounded to the frame ground bar (these systems' only return path is through this framework return system). This system requires a 750 kcmil main aisle equalizer with connecting 350 kcmil aisle equalizers (however, the individual bay connections need be no larger than the traditional 6 AWG). Reference to a Relay Rack Ground busbar may be construed to mean an Equipment Frame Ground busbar as described in paragraph 5.9. However, in modern communication systems, "Relay Rack" is no longer used as a generic term to denote frames.

5.11 Distributing and Protector Frame Busbars

Protector frames come with ground bars to provide a direct path to ground for high potential energy intercepted from cables entering the office through the CEF. Protectors may be mounted on an individual framework in proximity to a distributing frame or may be mounted on a distributing frame. A protector ground bar is normally mounted at the top of the frame, fastened to each protector mounting support. A frame ground bar is furnished near the bottom of protector frames or distributing frames mounting protectors.

An insulated stranded 1/0 AWG (2/0 AWG in PANI CO's) conductor bonds the upper and lower bars. The lower bar functions as a FRWK GRD, a grounding point for cable sheaths and for miscellaneous ground connections. A 1/0 AWG is extended from this bar to the COGB/OPGP (or 2/0 to the PANI- MGB/FGB) on the same floor. In addition, a 1/0 AWG (2/0 in PANI CO's) ground conductor should be extended from this point to the cable vault for bonding to the cable sheaths.

Miscellaneous metal within 6 feet of a protector frame should be grounded. In a PANI office, there should be separate leads for the protector frame ground (going to the P section), and the nearby miscellaneous metal (going to the N section).

When the protector frame is located on the same floor as an isolated-integrated ground window, an insulated stranded 1/0 AWG conductor bonds from the integrated side of the MGB in the ground window to the main ground bar of the frame (lower bar). The 1/0 AWG ground conductors serve as a discharge ground path for lightning currents, as a voltage equalizer, and as a frame ground.

Cosmic® type distributing frames (single or double sided) are designed to be grounded with a 6 AWG or larger from each frame to a 1/0 AWG (or to the bare 6 AWG that comes as part of the frame – which is then tapped to a 1/0 AWG) to the CO Ground bar (or OPGP, whichever is closer and more convenient), and to the ground window if the distributing frame and ground window are both located on the same floor.

Intermediate Distributing Frames (including ICDF frames) that do not tie to OSP metallic cables may be simply grounded to the integrated CO grounding system with 6 AWG.

Main and Cosmic® Distributing Frame and Protector Frame Grounds must use their own unique (separate from the rest of the integrated ground plane) grounding leads run directly to the COGB (see Figure 3-7). Only the protector frame (not other distributing frame types) is required to have a 1/0 AWG run to the CEF, and a 1/0 AWG run to the ground window (when located on the same floor).

5.12 Collocated Local Exchange Carrier Grounding

Lumen offers several different types of CO collocation: physical collocation, shared collocation, virtual collocation, and common or cageless physical collocation. Any of these may be requested by a given CLEC (Competitive Local Exchange Carrier).

Besides this document, Lumen/ CenturyLink Technical Publication 77350 contains further references to grounding installation, both for Lumen and CLEC equipment.

Note: CLECs are not held to more stringent grounding standards than those to which Lumen holds itself.

5.12.1 The Grounding "Feed" for Caged Physical Collocation

The type of collocation typically chosen by larger CLECs (i.e., those who want to install more than one or two frames of equipment) is caged physical collocation. In caged physical collocation, the collocator's space is physically separated from that of Lumen by fences, walls, or other barriers. The CLEC installs, monitors, and maintains its own equipment, while Lumen provides common items such as power, grounding, HVAC, and sometimes an interface point known as the Single Point of Termination or Interconnection Distributing Frame (ICDF), etc.

For these physical collocators, Lumen's grounding interface to them is an extension of the nearest COGB, FGB, OPGP, or PANI- MGB. A cable equivalent to a horizontal equalizer is run from one of these bars (from the non-isolated section of a PANI-MGB or an FGB) to the collocated local ground bar (CLGB). The CLEC should use this CLGB for grounding their equipment frames. Each CLEC must have a dedicated grounding conductor run between the CLGB and the COGB, FGB, OPGP, or PANI-MGB.

The size of the grounding conductor from the COGB/FGB or OPGP / PANI- MGB to the CLGB (the CLGB is located inside each CLEC area) is summarized in Table 5-6.

Table 5-6 Minimum and Typical Grounding Conductors Run for CLEC Cages

Cage Type and Distance from Lumen Ground Bar	Minimum Grounding Conductor Size
All	$\leq 0.01\ \Omega$
Cage $\leq$ 100 ft^2, and cable run $\leq$ 75 ft	1/0 AWG (2/0 for PANI CO's)
100 ft^2 > Cage < 500 ft^2, or cable run is > 75 ft	4/0 AWG
Cage $\geq$ 500 ft2	750 kcmil
Multiple Cages	750 kcmil with individual drops
Cages containing equipment with ground-bonded returns	750 kcmil

NOTE: Lumen horizontal equalizer must not be used for CLEC cages, nor should Lumen connect its equipment to a caged CLEC ground "feeder".

Collocator's are generally prohibited from using frames as a battery return path. However, if their equipment uses this method, Lumen must be informed up front in order to properly size grounding conductors. In those cases, the ground cable "feeding" them has to be upsized, as shown in Table 5-6.

5.12.2 Fence Grounding for Caged Physical Collocation

Most physical CLEC areas (as well as some Lumen subsidiaries) use chain link fence as the barrier between Lumen and the CLEC. All fence sections and hardware must have bonding continuity. Fence hardware can be used to meet this function. If the door or gate is metallic, it too must be bonded to the adjacent metallic wall or fence with a flexible bonding conductor. In some cases, the fence sections and the door/gate are bonded together with clips attached to an incidental bonding conductor run along the top of the fence. Because it is an incidental bonding conductor, it is treated similarly to rack connection hardware and is not subject to most of the requirements of this publication.

<u>Incidental Bonding Requirements for CLEC Cages</u>

The cage fencing must be bonded to the CLGB from two locations at opposite corners whenever three or four chain link or other metallic walls are used (one bond can be used if only one or two of the walls consist of chain link or other conductive material). The CLGB connections to bare fencing must be made with a minimum 6AWG stranded copper conductor and a two-hole crimp-type copper lug or H-tap connector which is sized properly for the connection point. This connection must be cleaned and treated with a conductive corrosion inhibitor.

Note: Fence hardware bonding connections are considered incidental bonds and are not subject to the same crimping and anti-corrosion requirements as Central Office Ground System connections.

Note: Not all anti-corrosion compounds are conductive. Only products that are listed as conductive are acceptable to use where an anti-oxidant compound is required.

5.12.3 Isolated Ground Planes in Caged Physical Collocation

Most CLECs do not desire (and Lumen and Regulatory bodies generally prohibit it) to place Class 5 end office switching equipment in their physically collocated space. In some rare cases this has occurred. When it does occur, or if there is other CLEC equipment requiring an isolated ground plane, this equipment is restricted to physically separated collocation — i.e., it will not be allowed for virtual collocation or cageless physical collocation within our lineups if it requires an isolated ground plane. Not all “switches” require isolated grounding. If the CLEC’s “switch” does not require isolated grounding, connections are made to the CLGB just as with any other type of integrated ground plane equipment.

When an isolated ground plane switch is placed in caged physical collocation, the cage fencing or walls provide a needed physical separation for the isolated ground plane. However, when an isolated ground plane switch is placed in a cageless environment, a 6 foot separation from all other office equipment, physically marked on the floor, must be maintained.

When a physical collocator places a switch in their area which requires an isolated ground plane, they should follow the general rules laid out in Chapter 8 of this document. Lumen, however, will not mandate what grounding rules a CLEC follows internal to its own equipment. Lumen is concerned about the interface between the Lumen grounding system and that of the CLEC and will not allow direct connections to its own ground windows by CLECs except in extenuating circumstances, evaluated on a case-by-case basis, through the Bona Fide Request (BFR) process.

As mentioned, Lumen will not dictate how the CLEC establishes an isolated ground plane, but using the principles of Chapter 8, a few suggestions can be made for offices using an isolated-integrated ground system (as opposed to the PANI- MGB system). Essentially, Lumen uses two types of isolated-integrated Ground Windows (Main Ground Buses): those physically separated from the power plant or power source (separate ground window) and those that are the return bus bar of the power source (using a return bus as the ground window). These types of setups are detailed in Figures 8-1 and 8-8 through 8-11. The CLEC is free to do essentially the same.

Although the CLEC does not place their own power plant, CLECs large enough to place isolated ground plane switching equipment will typically have a large BDFB or other type of Power Distribution Board to which Lumen will provide power. The CLEC may use the return bar of this "BDFB" as a ground window, following the guidelines of Chapter 8 (Figures 8-9 and 8-10 are especially helpful). The BDFB return bar separation point for the isolated and integrated sides would be the point on the bar where the CLGB connection is made.

As an alternative, the CLEC may choose to set up a separate ground window. Figures 5-1 and 5-2 illustrate this separate ground window concept. In these figures, the CLEC's separate ground window bar is referred to as a CMGB (Collocator's Main Ground Bus). This setup follows the general principles represented in Figures 8-1 and 8-7 through 8-9.

As noted in Chapter 8, and in Figure 5-2, integrated ground plane metallic objects (frames, ironwork, etc.) that are located within six feet of an isolated ground plane must be "foreign-object" grounded back to the integrated side of their "ground window". This includes any chain-link fencing.

Physical collocator's who place isolated ground plane equipment should be served with a 750 kcmil COGB / FGB / OPGP / PANI- MGB to CLGB equalizer, even if they are "cageless physical" CLECs that would not even normally require a CLGB.

Note: When a CLEC is fed directly from a DC power plant PBD (regardless of whether they have isolated or integrated equipment), and that power plant has a remote ground window, the return conductor serving the CLEC must be run through the ground window and bonded to its MGB.

5.12.4 Grounding for Other Types of Collocation

There are several other types of collocation offered by Lumen. In virtual collocation, the CLEC pays Lumen to buy, install, monitor, and maintain equipment. This equipment is placed in Lumen lineups and treated just like Lumen's own equipment. It is grounded in the same way as any other Lumen integrated ground plane frame in that lineup. This is typically done with a 6 AWG bonded to the framework and then connected to a. 2 AWG "stringer" (2/0 in PANI CO's) which runs down the lineup. The stringer runs back towards the COGB, FGB, OPGP or PANI- MGB (possibly connecting to a horizontal equalizer extended from that bar).

Another type of collocation is known as cageless physical, or common collocation. This is similar to virtual collocation in that it is sold on a bay-by-bay basis, and is often in existing Lumen lineups, next to Lumen frames. But, like physical collocation, the equipment is bought, installed, monitored, and maintained by the CLEC. Because the equipment is often in Lumen lineups, it is grounded and installed to quality standards mentioned in this Publication and in Tech Pub 77350, in the same way as the aforementioned virtual collocation.

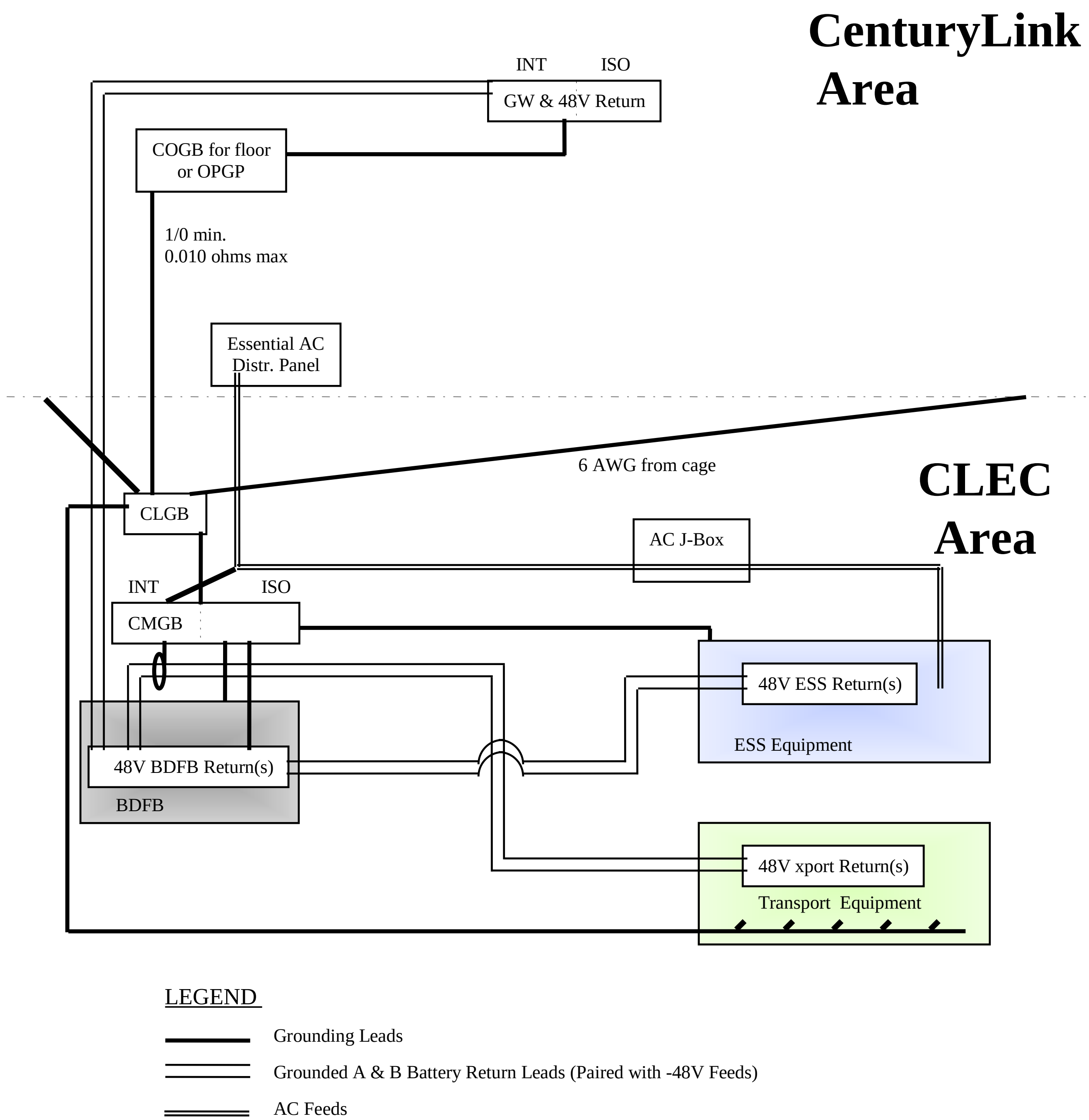

Figure 5-1: Example of a Possible CLEC Switch Isolated Ground Plane Environment

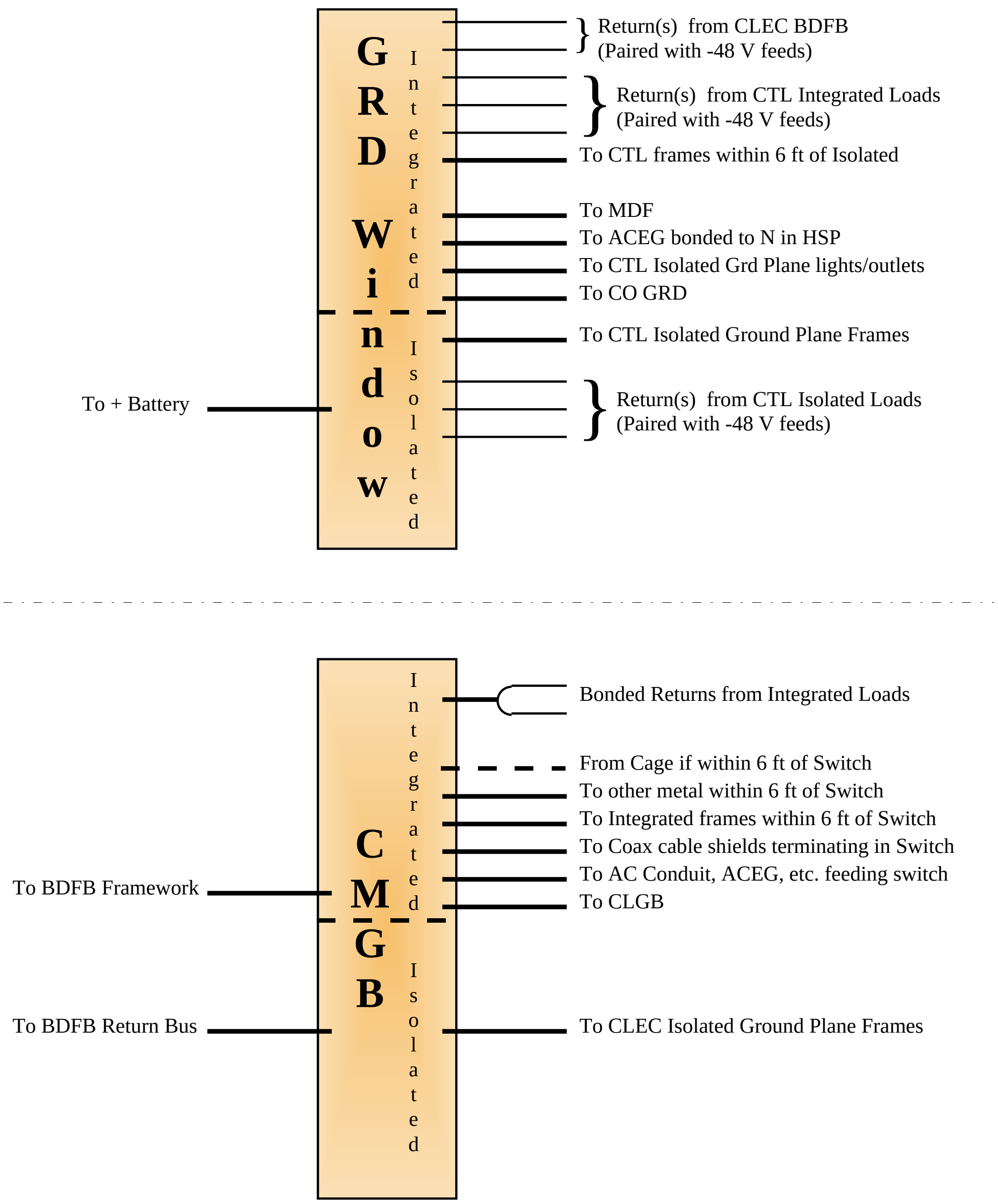

Figure 5-2: Example of Lumen Ground Window Sequencing and Possible Sequencing for a Separate CLEC Ground Window

Another type of collocation offered by Lumen is known as shared collocation or shared physical space collocation. This is a type of physical collocation where an area of floor space is given to a group of collocator's (typically 2 to 4 of them). They may or may not be physically separated from each other (those that are physically separated are known as "shared physical space collocation, and those that aren't separated are termed "shared collocation", or from Lumen, by a cage, wall, or other barrier. If it is separated by a cage or other barrier, the caged physical collocation rules given previously apply. For shared collocator's not separated by a physical barrier, if the shared collocation area is physically separated from Lumen lineups by 6 feet or more, then the shared area will be served by a single CLGB (shared by all CLECs in that shared area). In these cases, the COGB / FGB / OPGP / PANI- MGB to CLGB feeder is sized in accordance with the rules given previously. However, if the shared uncaged area is not separated from Lumen lineups by at least 6 feet, then the CLEC frames are treated like those of virtual or cageless physical collocator's, as far as grounding and quality standards are concerned.

Finally, wireless collocation is available. Grounding requirements for wireless collocations are found in Section 7.23.

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6 Cable Entrance Facility (CEF)

6.1 Determining Exposure to Foreign Potentials

Depending on its environment, outside plant cables may be subjected to the following sources or potentials, either singly or in combinations:

- Lightning
- Power Contacts
- Power Induction
- Ground Potential Rise

Exposed vs. Unexposed Plant — The terms exposed and unexposed are used to classify the plant with respect to its vulnerability to these sources of current and voltage. Outside plant that is subject to electrical disturbances from any of these sources is classified as exposed. Plant not subject to their effect is classified as unexposed. The exposed classification of outside plant is a function not only of the outside plant environment, but also of the physical characteristics of the plant. For example, a conventional shielded, paired conductor cable subject to the electrical disturbances detailed above would be classified as exposed. An all-dielectric optical fiber cable placed in the same environment would be classified as unexposed because the optical fiber cable contains no metallic sheath components, metallic strength members or metallic pairs. (See the National Electrical Safety Code® [NESC®] for further detail.)

6.2 Central Office Protection

All telecommunications cables that contain metallic components such as a metallic shield, a metallic strength member, metallic pairs or a vapor barrier, require some form of electrical protection at the central office. The electrical protection includes bonding and grounding of cable metallic sheath components and metallic strength members, and the application of protectors to metallic pairs, along with fuse links and heat coils, where required. Air pressure pipe that is exposed and is metallic or contains a metallic vapor barrier also requires bonding and grounding. Where the cable complement consists of both exposed and unexposed cables, it is advisable to provide protective devices on metallic pairs on both the exposed and unexposed cables for ease of administration and the possibility of future rearrangements. Cables containing no metal components, such as all-dielectric optical fiber cables without metallic pairs, are considered unexposed and will not require electrical protection at the central office.

Generally, "exposed" cables enter through the CEF (where their shields and/or metallic strength members are bonded), and then are routed directly to an MDF or COSMIC protector frame. Routing of "exposed" cables before they reach a protector frame cannot be with internal building "unexposed" metallic voice and data cables.

Note: In Customer Premises buildings, the CEF may be called the TEF.

In order to minimize exposure of the network equipment to lightning in Lumen buildings, entrance of any metallic member from the outside of the building must enter through one of the following three entrances so that it can be easily protected and bonded to ground: CEF, AC service entrance, or waveguide entry plate.

6.3 CEF Protection Measures (Bonding and Grounding)

The OPGPB (or PANI- MGB) is the CO location for grounding conductor connection to earth electrodes. The major emphasis of bonding and grounding is to equalize potentials between equipment ground, power ground, metal cable components, MDF ground, and the site principal ground point. The metallic sheath components and metallic strength members of all cables entering the central office must be connected to the site ground as close to the entrance as possible but not more than 50 feet after entering the building structure. A minimum 1/0 AWG or 2/0 AWG ground conductor (maximum of 0.01 Ω – see section 5.6) must be run from the OPGPB (PANI- MGB) to each cable entrance. In addition, a 1/0 AWG must be run from the CEF to the protector frame. Insulating joints may be required in certain areas, as designated by the Lumen Electrical Protection Engineer, where corrosion of cable or potential high voltage DC faults are a problem. Insulating joints do not provide good personnel protection against hazardous voltages and are not intended for that purpose (see Figure 6-3). Because the cable entrance is a place where lightning can enter the building, all metal in the cable entrance facility should be grounded (in a PANI office, the CEGB is connected to the P section, and the cable entrance miscellaneous metal is connected to the N section).

6.3.1 Central Office Without Insulating Joints

In a CO without insulating joints, bond metal strength members and shields of entrance cables with 6 AWG or bonding ribbon to the ground bar (or 1/0 AWG or larger wire) which is run from the CEF to the OPGPB (if a CEGB isolated from the vault wall is used, a 2 AWG stringer can be run from it to ring the vault, unless multiple duct banks are daisy-chained, in which case the ground “feeder” back to the CEGB should be 1/0 AWG or larger). The routing of the 1/0 AWG or larger cable to the OPGP (or 2/0 AWG to PANI- MGB) should be as direct as possible and routed away from equipment that might be affected by surges.

Figure 6-1 shows CO entrance cables without insulating joints. Often, the bonding is done at CEF splice cases. In addition to bonding to the CEF ground system at the splice, the shield is usually bonded across the splice (usually a direct bond, or bonds from the cable entrance ground system to the shields on both sides of the splice; except for capacitive insulating joints) in traditional Bell System isolated-integrated offices (known in ANSI/ATIS 0600313.2008) as a “traditional entrance”. In traditional PANI offices, the cable shields are not bonded (the TIP cable shields are only bonded at the MDF), with a minimum 3 inch separation between the grounded shields and TIP shields (preferably with the TIP cable shields tape-isolated). This latter configuration is described in ANSI/ATIS 0600313.2008 as an “isolated entrance”. (See figure 6-2)

6.3.2 Central Office With Insulating Joints

Figure 6-3 shows an entrance cable with an insulating joint. Insulating joints are rare (except where "light rail" cable exposure exists in traditional RBOC isolated-integrated offices); however, where they exist:

- The metal sheath components and strength members of all entering cables must be bonded together with 6 AWG or bonding ribbon on the OSP side of the insulating joint within the first utility hole adjacent to the office (MH-0). The cables, together with all associated metal (such as capacitors, pressure pipes, and bonding wire or ribbon), must be isolated from all grounded objects (such as building steel, equipment, and racks) on the outside plant side of the insulating joint.
- The insulating joint must be as near as possible to the point of entrance. Insulating joints must be capacitor-bridged — see Figure 6-3 (this capacitor is usually about 1,000 microfarads for single cables; and 10,000 microfarads if it serves more cables).

All “exposed” metallic conductors (excluding waveguides — which include coaxial cables — whose bonding requirements are found in Chapter 7) must enter the CO through the CEF and be bonded and grounded as specified in the preceding paragraphs.

Bonding and cable continuity in the CEF can be verified using a CORM (see Telcordia BR 802-010-100 for proper application).

6.4 Alternative Arrangements for Bonding and Grounding Optical Fiber Cables

There may be operational or economic liabilities associated with CEF grounding and bonding of optical fiber cable metallic sheath components and strength members. For example, access to these components may require a fiber splice (preferably to a cable that has no shield or metallic strength member so that there is no possibility of carrying lightning further into the building). Grounding and bonding metallic sheath components and strength members at the interconnection equipment would overcome these liabilities but would allow lightning and power fault currents to be carried past the CEF and into the central office. Although bonding and grounding of all metallic sheath components and strength members at the CEF is recommended, the methods described in the succeeding three paragraphs offer adequate protection.

If the outermost metal on a fiber cable is a full circumferential shield(s), only this shield may be grounded at the CEF. All metal components internal to this shield may not be bonded at the CEF, but, if electrically continuous, should be bonded together and grounded at the interconnection equipment. Extensions of outside plant optical fiber cable into the central office should conform to fire protection requirements (NEC® Article 800.48 allows unlisted cable to extend no more than 50 feet into the building; however, unlisted OSP cable in the CO that is not in a cable vault needs to be covered with fire-retardant tape or placed in FR metallic conduit). Where insulating joints are used at the central office, this method should not be used as it will short circuit the insulating joint.

Bonding and grounding may be done only at the interconnection equipment when there are compelling reasons for not bonding and grounding all metallic components in the CEF. The pathway within the central office through which the outside plant optical fiber cable is routed should conform to fire protection requirements (see NEC® Articles 770 and 800).

All metallic sheath components and strength members, as well as the interconnection equipment itself, must be bonded and grounded to the building ground system. A 6 AWG copper wire or equivalent should be used. If there is more than one cable, the 6 AWG wires should be joined to a 1/0 AWG (2/0 AWG in PANI CO's) copper conductor running to the CO GRD system. The routing of this conductor should be as direct and straight as possible, and away from equipment that might be affected by flashover from the conductor. The bonding and grounding of a single optical fiber cable containing a shield and central metallic strength member is illustrated in Figure 6-4. Where insulating joints are used in the central office, the metallic components must be separated from the central office building system ground through a capacitor as shown in Figure 6-3.

6.5 Location of the CEF

In accordance with NEC® 800.100, the CEF should be within 20 conductor feet of the building AC HSP. Exceptions are allowed when this is not practical (such as larger buildings).

Often the CEF is under the building or in a separate room on the lowest floor (both are a cable vault). In small structures, it may be a space on the wall (preferably with the non-fire-retardant cable in a fire-resistant box enclosure); and in a few sites it is a pedestal (14 inch wide or larger) with a copper ground bar (as opposed to steel) just outside the building wall. If this pedestal is metallic, its internal ground bar (the CEGB) should be bonded to this metal. If the CEF pedestal (when used) is not within 6 feet of the COGF, drive a ⅝ inch x 8 foot minimum ground rod and bond it to the COGF with a tinned solid 2AWG copper conductor; otherwise bond the CEGB bar of the pedestal to the COGF with the solid 2 AWG conductor. (If the COGF is not readily accessible, bond the pedestal CEGB to the PANI- MGB "P" section, entering the building at a point close to the PANI- MGB.

6.6 Air Dryer Grounding

There are typically air dryer(s) and an air pressurization system near the CEF for non-gel-filled and/or non-PIC (pulp) cables. The process of desiccating the air prior to cable pressurization builds up static on the air dryers and metallic components of the air pressure system. Because of this, it is recommended not to place the air dryer in the engine room. It is common practice to ground the air dryer(s), manifold, and air pressurization monitoring system to the DC grounding system (regardless of any ACEG grounds that may exist) with a minimum 6 AWG, green-insulated, stranded conductor, connected to the nearest CO GRD system cable or bar. Air dryers for waveguide and microwave horns must be grounded in a similar manner.

PICS storage cabinets in the air dryer room, and any metallic objects with metallic exposure or metallic connections to outside the building should also be grounded, as detailed elsewhere in this document (see section 9.11). Air dryers not located in a CO shall also be grounded (including metallic housings) and should be separated from static-sensitive electronics.

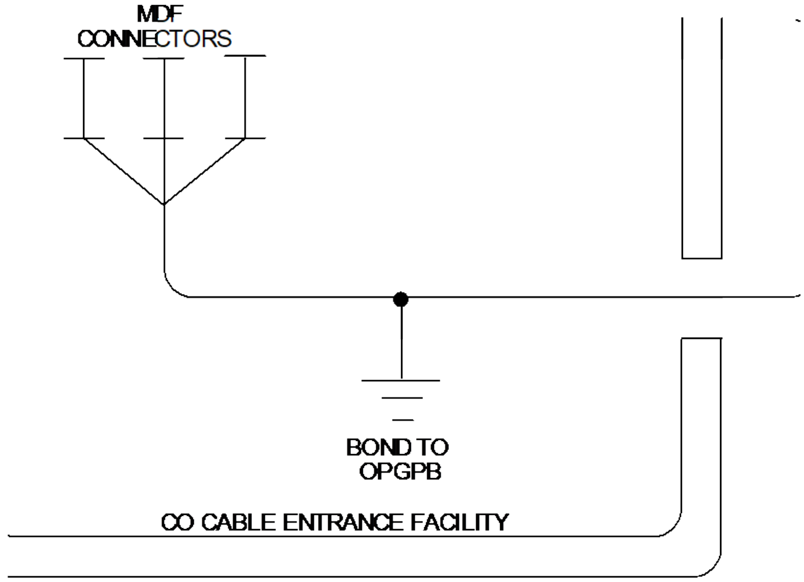


Figure 6-1: Underground CO Entrance with Exposed Entrance Cable for Traditional Isolated-Integrated Offices

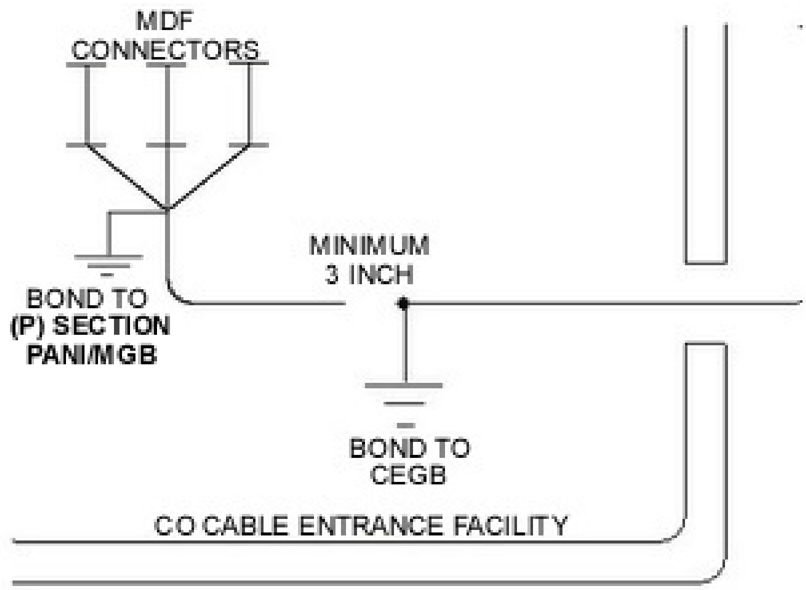


Figure 6-2: Underground CO Entrance with Exposed Entrance Cable for RUS Standard "PANI" Isolated Offices

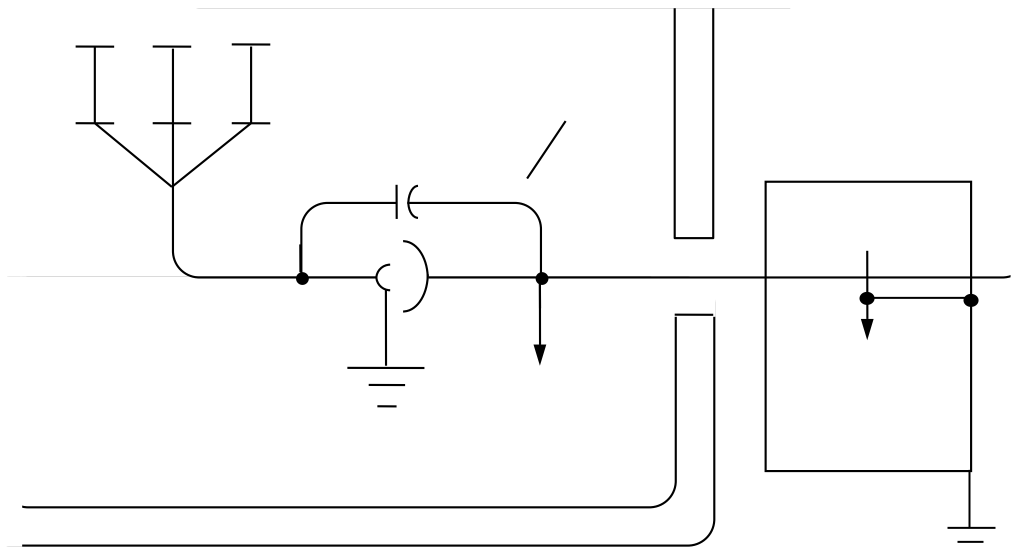
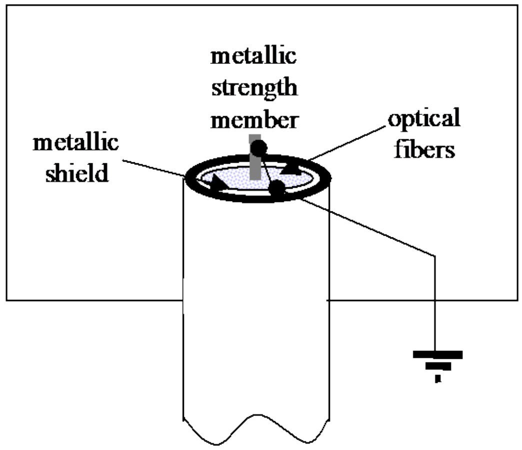
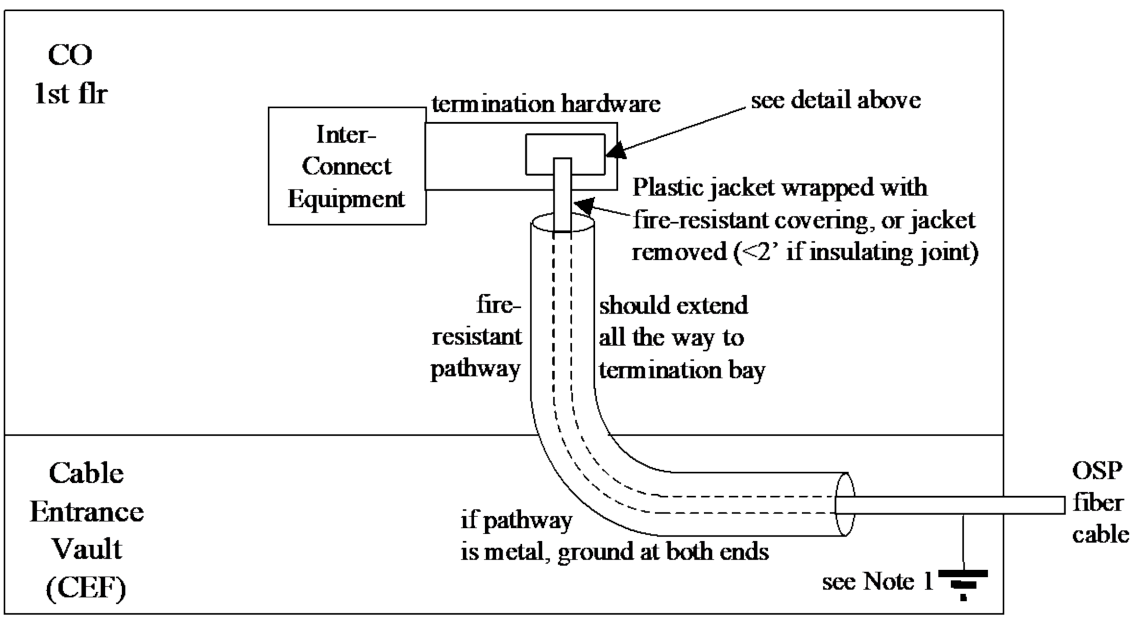


Figure 6-3: Underground CO Entrance Cable Incorporating an Insulating Joint





Notes:

1 All Metallic Members in the Fiber Cable Shall Be Grounded to the CO GRD at the CEF.

2. If Insulating Joint is Required, the Insulation Joint Must Be placed in the CEF in A Standard Manner.

Figure 6-4: Bonding and Grounding of Optical Fiber Cable in Interconnect Equipment

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7. Radio Equipment Ground Systems and Rooftop Lightning Protection

7.1 Driven Ground Electrodes for Radio/Microwave Sites

Ring Ground System (RGS) general requirements for establishment of driven ground electrodes for Microwave Radio sites that are susceptible to frequent lightning exposure, are based on principles covered in this section. The system is essentially similar to that employed for central offices. The ring is extended around and bonded to the antenna tower legs. Other metallic objects on the premises and on the exterior of the building (such as fences, gutters, down spouts, pipes, air conditioning units and other conductive structures that might constitute a hazard due to excessive voltage and arcing during lightning strikes) are bonded to the grounding electrode system. Rods, wire, connectors, and other material used in the construction and placement of such material are identical to that described for the driven ground electrode for central offices. One exception is the method of extending the Ring Ground electrode into the building interior. Stations of this type employ an interior grounding ring conductor as part of the lightning protection feature. Connections are required between the exterior and interior grounding rings at approximate intervals of 50 feet or less, with a minimum of four, located near the building corners. The method of entry is through nonmetallic conduit, where the entering conductors are routed vertically on the interior wall to connect to the interior ring grounding conductors.

7.2 Frame Grounding Methods

Treat radio equipment as an integrated ground plane. Bond all frames to the nearest ground reference. Depending upon each office layout, the nearest ground reference could be the CO GRD, the OPGPB, or the interior ring ground.

Note: All grounding or grounded conductors associated with radio gear that can conduct lightning currents (this includes shields and the outer conductor of coaxial cables) should be kept as far away as practical from any isolated ground plane within the building structure.

7.3 The Exterior Ring Ground System

The exterior ring ground system establishes a station ground electrode for the purpose of equalizing potentials in the earth surrounding the building and towers, regardless of earth resistivity, by ensuring that a low impedance current path exists throughout the area. The system is comprised of exterior ring ground conductors encircling the building and tower. The ring is composed of a 2 AWG solid tinned copper wire buried at least 30 inches below grade and spaced 2 feet minimum from building foundation and tower footings. The ends of the wires are joined together to form a ring. Driven ground rods are typically connected to the ring bus at 10 to 20 foot intervals as described in paragraph 3.2.1 (see Figure 7-1). Under adverse soil resistivity conditions or when bedrock prohibits driving of rods, horizontal counterpoise conductors are employed to improve equalization of the system. Radial grounds may also be used as along as the radials are placed on the side of the tower ring opposite from the CO/ Radio equipment structure.

Figure 7-1 illustrates a typical exterior-interior ring bus system and the relationship between various components of the ring ground system. As shown therein, the exterior ring ground is bonded to the tower legs, to exterior buried and above surface metallic objects, to other electrodes, and to the interior ring ground and waveguide entry plates. The tower ring portion is bonded with two 2 AWG solid tinned copper conductor to the building ring ground. Figures 7-1 and 7-2 illustrate a typical exterior ring-ground tower bonded to the metal antenna tower legs. When metal towers are installed, proper grounding procedures should be followed to prevent damage to the tower support footings. If lightning energy is forced to flow to earth through the concrete footings, the concrete can become super-heated and may "explode" as embedded moisture turns into steam in the confined space, thus causing damage. If the solid 2 AWG needs to be run through the concrete, then it must be routed in a non-metallic conduit. Rebar-embedded concrete footings (Ufer ground) can serve as a supplementary grounding electrode (see Section 3.2.5).

If the antenna tower has metal guy wires for support, the guy wires must be grounded by adding a buried 2 AWG solid tinned copper conductor in a ring configuration and connecting each guy wire to the 2 AWG ground conductor. Connect this ground ring to the driven ground system with two bonds. If the guy wires are spread out at a long distance, install a ground rod at each guy wire end and connect a ground wire from the anchor head or the guy wire to the ground rod. Then run a 2 AWG to the tower or to the building ring ground system (see figure 7-17).

A separate buried exterior ring ground around the building is not required when the building is a central office, wherein the radio equipment area comprises a relatively minor part of the communication equipment area, and the building is adequately grounded by means as described in paragraph 3.2. Many radio sites are located in rocky areas where proper grounding is difficult to maintain. Enhanced grounding methods may be provided as follows (these methods are described in further detail in Section 3.2):

- Rods inserted in drilled holes and backfilled with Bentonite, Calcine petroleum coke or low-ohm concrete
- A counterpoise grounding system
- Deep driven rods, or wells cased with steel pipe
- Ground ring installed without rods using a grounding enhancement material (GEM) such as lo-ohm (conductive) concrete.

Note: Rods enclosed in bags of chemically treated backfill are prohibited in Lumen for environmental reasons.

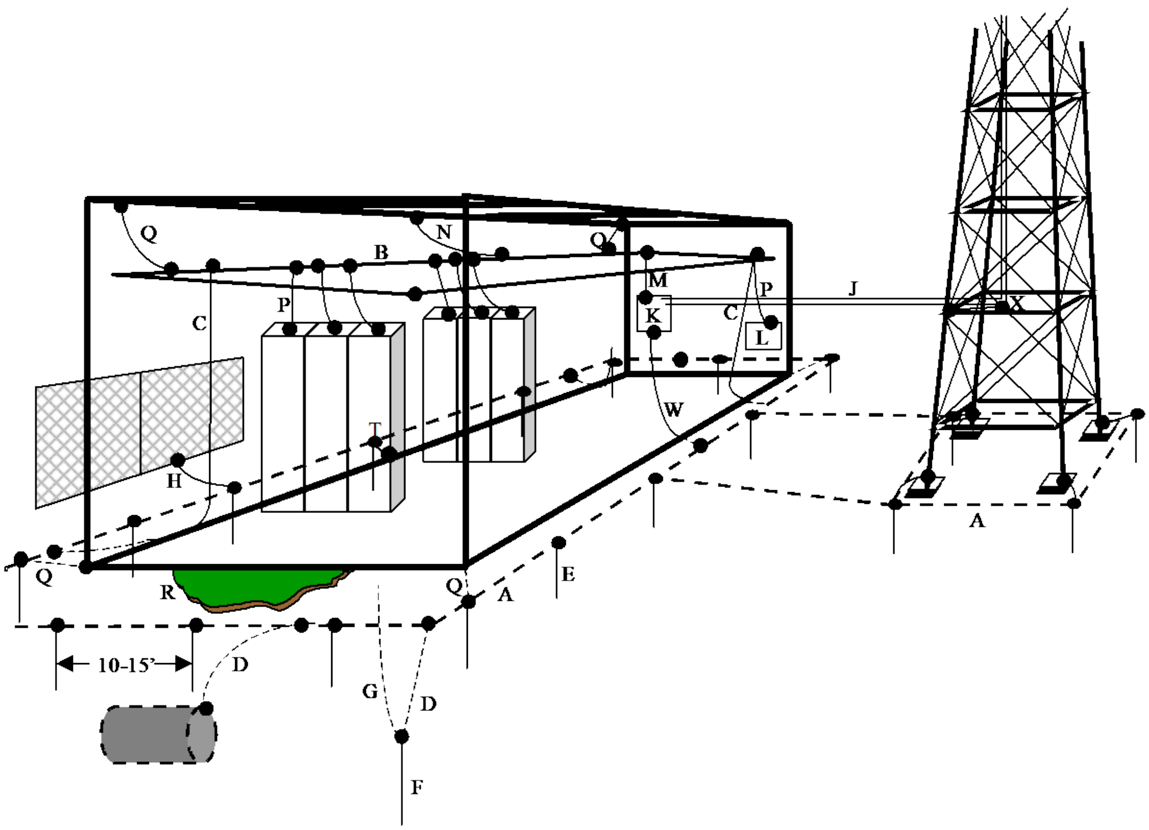
All grounded metallic objects external to or mounted on the building must be bonded to the exterior ring ground to ensure equalization of potential (see bonding requirements ANSI/EIA-222-D® and ANSI/NFPA 780® Lightning Protection Standard).

Unit bonds connected to the exterior ring ground must be 2 AWG bare tinned solid copper conductor. Connections to ring conductors must be made with an exothermic weld, when buried. Connections to above ground units may be made with exothermic weld. Crimp type connections on solid wire can be made using the appropriate connector, crimping tool, and die approved for solid wire. Connectors other than exothermic weld must be located to facilitate periodic inspection and maintenance.

A "tree" is generally applicable to grounding on the building exterior. A "tree" system consists of a single conductor run from a ground point in a generally direct route toward a group of units requiring grounding. Branch conductors are extended to individual units from points on the main or "trunk" conductor. Sub-branches may also be extended from branch conductors. The trunk conductor is extended to the furthest unit from the ground point.

7.4 Rooftop-Mounted Ring Grounds

An external grounding system for radio/microwave structures, including waveguides and feed lines, is necessary for the dispersal of lightning current to earth before it is able to enter the site. It is impossible to prevent all surge current from entering the building due to the multiple metallic paths between the building exterior and interior, but most of the current can be controlled and diverted. Unless stated, this section uses the practices of the Lightning Protection System Installation Standard (ANSI/NFPA 780®).



LEGEND

(A) Buried Exterior Ring Bus
(B) Peripheral Bus (Interior Ring Ground)
(C) Inter-Bus Bond (@ all 4 corners)
(D) Bond to Buried Objects
(E) Ground Rod
(F) Power Company Grounding Electrode
(G) Power Company Neutral Bond
(H) Bond to Fence Within 6 Feet
(J) Waveguide (Rectangular, Circular, Elliptical, Helix, Coax, etc.)
(K) Waveguide Entry Plate
(L) Wall-Mounted Cabinet
(M) Entry Plate Bonc
(N) Supplementary Bond
(P) Equipment Bond
(Q) Building Steel Bond
(R) Grade Level
(T) Bond to Metallic Object or Building Exterior
(W) Waveguide Entry Primary Bond
(X) Waveguide Vertical to Horizontal Transition

Figure 7-1: Microwave Ring Ground System and Principal Ground Bonds

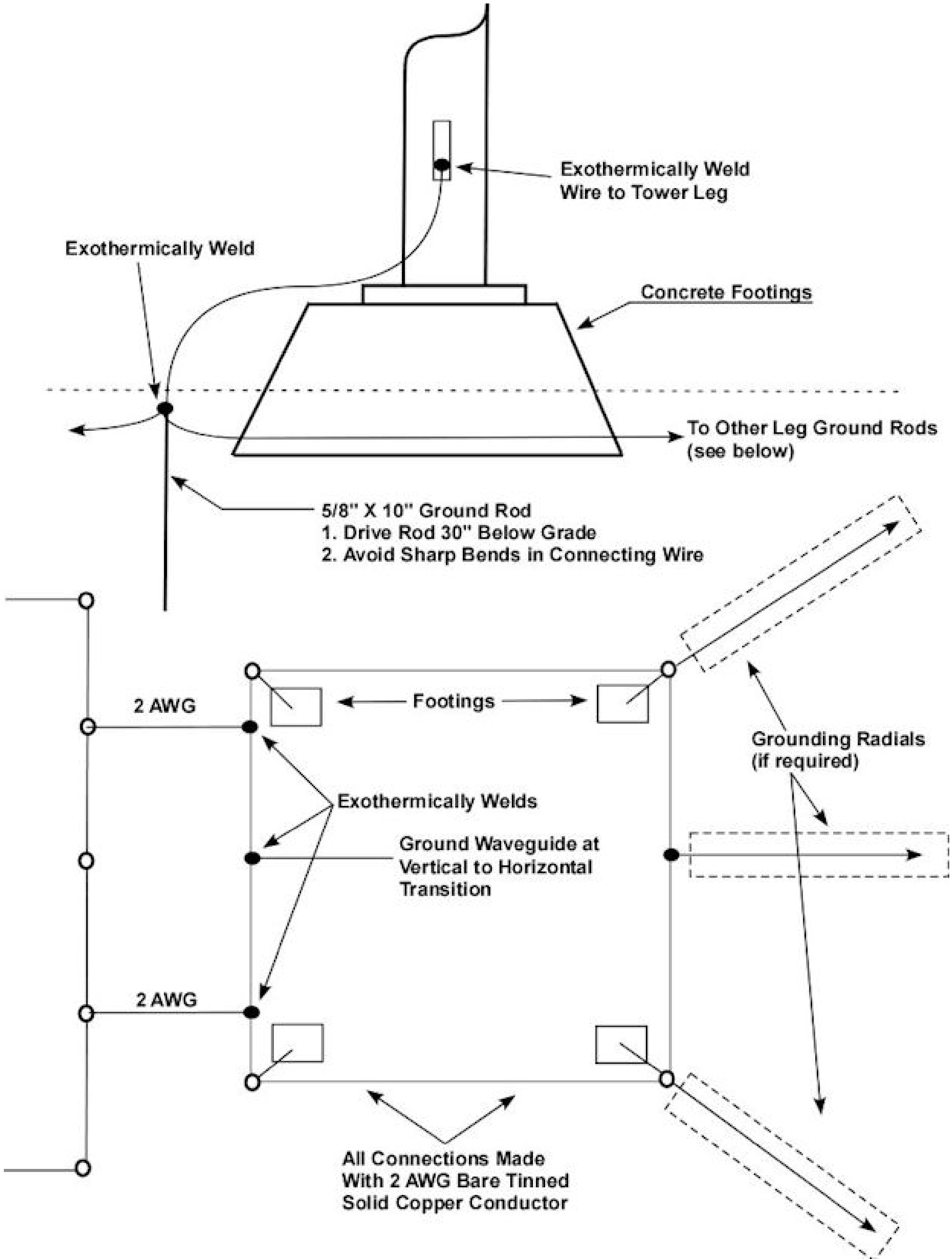
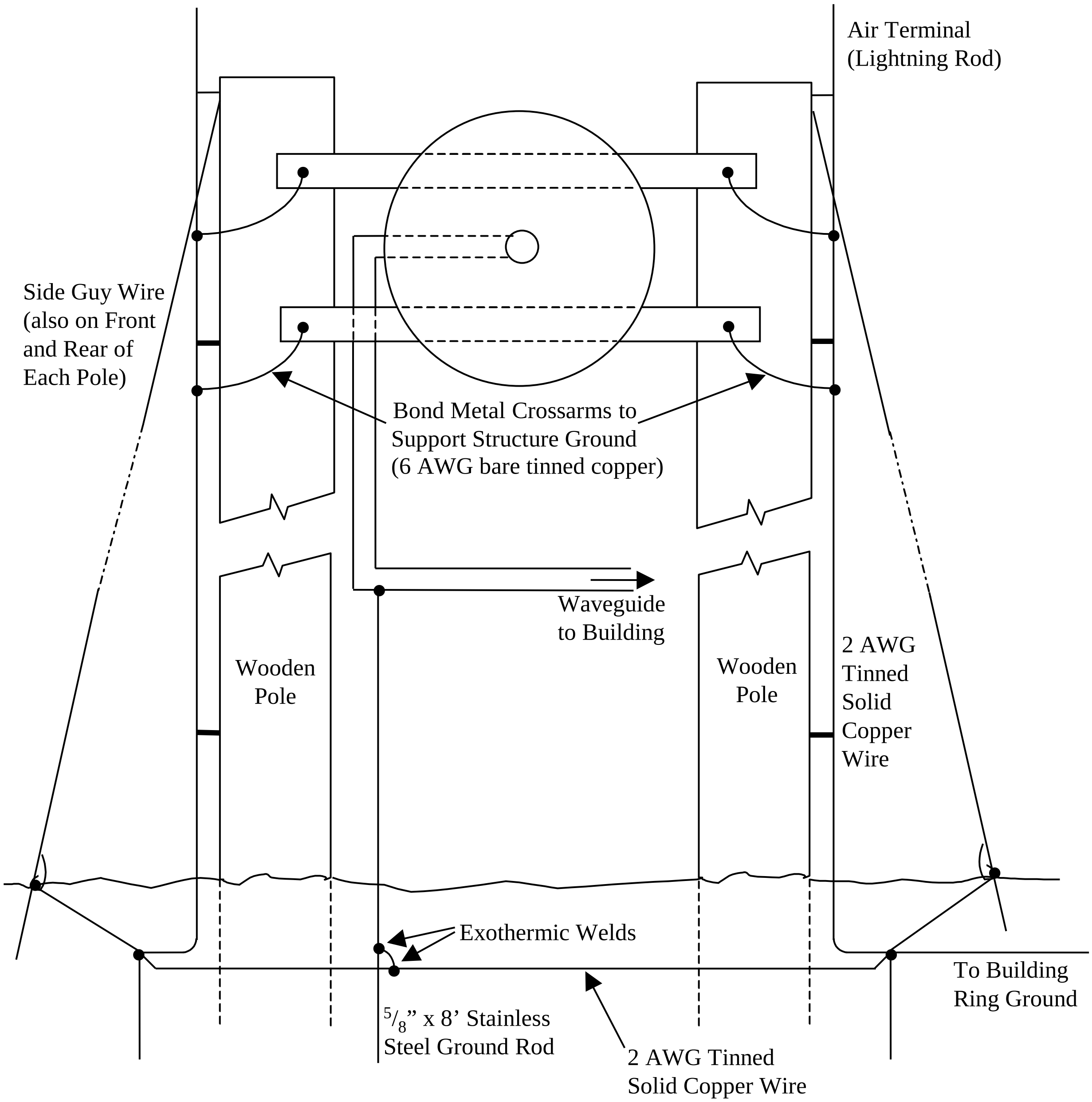


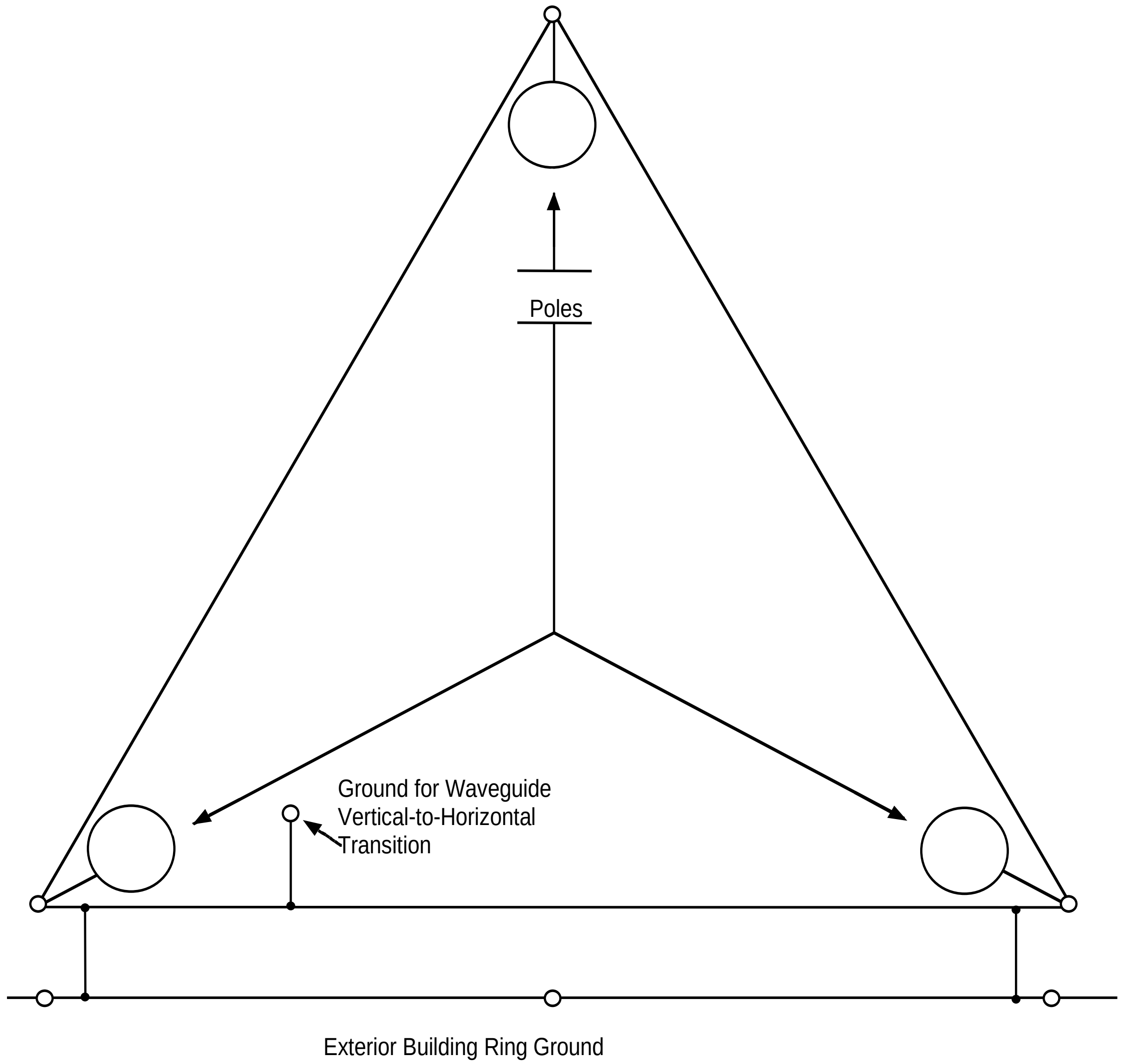
Figure 7-2: Typical Grounding Arrangement for a Metal Antenna Tower



Notes:

1. Extend wire 8 to 12 inches above the top of the poles
2. Mount the antenna below the pole tops
3. Ground the waveguide vertical-to-horizontal transitions

Figure 7-3: Grounding Arrangement for Wooden Antenna Supports



Notes:

1. Make all connections with 2 AWG tinned solid copper wire.
2. All connections to be the exothermic process.
3. Add air terminal to top of pole and ground to tower ring ground.
4. Use ⅝ in X 8 ft (or 10 ft) ground rods 10 ft – 20 ft apart.
5. Crossarms and antennas omitted for clarity.

Figure 7-4: Grounding Arrangement for a 3 Pole Wooden Antenna Support

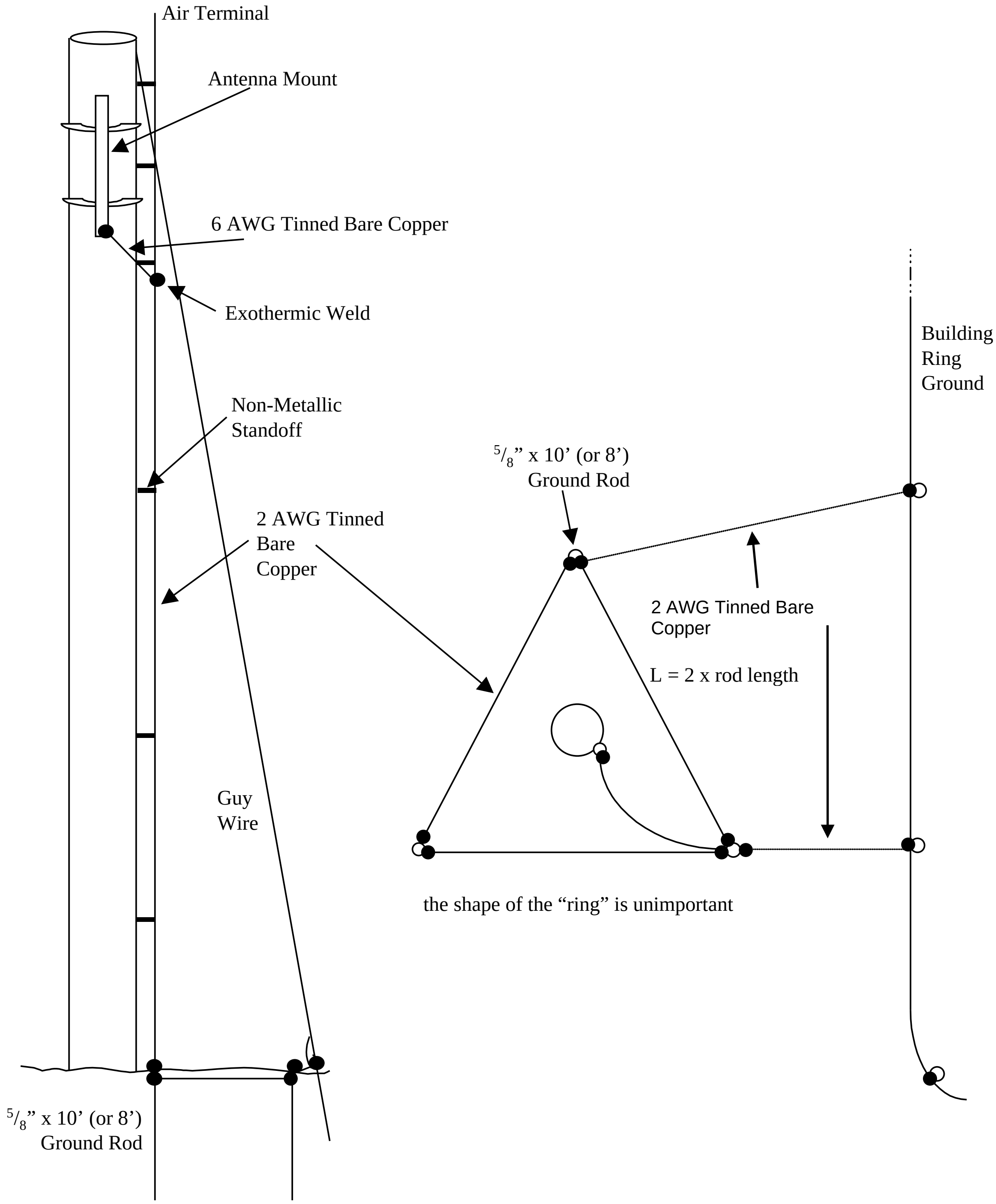


Figure 7-5: Grounding Arrangement for a Single Pole Wooden Antenna Support

Rooftop towers increase the lightning risk for the building. Due to their height and lightning risk probability, all buildings with rooftop towers shall be equipped with an NFPA 780® lightning protection system. Other metal objects on the roof with metallic connections to the building interior (such as air-conditioning units) are only required to use a lightning protection system or down conductor(s) if they are taller than 5 feet and if their top height exceeds 25 feet above the ground. However, if there is a lightning protection system on the roof for other reasons, all metal objects on the roof that have metallic connection to the building interior, and are taller than 2 feet, should be bonded to it with a minimum 6 AWG copper conductor. In addition to these requirements, tower support legs shall be interconnected with a bonding ring of 2 AWG minimum at its attachment to the roof structure. This ring shall be bonded to the main perimeter lightning protection roof ring by at least two opposing conductors of 2 AWG or larger, at or within 24 inches of a down conductor. All tower guys/anchors that attach directly to the building shall be bonded to the roof perimeter ring. Per NFPA 780®, if the structure is non-conductive, then multiple exterior down conductors shall be used, each sized per NFPA 780®. These down conductors should be kept at least 6 feet from external conductive metal objects in the vertical portion of their run to prevent flashover during a lightning strike. They should also be at least 3 feet away (measured horizontally through the wall) from any metal internal to the building.

Transmission lines and waveguides should be grounded where they make directional transitions, especially the vertical to horizontal near the tower bottom. The transmission line should be bonded to the grounded entry plate both inside and outside the service building or Central Office.

7.5 Non-Metallic Antenna Structures

One, two, and three pole wooden support structures are used in Lumen. The 3-pole structure is less susceptible to torsion and is preferred. These structures should be grounded as shown in Figures 7-3 through 7-5. For a wood structure, it is advisable to mount the antennas with their extremities below the top of the structure and add an air terminal on top of the pole. (In addition to Figures 7-3 and 7-5, see Figures 7-20, 7-21 and 7-26 for examples.) Ground the air terminal to the antenna tower ring ground. (Air terminals are commonly referred to as Franklin rods or lightning rods, and their proper use and installation is governed by NFPA 780®.) When lightning strikes occur, the energy on the antenna and transmission lines will be reduced.

7.5.1 Metal Monopole Grounding

Metal Monopoles, instead of the wooden support structures mentioned above are being used with increasing frequency (see Section 7.23 for examples). Grounding of these monopoles when used for microwave transmission (as opposed to Cellular, whose grounding is covered in Section 7.23) should be similar to what is shown in the top halves of Figures 7-17 and 7-2. As an alternative to running the ground wire outside the concrete footing (as depicted in the top half of Figure 7-2), a non-metallic conduit may be placed inside the footing, in which the ground wire may be run. It is only required to connect to the ground ring at one point (as shown in Figure 7-5), but two or more connections are better.

7.6 Waveguides and Transmission Lines

Waveguides and transmission lines should be bonded and run as directly as possible to the metallic tower at the top and bottom of the vertical run on the structure. Additional bonds are required, per NFPA 780® article 4.9.13.1, where towers are over 200 feet. Additional bonds may be used across flexible sections of waveguide (see Figure 7-6), and at support points where flashover/arcing potential exists from non-insulated waveguide. The bond at the bottom of the vertical waveguide run should be applied just above the point where the waveguide bends to the horizontal plane. For small cross-section waveguide, the connectors for the bonding strap may necessitate conductors as small as 16 AWG, but normally they should be as large as possible up to a maximum of 6 AWG.

If connectors with inspection holes are used on bonds for flexible waveguide bonding jumpers, these bonds must be sealed to prevent corrosion. An appropriate corrosion prevention product is weatherproof heat shrink that contains an emulsion. Not sealing these crimp type connections will allow moisture to accumulate in the crimp and in the wire under the outer covering, and this will corrode the connection. Because these connectors are bent at 90 degrees to allow a flange connection at Flex Waveguide, it may not be possible to ensure that the heat shrink adequately seals the inspection hole. If an adequate seal is not obtained, then connectors without the inspection hole should be used, including an appropriate corrosion prevention product.

7.7 Tower Warning Lights

Towers that have aircraft warning lights shall enclose all AC power conductors in metal conduit. The conduit shall be supported at least every 10 feet and within 18 inches of any conduit body to meet NEC® Articles 314.23E, and F. Expansion joints for the metallic conduit shall be bonded with a copper conductor of 6 AWG.

The power to the tower lighting system shall have a suitable fast (less than 10 Nano-second response time) low voltage surge protection device installed outside the serving building at the point it enters the structure. As the wires enter the building, the through conduit through the wall shall be non-metallic. The surge protection device shall be grounded to the external grounding electrode system or to the tower roof ring ground.

7.8 Metallic Feed Line Support Structure

Where a metal frame is used to support waveguides and coax between the tower and the building, the frame should be bonded to the tower or the tower ring ground with a 6 AWG conductor or larger. At the building, the waveguides and supporting structure and the entry plate are bonded together and the plate is connected directly to the external ring ground at the station with a 2 AWG conductor. (Some of this metallic support structure, when located above the waveguide for protection from the elements, is called an "ice bridge".)

7.9 Waveguide Entry Plate Bonds

Waveguides, metallic supportive framework, and tower lighting system conduits extend the current path from the tower to the building. All external metal conductors (like waveguides and metallic conduit) shall be bonded to the external ground ring at the point of entry. All waveguides entering a radio facility shall be bonded to the internal ring ground system within three feet of the entry point. Metallic conduit shall be made electrically discontinuous by use of a non-metallic section through the wall. The only building entrance points for any metallic facility in a Lumen site are waveguide entry plates (as described in this chapter), the cable entrance facility (see chapter 6), and the AC service entrance.

The waveguides can be bonded to the entry plate by the mounting flanges furnished with the pressure window section that passes through the entry plate. If the mounting flanges do not make metal to metal contact to the entry plate then the waveguides need to be bonded together with a. 6 AWG conductor and grounded to the entry plate. Waveguide and transmission lines can also enter a building through building entries or feed-through assembly entry plates. These entries or feed-through assembles allow waveguide and transmission lines to pass through without making metallic contact with the entry plate and must be bonded individually and externally on the entry plate with a 6 AWG grounding cable. Where an RF transmission line, other than rigid or elliptical waveguide, passes through the entry plate, it shall be connected to a Listed overvoltage protective device and grounded before entering the building.

Metallic supportive framework must be bonded with a 2 AWG bond to the entry plate exterior surface with a two hole compression connector if it is not mechanically connected to establish continuity.

Metallic conduit entering the building in proximity to the entry plate shall be bonded to the entry plate exterior. If the conduit is run on the building exterior before entering, it shall be bonded to the exterior ring bus or roof ring ground. This bond shall be made immediately prior to entry through the building wall or roof. The conduit shall be made electrically discontinuous by use of a non-metallic section where it passes through the wall.

An appropriate corrosion prevention product for these entry plate bonds is weatherproof heat shrink that contains an emulsion. Not sealing these crimp type connections will allow moisture to accumulate in the crimp and in the wire under the outer covering and corrode the connection. Transmission line bonds for entry plate or plate bus ground connections can be purchased with two-hole connectors already attached, or included as part of the grounding kit, including the appropriate weather seal.

The entry plate shall be bonded directly to earth with a primary bond, as described in paragraph 7.11, "The Interior-Exterior Ring Bonds", when a buried exterior ring ground exists. When entry plates are located in the roof, they shall be bonded to the roof ring ground (or lacking a roof ring ground, to a down conductor going down the outside of the building to the external ground electrode field). The primary bond shall be connected to the entry plate on the inside, routed in proximity to, and connected to the interior ring ground. (In some COs where microwave radio and/or other waveguides or external transmission lines are not the primary purpose of the CO, there may not be a ring ground. In these cases, a direct 2 AWG minimum bond from the entry plate to a nearby COGB or OPGP is required. This bond must be routed as near as possible to external walls and to ceilings, and as far away as possible from other equipment frames). It must be extended to the CO ground bus in multistory buildings (with a minimum 6 AWG), and to the external ring ground (in PVC conduit, if conduit is used at all) in single story buildings (see Figures 7-7 or 7-8).

The modern method for bonding and grounding the external entry plate and entering waveguides is to mount an external ground bar below the entry plate (see Figure 7-10). Bond the entry plate to this bar as well as all of the entering waveguides. Then tie the bar to the exterior ground ring. If the external ground ring cannot be accessed, the bar can be tied to a new ground electrode field (see Figure 7-23 for an example of a 3-rod minimum configuration), but this field must also be bonded to the OPGP.

Normally, only one metallic plate is installed approximately in the center of the opening in the building, bonded both internally and externally, as shown in Figures 7-7 and 7-8. The entry plate shown in Figure 7-10 is a little different in that it is externally mounted (rather than centered in the opening. Generally, this is good enough, and a second metallic plate mounted to the inner wall is not necessary, nor desired. In cases where both an exterior and interior plate are used, a 2 AWG minimum bond must be made between the plates.

Waveguides require no inter-bonding to the interior ring ground when the entry plate is located within 25 feet of the interior ring ground system. When the entry plate is further away, as when antennas are roof mounted and radio equipment is on a lower floor of a multifloored CO, waveguides shall be bonded to the interior ring ground (or to the direct entry plate -to-COGB conductor). Waveguides within 6 feet of each other must be bonded together with 6 AWG wire, similar to the multiple conduit bonding arrangement shown in Figure 7-9. The bond shall be extended to an interior ring ground or supplementary bus. The bonding point must be at the waveguide's entry point into the area protected by the interior ring ground. In this arrangement, the waveguides act as discharge current paths between the entry plate and interior ring ground system. Primary bonds between such remote entry plates and interior ring ground may be omitted when waveguides are so bonded (see Figure 7-6).

7.10 The Interior "Ring" Bus System

The Interior Ring Bus System consists of the following:

- A 2 AWG insulated stranded copper wire extended around the periphery of the radio equipment area with a small open section (minimum 4 inch) at the furthest point from the PANI- MGB / OPGP per Motorola R56® section 5.3.7.1
- A number of 2 AWG bonds between the interior ring ground and the exterior buried ring ground
- Supplementary buses
- Unit bonds to equipment frames
- Bonds to miscellaneous metal (auxiliary framing, metal conduits, air-conditioning duct, cable racks, etc.) within the interior ring ground periphery. In order to ensure the best possible Faraday cage, cable racks within this interior radio ring ground should be positively joined by 6 AWG or larger bonding jumpers run between cable rack sections. The bonding jumpers must be installed with two-hole irreversible crimp compression lugs with the paint removed (bright shiny metal) at the connection points on the cable rack.

The system is illustrated in Figure 7-1. It provides a means of establishing low impedance between neighboring metallic objects within the communication building, and a low impedance path between that bonding network and earth. Any metallic object within, or which is part of, the building may function as a current path during discharge, dependent on its relationship in terms of coupling to the focal point of current flow between the tower and the building interior, and to earth. The probable focal point is assumed to be the waveguide entry plate(s) or coaxial cable outer sheath.

No grounding conductor coming from radio-related equipment (such as the interior ring, bonds to the waveguide entry plate, etc.) should ever pass within 3 feet of an isolated ground plane. They should be as far away as possible (preferably greater than 10 feet).

7.11 The Interior-Exterior Ring Bonds

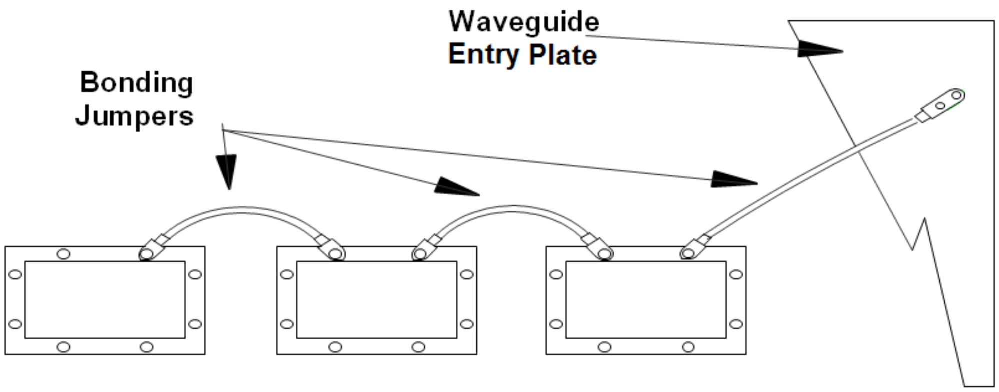
When a buried exterior ring ground system is the site's ground electrode, multiple bonds (2 AWG solid, tinned; at least every 50 feet) are required between that system and the interior ring ground. These bonds complete the low impedance current path between waveguide entry plates and earth. At a minimum, bonds between the interior and exterior ring must be made at each corner of the building).

Crimp connections to solid copper wire must be made with the appropriate connector, crimping tool and die designed for solid wire. Termination of stranded wire on the entry plate must be made with a two-hole bolted tongue crimp connector. The solid wire may alternatively be joined to the stranded wire with an exothermic weld connection or extended to the entry plate. Exothermic weld type two-hole bolted tongue connectors must be used to terminate solid wire to the entry plate. The primary bond wire must be supported on the interior wall with supports as shown in Figures 7-12 through 7-14. Unnecessary bends must be avoided. Necessary bends must have an 8-inch radius or greater and must not exceed 90 degrees (12 inch minimum bend radius is preferred for grounding conductors).

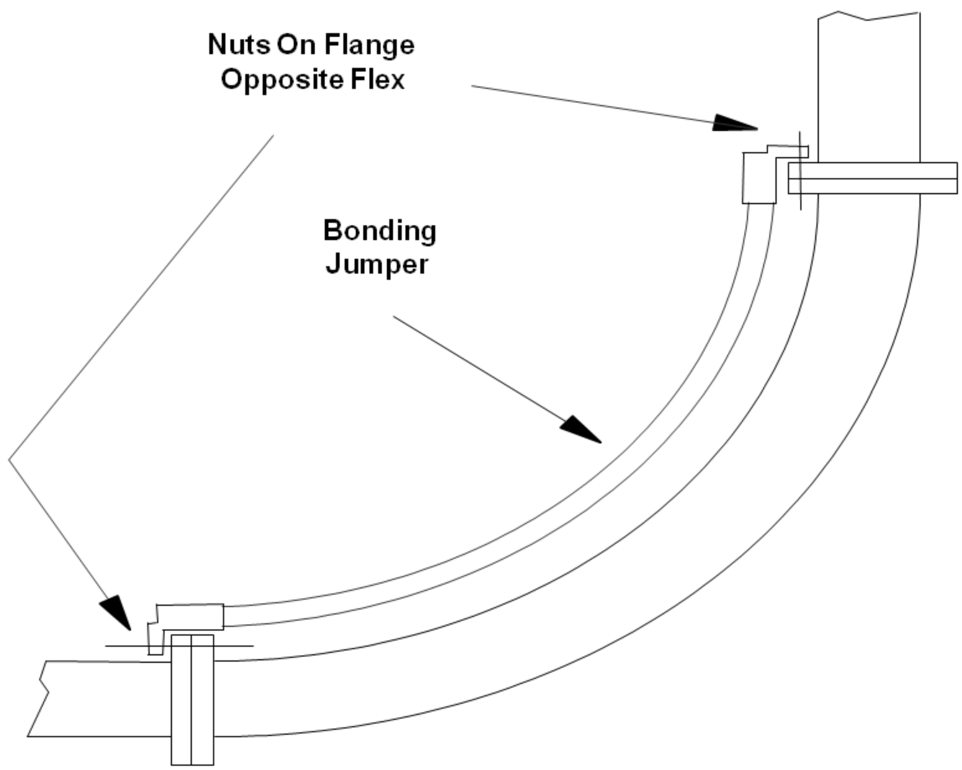
7.12 Supplementary Ring Grounding

Metallic objects in the radio area must be bonded to the interior ring ground.

For COs with switches where there are 4 or fewer bays of radio equipment, an interior ring around the radio bays is not necessary. However, these bays should have their own minimum 2 AWG stringer run directly to a COGB or OPGP / PANI- MGB.



Bonding Outdoor Waveguide Flanges To Waveguide Entry Plate (Typical)



Flex Waveguide Bond (Typical)

Figure 7-6: Bonding of Outdoor Waveguide

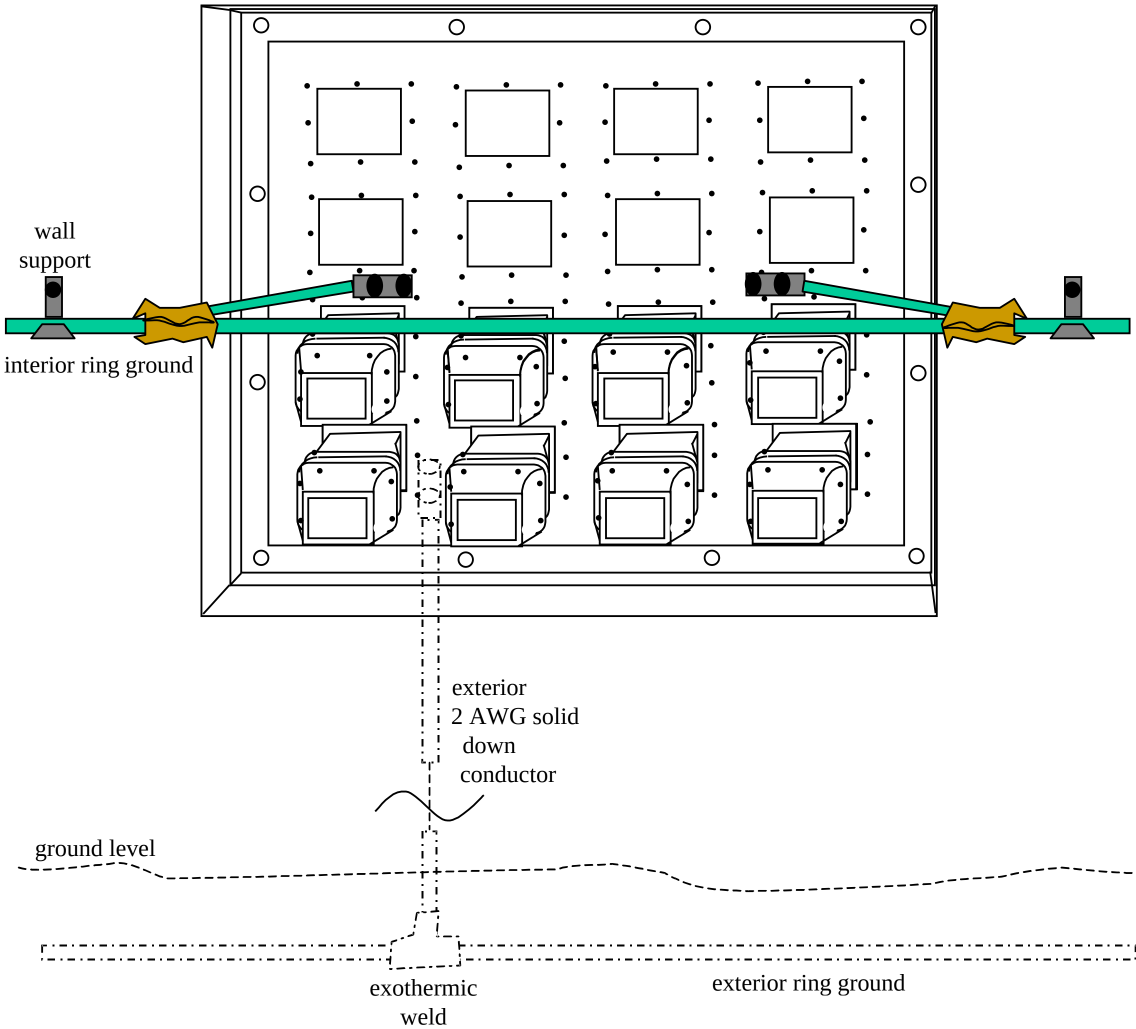


Figure 7-7: Typical Arrangement of Peripheral and Exterior Ring Bus Bonds at Waveguide Entry Plates for Single Story Structures

(Special consideration needs to be given to metallic conduit using "set screw" type fittings due to the poor bond these fittings provide. If these were used [although they are generally not allowed for smaller conduit sizes], all conduit joints must be bonded together with a minimum 6 AWG conductor.)

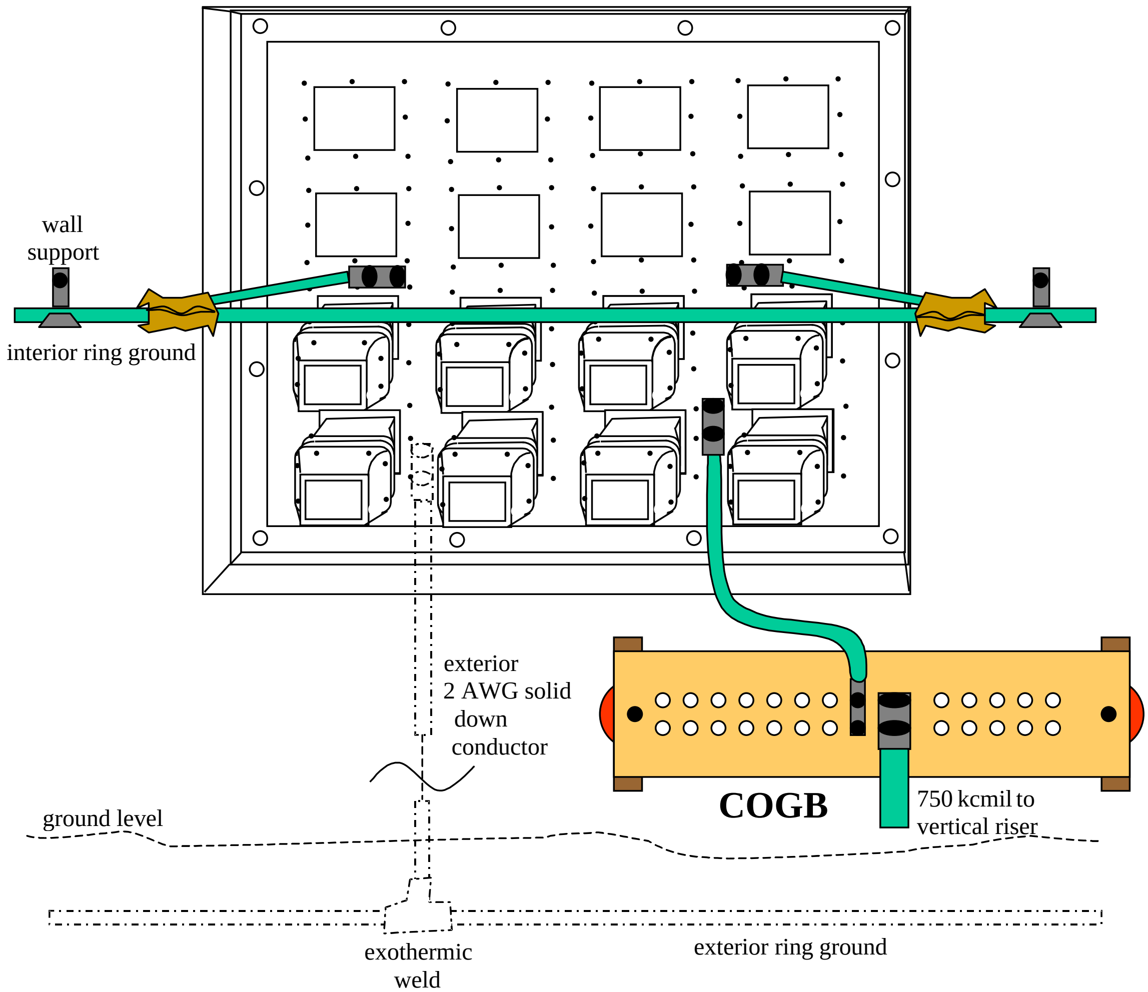
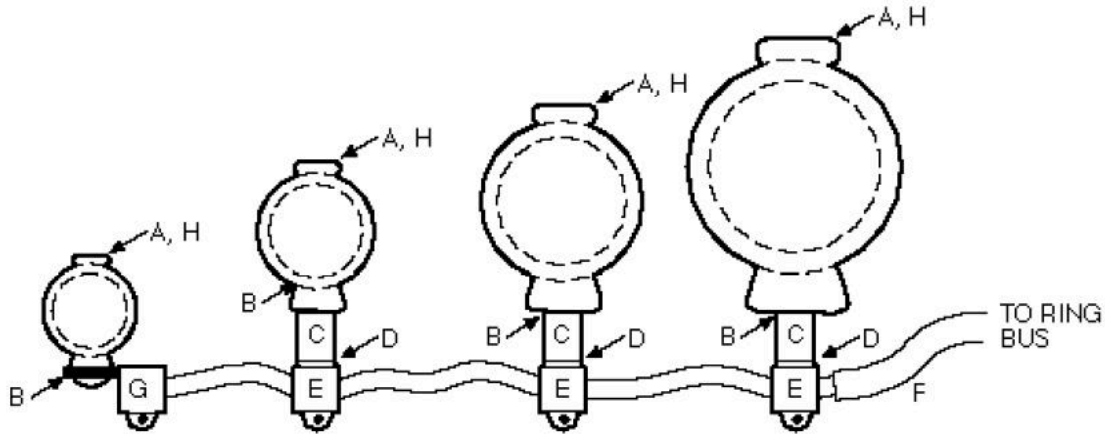


Figure 7-8: Typical Arrangement of Peripheral and Exterior Ring Bus Bonds at Waveguide Entry Plates for Multistory Structures



Legend:

(A) Conduit Clip
(B) RHM Screw Lock Washer
(C) Bracket
(D) RHM Screw Lock Washer Hex-Nut
(E) Steel Clamp
(F) 6 or 2 AWG insulated, stranded
(G) Use 2 clamps for a 2-hole crimp lug
(H) Clip must conform to conduit size

Notes:

1. In lieu of the clips, conduit clamps may be used.

Figure 7-9: Method of Bonding to $^{1}/_{2}$" - 2″ Conduit or Pipe

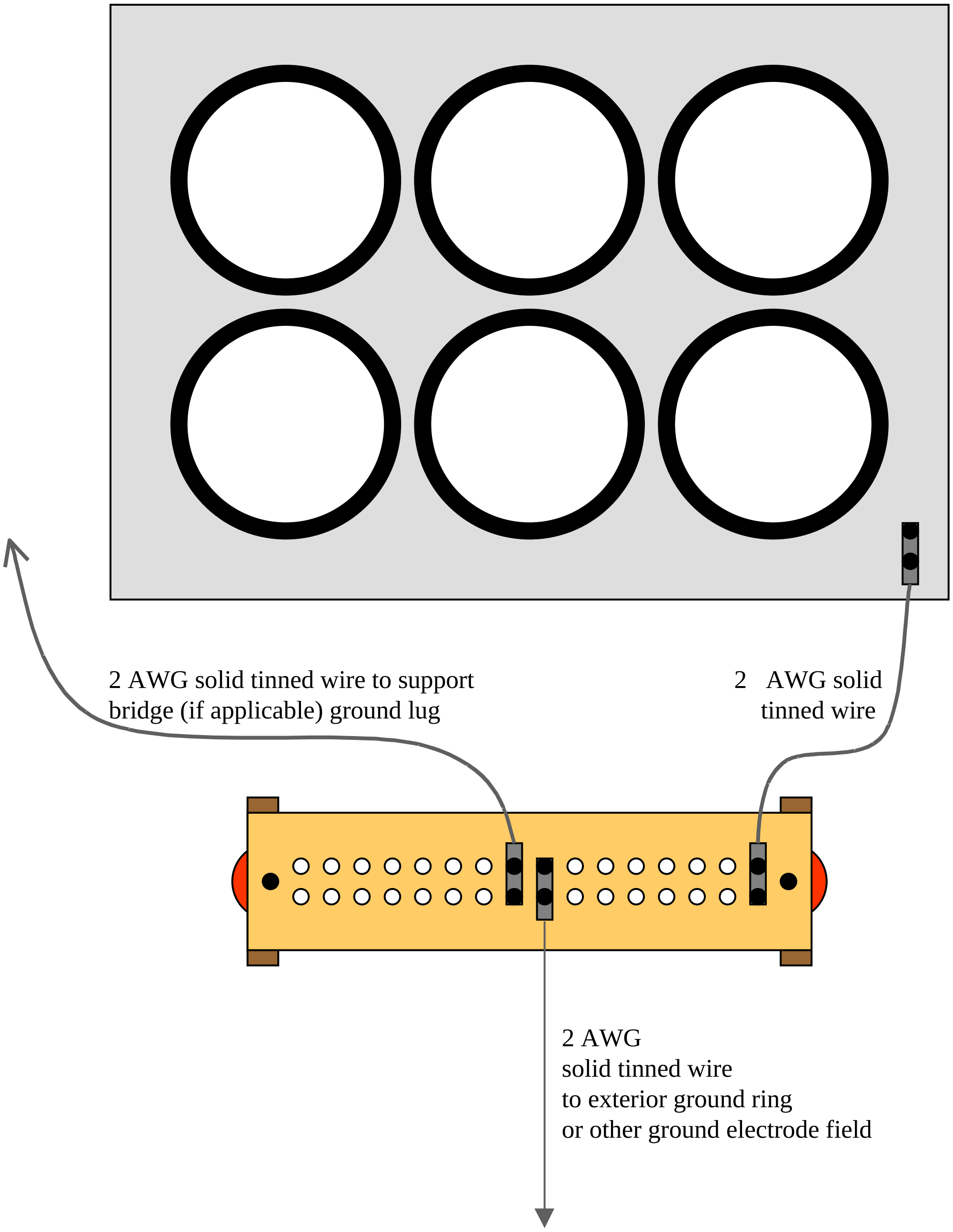


Figure 7-10: External Ground Bus for a Waveguide Entry Plate

Additionally, objects within 6 feet mutual proximity must also be bonded. This is normally accomplished via paths established by unit bonds connected to the interior ring ground. Impedance of such inter-connective paths is dependent on the length of the path; therefore, a practical limitation of path length is necessary to ensure effective equalization. For this purpose, the following general guidelines are presented as a guide in determining acceptable path lengths:

- For objects located within one foot of each other, the bond path length shall not exceed 15 feet.
- For objects located from one to six feet of each other, the bond path length shall not exceed 30 feet.
- When either of the first two bullets cannot be met, a supplementary ring ground shall be provided, or direct bonds between objects shall be provided in addition to bonds to the ring, to meet the requirements stated in the first two bullet items.

  Notes:

  1. Bond path length shall be calculated as the shortest path between points of closest proximity of the two objects via the objects' metal and interconnection bond paths.
  2. Mechanical connections between objects (e.g., inter-frame bolting) shall not be considered as a bond path except where the interconnection device is a junctioned ground or an equivalent device intended for frame line grounding purposes.

- The preceding rules are not always applicable to every occurrence of object proximity. They express limits considered desirable to ensure equalization of potential. In certain cases, it will be expeditious to exceed the length limits for physical or economic reasons. Where limits are exceeded via the path through unit bonds and ring ground, and where the addition of a direct bond between objects or ring ground is not practical, under no circumstance shall the lengths be more than double the lengths expressed in the guidelines.
- The inter-object bond shall be kept as short and straight as possible. In order to facilitate this objective, supplementary buses must be provided over frame lines within the area bounded by the interior ring ground.

- Supplementary ring ground arrangements are shown in Figure 7-14. Supplementary ring grounds shall be provided as required to satisfy the inter-object bonding requirements. These ring grounds also function to provide minimal length low impedance paths between the current focal points (entry plates) and earth, in parallel with interior ring grounds. To provide a parallel path, the supplementary ring grounds must be connected at both ends to the interior ring ground. The ring ground conductor must be the same as that of the interior ring ground.

7.13 Forming and Support of the Interior Ring Ground

Crimp type parallel connectors or exothermic welds are recommended for bonds to the interior ring ground. Space for tools between the supporting surfaces and wire is necessary to make such bonds. A standoff support assembly, as shown in Figure 7-14 is recommended for support of wire on walls. A nylon expansion anchor, as illustrated, must always be used. Supports must be provided at approximately 2-foot intervals. Additional supports at points that tend to distort the interior ring ground, such as at bonding points, may be provided on an “as needed” basis. The interior ring ground conductor, not run on walls, is generally supported from cable racks framing channels, or fire rated wood sleepers (see "Supplementary Buses" for method support).

When stranded wire and exothermic welds or crimp type parallel connectors are employed, the interior ring ground need not be installed as a single continuous run of wire. Unnecessary splices should be avoided, but where installation is greatly simplified by installing the interior ring ground in several segments, with the segments joined by an exothermic weld (preferred) or crimp type parallel connector, such segmentation is permissible. You must allow for a small open section (minimum 4 inch) in the interior ring ground at the point farthest form the OPGPB/ PANI- MGB. This gap will prevent unwanted current loops during lightning induced voltage and current events. Solid wire interior ring ground may be segmented only if segments are joined with an exothermic weld or an approved crimp type connection.

To minimize impedance and the incidence of arcing, the interior ring ground shall be installed with a minimum number of bends, and such bends as are required shall be made with the greatest practical radius. The bend radius shall not be less than 12 inches. The use of 90° bends to route around obstructions shall be avoided when lesser bends (e.g., 45°) can be adequately supported. The probability of arcing may be significantly increased by unnecessary bends.

Any closed metal ring around a ground conductor acts as inductive impedance to the flow of other than DC current. For this reason, routing of ground conductors through metallic objects that form a ring around the conductor, such as metallic conduits, is prohibited. Use of non-metallic material such as PVC plastic conduit is recommended. Where use of metal conduit is unavoidable (e.g., non-metallic conduit prohibited by local code), the ground conductor shall be bonded to each end of the metal conduit:

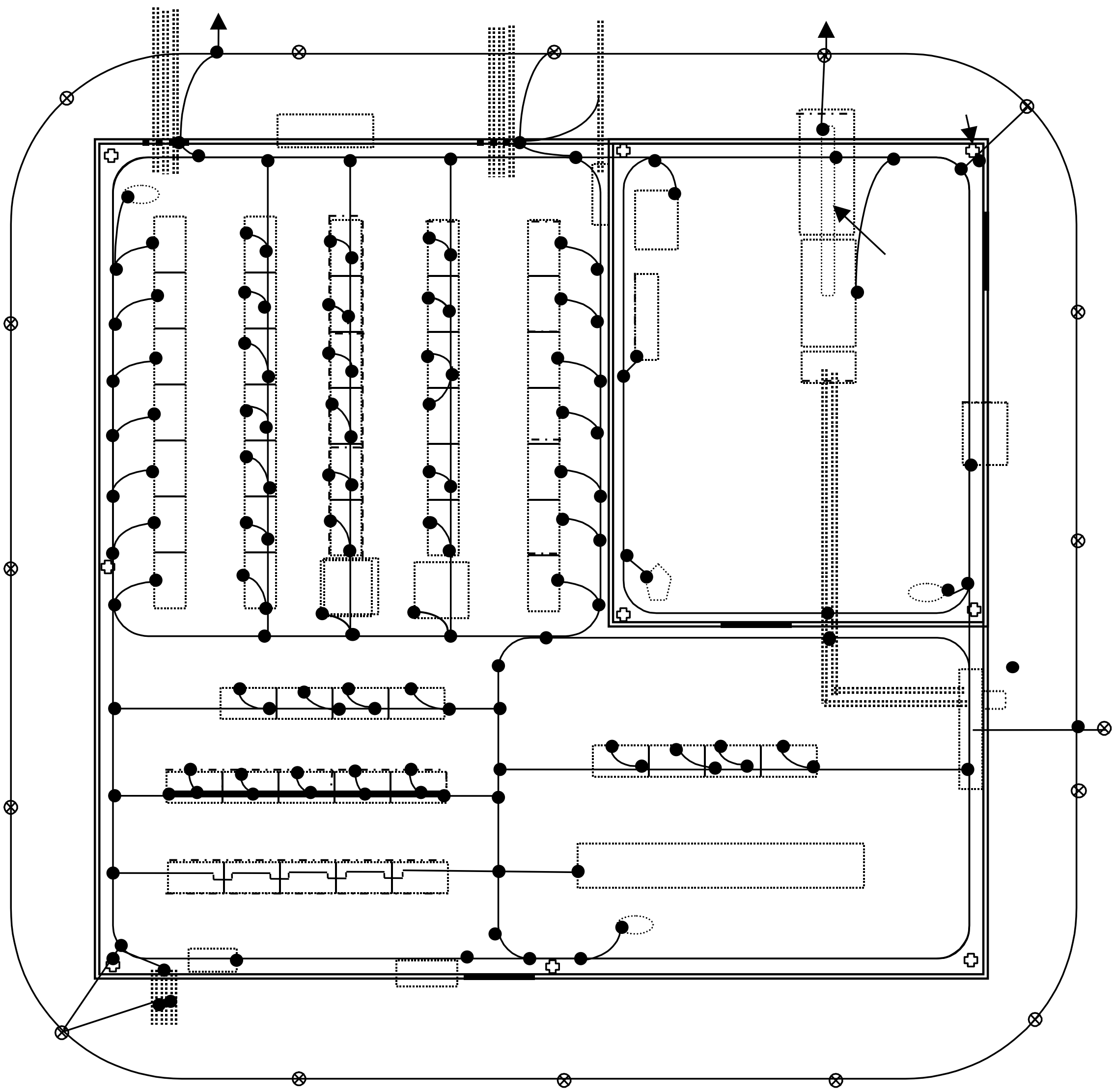
- To avoid increasing inductive impedance.
- To reduce voltage-drop by paralleling the metal conduit conductance with that of the ground bus.

The interior ring ground conductor must not be painted and must be run exposed to allow for visual inspection of the system and so that any point is available for bonding. Routing of a conductor through PVC conduit for purpose of support should be avoided for these reasons.

7.14 Forming and Support of Supplementary Buses

Supplementary buses are normally supported from cable rack stringers (see Figure 7-15) or framing channels furnished for support of cable racks, conduits, and similar structures. When so routed, the ring shall be bonded to the supportive unit at not more than 15-foot intervals. In order to avoid drilling of cable rack, it is recommended that supports of the type shown in Figure 7-13 SK-A be used at 2-foot intervals (although tying to the cable rack or its J or L brackets with #9 waxed cord is permissible). The spring type universal clamp, when mounted on a cable rack stringer, ensures a maintenance free bond to the cable rack (if the insulation is stripped from the cable and the clamp makes metal-to-metal contact with the conductor). The assembly supports the wire away from the rack to avoid interference from rack supporting hardware. At points of rack junction or other points of interference with the ring run, a job fashioned detail equivalent to the zinc plated steel bracket may be used to route the wire around obstructions. Removal of paint from the stringer is not required when the clamp is installed. Scratches in the finish must not be painted, and the clamp must not be painted.

Where cable racks are not available to support supplementary grounding conductors, framing channel superstructure may be utilized (see Figure 7-16). Such channels must be bonded to the wire at both ends of a bus run portion supported in this manner and at 15 foot or less intervals when the run portion exceeds 20 feet. The bond must be made by drilling the channel and mounting a ground clamp thereon, so that the lower edge of the wire insulation is close to the bottom edge of the channel. Supplementary supports for the wire (clips), must be provided at 2-foot intervals along the channel.



Notes:

1. ⊗ Driven Rod
3. Exothermic Weld or Crimp
5. 8″ min. radius bend in wire
7. For Crimp Connections see Fig. 7-13
9. For Conduit Bonds see Fig. 7-9

2. Minimum 2 AWG Wire
4. 6 AWG Ground Connection
6. For Wall Supports see Fig. 7-12
8. For Cable Rack Support see Pub 77351
10. For Hatch Plate Bonds see Figs. 7-7,
11. For Framing Channel Support see Fig. 7-15
7-8, and 7-10

Figure 7-11: Typical Ring Ground Installation in a Microwave Station with no master ground bar

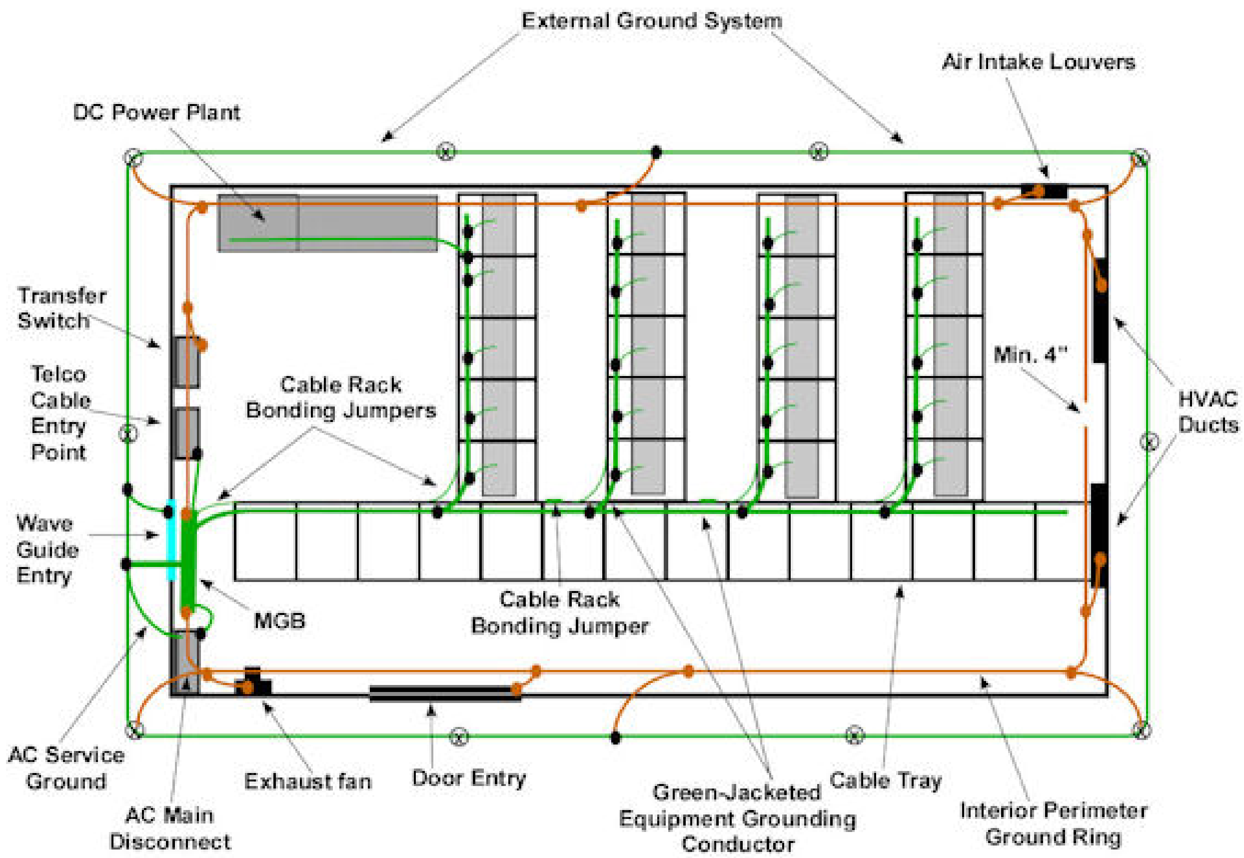


Figure 7-12: Typical Ring Ground Installation in a Microwave Station Equipped With a Master Ground Bar

7.15 Miscellaneous Unit Bonding

Electrical and mechanical units, not classifiable as bays, cabinets, or stands, such as engine-alternator sets, fuel tanks, motor driven fans, air pressure and alarm units, dehydrators and similar units require unit bonding. Connection of the unit bond must be made with 2-hole crimp connectors.

Units of similar nature to the above, that are associated with heating, air conditioning, personnel facilities (such as electrical toilets, including metallic partitions), protective grill-works and other metallic items furnished as part of building facilities, except such items as electric clocks or other units of relatively insignificant bulk (that are located at least 1 foot from unit bonded items) shall be unit bonded.

7.16 Conduit, Pipe and Duct Bonding

Conduits, pipes and ducts invariably are routed throughout the area bounded by the interior ring ground, and in central office installations they usually extend beyond that area into areas of a floor occupied by other types of communication equipment or building facilities. Pipes and conduits, raceways and air ducts, when joints are permanently joined by conventional means (without slip joints), are excellent electrical conductors. When these objects terminate in bonded units (e.g., cabinets, etc.) within the interior ring ground area, they may be considered to be adequately bonded by that unit bond for a distance of:

- 15 feet if electrically insulated from supportive steel hardware.
- 30 feet if metallically fastened to supportive steel hardware (e.g., high level superstructure) at intervals of less than 15 feet.
- It is recommended that conduit and pipe unit bond connectors be made using spring type conduit clips, rather than strap type clamps (see Figures 3-8 SK-A and 7-9). These clamps are spring loaded, and periodic maintenance to ensure a tight connection is not required. The clips and recommended methods of terminating unit bonds thereon may be used on conduits and pipes from ½-inch size to 2 inch size.
- Points of discontinuity in conduit, raceway, pipe and duct runs must be made electrically continuous by bonding across points of discontinuity with 6 AWG stranded conductor with crimp lugs on the outside surface of the unit being bonded, utilizing spring type conduit clips, self-tapping screws, nuts and bolts or equivalent methods of obtaining reliable continuity between the unit and connectors.

- Fluorescent lighting system fixtures and interconnecting conduit installed in frame lines within the ring ground system area will be considered as conduit runs. Unit bonds therefrom must be provided in accordance with requirements outlined above for conduits. Additionally, an AC equipment ground conductor shall be furnished in conduit runs and terminated in the fixture under the ballast mounting screw.
- When a ring ground system serves radio equipment in a portion of a floor and conduits, pipes, ducts, or similar units supported above the radio bays are run continuously from the radio area into other areas of the floor, each such unit shall be bonded to the peripheral bus at the exit point from the ring ground system area.

7.17 Bonding of Units Outside the Ring Ground Periphery

Electrical units of communication systems other than the radio system that may be installed on the same floor are considered to be adequately protected from lightning damage by the CO GRD and framework bonding arrangements provided for such systems. Such electrical units that are located outside the area but within 6 feet of ring buses, or of units located in the area, shall be unit bonded to the interior ring ground so that ground system continuity exists between the CO GRD and ring ground systems' components. (An exception to this requirement would be "isolated" ground plane units. Do not bond isolated ground plane framework to the ring ground.) Such bonds may be direct unit bonds; or where a number of unit bonds are required, such as when a number of frame lines terminate within bonding range of radio frame lines, a supplementary bus may be employed with individual unit bonds extended to the points of closest proximity to radio area equipment. Unit bonds must be terminated at the point on the unit that serves as the framework ground point for the CO GRD system to ensure optimum continuity between the radio ring ground and framework ground systems. A frame line that runs parallel to the perimeter of a ring ground system and within 6 feet of components or units bonded to the ring ground system shall be bonded to both ends of the line. If the bond path via the frame line ground continuity device between points of unit bond connections at the interior ring ground exceeds approximately 60 feet, it is recommended that an additional bond at the approximate midpoint of the frame line be provided.

7.18 Building Structural Member Bonding Requirements

The large variety of building construction methods used requires that individual studies be made to determine bonding requirements (of the structural members to the interior ring bus) for each structure.

Spark-over between points of discontinuity or between structural metal and units installed in the building can cause structural damage or hazard to personnel. As an example, close proximity of concrete encased structural metal to a wall mounted unit may cause an explosion of the intervening concrete if the potential difference becomes great enough to overcome the insulating properties of the concrete, permitting an arc to develop.

A central office building of steel frame or reinforced concrete construction is considered to be inherently self-protective and adequate equalization of potential between structural members and the ring ground system is assumed when the ring ground system is bonded to the building CO GRD system for continuity to earth. Small buildings, such as auxiliary microwave repeater stations or small remote central offices, afford a higher concentration of current through fewer paths and, dependent on construction features, deliberate bonding to ensure voltage equalizing is required.

General construction features normally encountered are listed below:

Walls

- Concrete block
- Brick veneer, concrete block
- Reinforced concrete
- Precast reinforced concrete panels

Columns

- Concrete block
- Reinforced concrete
- Steel section in concrete
- Steel section or pipe, exposed

Roof Beams

- Steel beams or fabricated metal
- Prestressed reinforced concrete
- Reinforced concrete
- Metal framed opening in walls and roofs

Metal framed openings in walls, such as door frames (bucks), air intake and exhaust openings, engine exhaust thimbles, etc., may or may not be grounded through continuity extended by rebars, hoods or other metallic objects from bonds connected to the exterior ring bus. Such frames shall be bonded to the peripheral ring bus, regardless of other paths of continuity to earth, except where metallic units are coupled/bonded directly to the peripheral bus by a reliable metallic connection, such as bolting. In this respect, frames of waveguide openings, where peripheral bus is bonded to the entry plate, need not be bonded.

Small, prefabricated buildings or huts of metallic frame and exterior surface construction, mounted on a concrete pad, are often used to house radio equipment. They are usually equipped with an interior peripheral ring bus (J rail) and all unit bonds terminate thereon. The metallic structure requires no bonding other than that afforded by the bonds furnished for connection of the structure to the buried exterior ring system. If the structure rests on metallic skids, they need to be bonded to the buried exterior ring system at each end.

7.19 Telecommunications Facilities at Radio Stations

In general, telecommunications facilities at radio stations in residential, industrial, or commercial areas (i.e., not on a remote mountaintop) do not present any additional protection problems. Antennas are usually located on high buildings having steel frames that provide a good path to ground for lightning strokes. In such cases, since the possibility of dangerous current being impressed on telecommunication facilities is very remote, only the protection normally required for similar locations without radio equipment is provided. However, common grounding at the radio station is essential to limit voltage differences and high-frequency induction.

7.20 Environmental Considerations – Mountain Top Installations

Radio station installations on mountaintops are built on high resistivity topsoil over bedrock where use of the exterior ring ground with counterpoise extensions or radial grounds using GEM such as lo-ohm concrete is recommended. If no external power service or communication facilities are required at such installations, the ring counterpoise will probably provide an adequate grounding electrode system. However, wireline facilities are usually connected to most radio stations and to distant switching centers or power substations, often located in a valley several miles away where soil resistivity is lower than on the mountaintop. A lightning stroke to the mountain top installation under these conditions can create some serious protection problems. The greater the difference in soil resistivity between the two locations and the higher the impedance of the connection facilities, the more likely will be the need for additional protection.

7.21 Frame and Power Plant Return Bus Bonding Requirements

Every metal frame, cabinet, battery stand and individual electrical unit (e.g., engine alternator sets) located within the area bounded by the interior ring ground requires unit bonding.

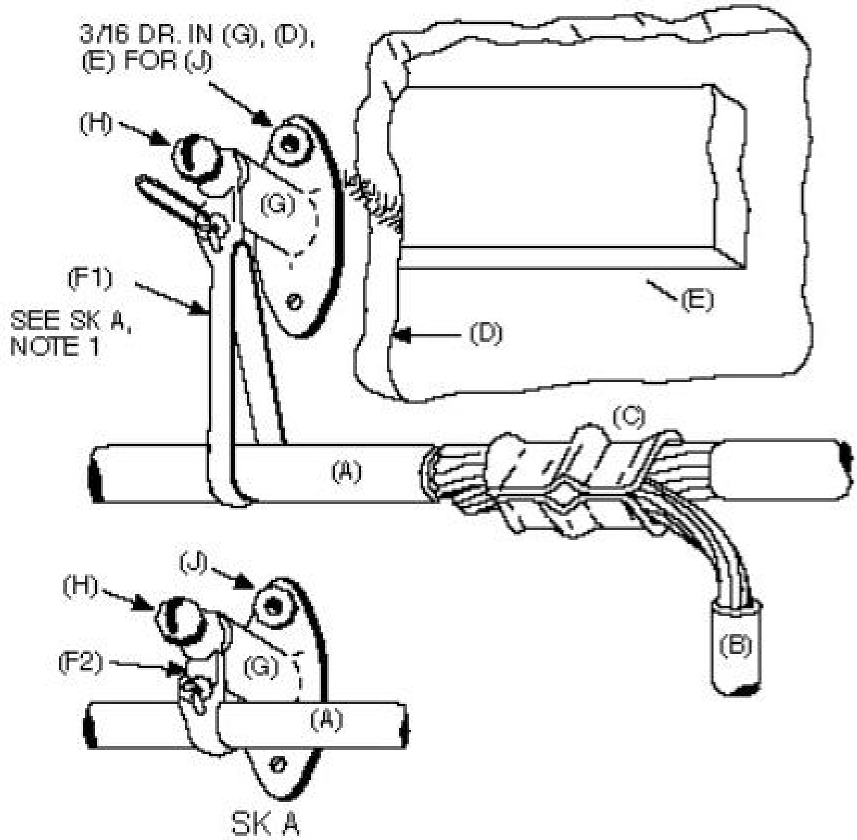
Bay frame lines may not be equipped with inter-bay ground junction facilities, or they may be equipped with inter-bay junctioned copper ground busbars (e.g., relay rack ground busbars) for frame grounding. Bays equipped with interjunctioning ground devices must be individually unit bonded to a supplementary or interior ring ground. Bays interjunctioned by means of copper ground bars require connection to a ring bus at each end of the continuous ring ground run, to form the equivalent of a supplementary ring ground in which the RR GRD bus serves as part of the supplementary bus. Duct bays supported by a common pipe are not considered adequately unit grounded frames (see Section 5.8).

The unit bonding points of frames requiring individual bonds are variable in accordance with the facilities provided with the frames. Certain frames may be equipped with ground buses located near the top of the frames but afforded with facility for interbay junctioning. The optimum unit bond point for such frames is the ground bus when the bus is not isolated from framework metal. The optimum unit bond point for frames not equipped with ground buses is the frame metal at the top of the frames. Such frames may be shop equipped with ground lugs, or holes for mounting installer furnished lugs or may have no provision for mounting ground lugs.

Two-hole bolted tongue crimp connectors are required for unit bond connections. Other types of lugs must be discarded, if furnished, and replaced with crimp connectors. Where ground lugholes are not provided and a ¼-inch thick top or upright angle is part of the framework, a universal clamp may be mounted on the ¼-inch thick angle to avoid the effort of drilling (see Figure 7-15). A two-hole bolted tongue crimp connector must be mounted with a screw and lock-washer in the tapped hole of the clamp. When the frame construction is such that a clamp cannot be mounted, the frame must be drilled to mount a two-hole crimp connector.

Note: Paint must be removed to provide a clean bare metal surface and a conductive anti-oxidation compound applied to all connectors.

Note: Not all anti-corrosion compounds are conductive. Only products that are listed as conductive are acceptable to use where an anti-oxidant compound is required.



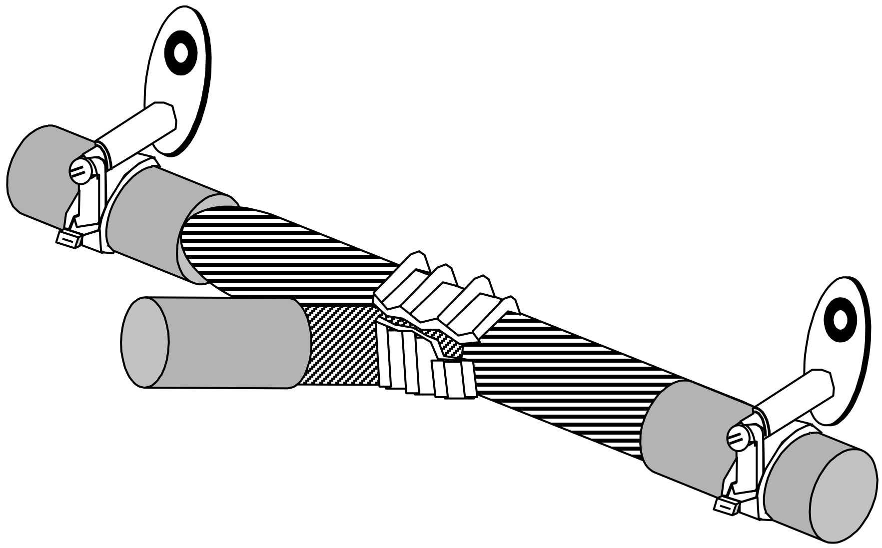
NOTE:

To facilitate crimping of wires to (A), strap (F) should be installed in position (F1) until all crimps are made, then adjusted to position (F2)

LEGEND

- (A) 2 AWG Stranded Copper Wire (Peripheral Bus)
- (B) 6 AWG Stranded Copper Wire (Unit Bond)
- (C) Crimp Type Parallel Tap
- (D) Drywall (illustrated), Concrete, Brick or Other Wall Material
- (E) 1 x 2 Fire-Rated Wood Sleeper 9 ft 8 inch From the Floor
- (F) Nylon Cable Tie: (F1) in Installation Position, and (F2) in Final Position
- (G) Nylon Standoff
- (H) Fastener Screw
- (J) Nylon Fastener

Figure 7-13: Wall Support Assembly for an Interior Ring Ground



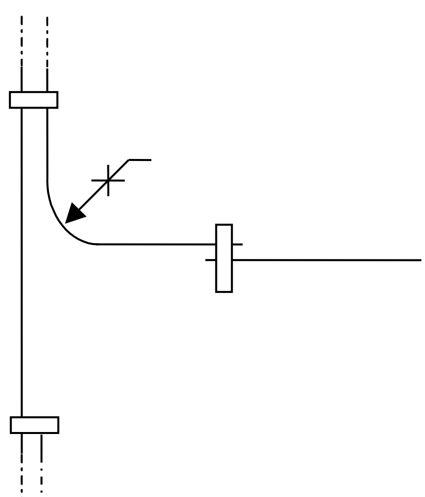
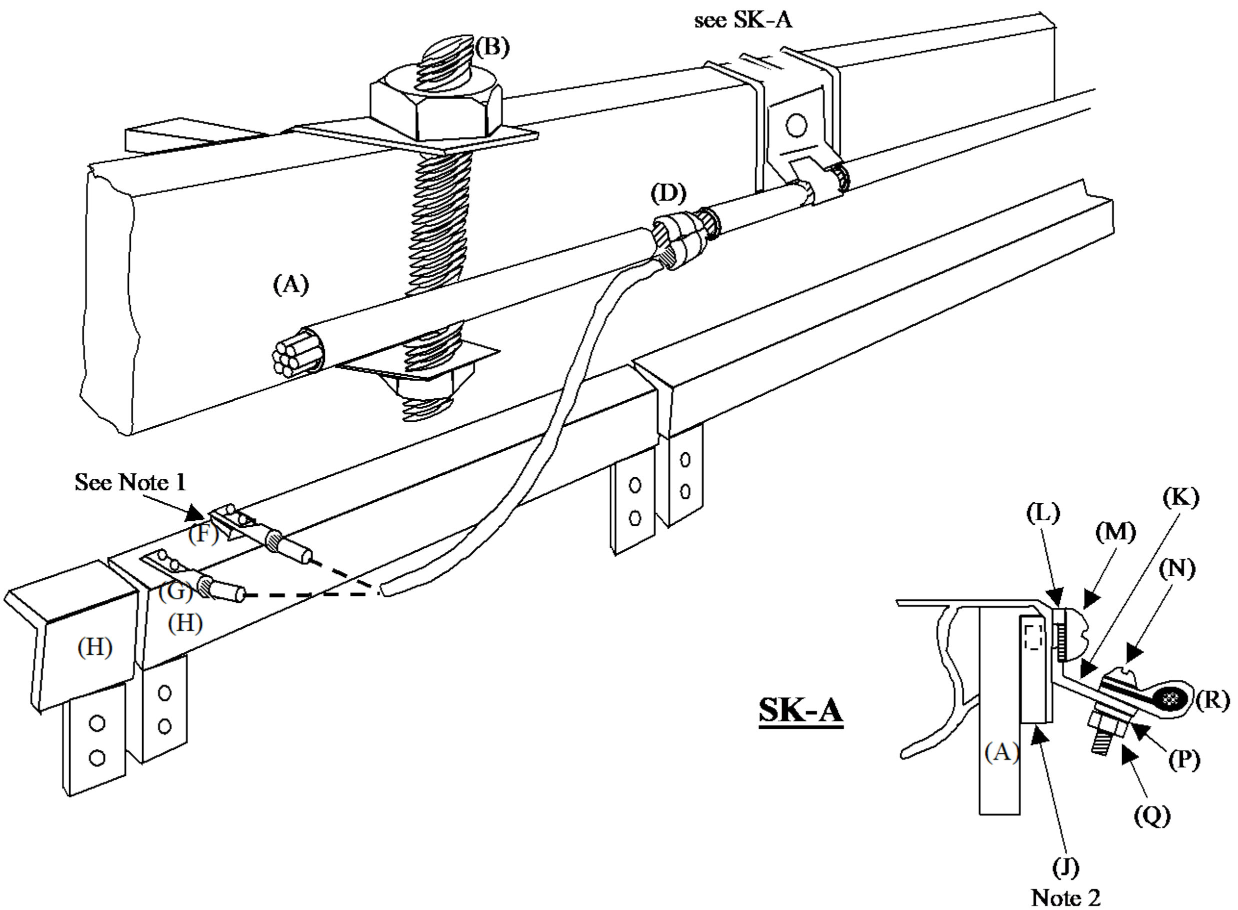


Figure 7-14: Typical Supplementary Ground Crimp Connections



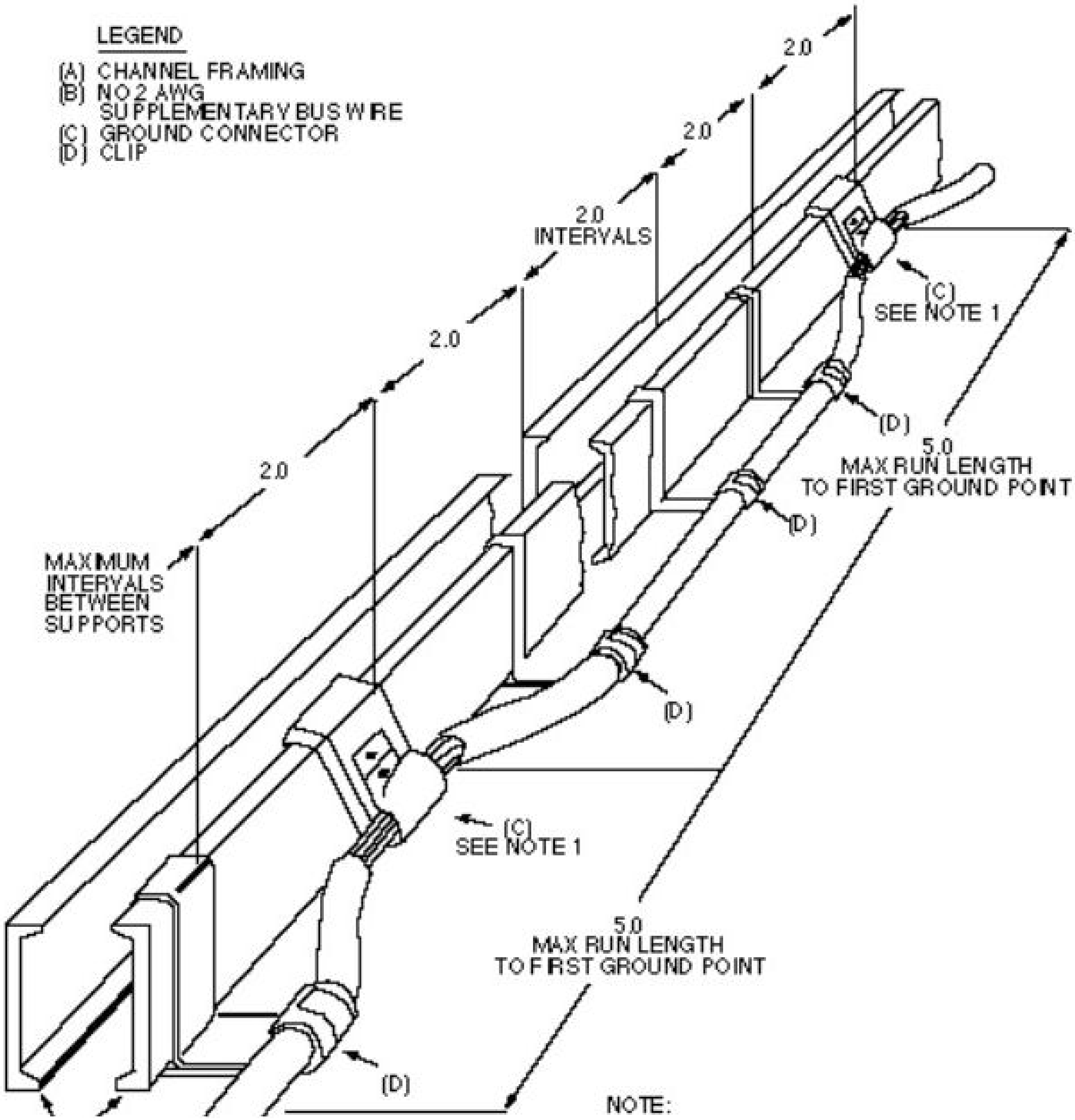
LEGEND

(A)	⅜″ thick cable rack stringer	(B)	Cable Rack Support Hardware (typical)
(D)	2 AWG THW supplementary bus wire	(D)	Parallel crimp connector
(E)	6 AWG green THW unit bond wire	(F)	Caddy universal clamp
(G)	2-hole bolted tongue crimp connector	(H)	Units requiring ground bonds
(J)	Universal clamp	(K)	Bracket
(L&P)	Lock washer	(M&N)	RMM screw
(Q)	Hex-nut	(R)	Steel clamp

NOTES

(1) (F) clamp may be used on ¼″ thick frame steel when the frame is not drilled for (G) connector
(2) (J) clamp may be mounted on top or bottom of stringer
(3) If (SK-A) caddy clamps are not available, C-tap (D) to a 6 AWG terminated in a 2-hole lug landing on a drilled bar

Figure 7-15: Supporting Ring Bus Wire on Cable Rack and Connection of Bond Wire



(A) (B)

NOTE 1.

One (C) is required when length of (B) supported from (A) is less than 10 feet, otherwise, addition (C) must be furnished at intervals of 15 feet or less (ground connector similar to Fig 7-14, SK-A)

Figure 7-16: Supplementary or Interior Ground Rings Supported by Channel Framing

Relay rack type framework equipped with ground bars and inter-bay junction plates is grounded through mechanical connection of bars to frame, and inter-bonding between frames is accomplished by its own individual unit bond to the ring. The ground bars are considered equivalent to supplementary ring grounds. Frames of this type are considered adequately grounded for lightning protection and equipment grounding purposes when 2 AWG supplementary ring ground conductors are extended from crimp connectors mounted on each end of the continuous ground bus. These conductors are run to the interior ground or other supplementary ring grounds (see Figure 7-11).

Electrical apparatus cabinets, such as AC service distribution, control, lighting, and similar metallic cabinets, shall be unit bonded to nearby ring ground buses. Termination of the unit bond must be made with two-hole crimp lugs on the exterior surface of the cabinet. Nonelectrical metal cabinets such as tool cabinets mounted within 6 feet of units requiring unit bonding, must also be bonded to the ring ground system.

Metal battery stands and similarly constructed metallic units must be bonded to the ring ground system. Connection, utilizing two-hole crimp lugs, must be made to the stand body or upright that affords shortest inter-unit bonding path to neighboring structures. Some of these units are long enough that additional unit bonds may be required to maintain low impedance path. (Individual structures should not be directly interconnected.)

The return bus of all power plants must be referenced to earth. The size of the reference conductor is dependent on the power plant and site size. In COs, this reference conductor is run from the return bus to the COGB (or the MGB in the case of a plant serving an isolated ground plane with a remote ground window). However, many radio sites do not have a COGB (they have an interior ring). In a radio site, a 1/0 AWG (although a 2 AWG will suffice) ground reference between the power plant return bus and the interior ring or OPGPB is sufficient.

7.22 Power Service

Radio station equipment and tower obstruction lighting are vulnerable to damage from lightning surges and switching transients originating on the connecting power facilities. Rectifiers and other equipment employing semiconductor components are particularly susceptible to damage from extraneous potentials originating on commercial power facilities. To prevent such damage, protective devices should be used on entrance service conductors and on branch power circuits, which exit the building (see paragraph 7.7).

Protective devices for limiting abnormal surge and transient voltages on power circuits function by discharging longitudinal surge current on a phase conductor either to ground or to neutral. It is desirable from an identification standpoint to use the term "arrester" in identifying power circuit protective devices to distinguish them from protectors associated with communication circuits. Note that the use of the term "arrester" here actually refers to a device rated both as a surge arrester and a surge protective device (SPD), per NEC® Articles 280 and 285.

At installations where bonding and grounding have been provided as recommended in this publication, the possibility of damage to station equipment from lightning strokes to the antennas and supporting structures is minimal; however, equipment powered from external power facilities is susceptible to damage from overvoltage surges originating a such facilities. In addition, lamp burnout in tower lighting primarily results from such surges. Tower wiring must be installed in metallic conduit.

Protection against hazardous surge voltages in power utilization circuits requires a systemic approach, starting with protection on the primary distribution circuit and ending with adequately protecting the station distribution transformer. This approach involves a variety of devices and arrangements dependent on the number of phases and type of secondary services and voltage. Primary circuit arrester grounds and the secondary neutral grounds should be solidly interconnected. This arrangement minimizes large voltage differences between primary and secondary winding of the transformer. Some electric companies prefer separate grounds for the primary circuit arresters and the secondary neutral, in which case, the electric company will not want a solid interconnection.

A commercially available spark gap must be installed by the power company to isolate the grounds at normal operating potentials while providing momentary interconnection for lightning surges.

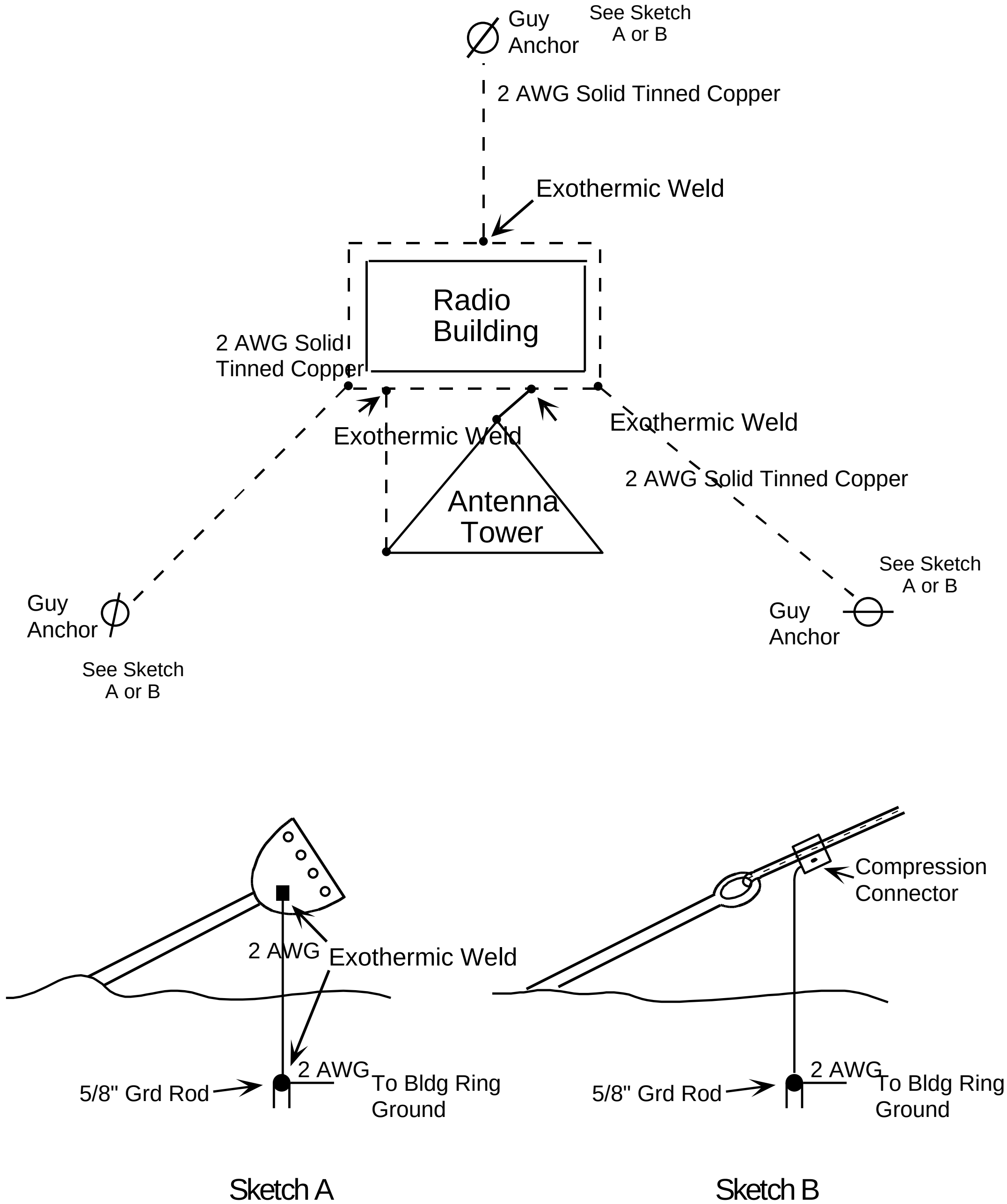


Figure 7-17: Typical Grounding of Antenna Tower Guy Wires

7.23 Grounding Issues Related to Wireless or WiMAX Antennas, Collocated Satellite and Microwave Antennas, ~~and~~ Ethernet Radio Systems, and PoE access devices.

Wireless /cellular (and in some cases WiMAX, satellite or other) antennas are now found at some Lumen locations. Many are located in high lightning areas and are prone to lightning damage, both from direct and indirect lightning strikes. Improper lightning protection can cause equipment damage, service outages, and personnel injury. In addition, Lumen often places higher speed fiber backhaul services with a metallic drop (such as DS-3 over coax, and 10/100 Base-T or GigE on Cat5 or Cat6 ethernet cabling) at wireless carrier locations.

Some sample drawings reflecting wireless base station and antenna grounding, as well as the interfaces between the wireless and Lumen equipment, are shown on the following pages. The different sample figures are primarily provided to show a few of the many configurations that might be found at an existing CO where someone wants to collocate external wireless equipment.

7.23.1 Lightning Protection for Wireless Antennas

Antenna monopoles make excellent air terminals and tend to provide an attractive strike attachment point. A tall antenna monopole may alter local strike density.

The first line of defense against lightning damages and personal injury is a correctly engineered/installed lightning protection system. This should include air terminals, down conductors, grounding electrode(s), equipotential bonding, and electrical transient protection for AC Power and data lines.

NFPA 780® provides the guidelines for the correct engineering and installation of a lightning protection system. Figures 7-20, 7-21, and 7-26 hint at some requirements of a proper lightning protection system. (Note that building or tower structural members may be used as air terminals and down conductors in accordance with NFPA 780®. However, it is much more preferable to not bring lightning into the building. If there is a roof ground system in accordance with NFPA 780®, it should be used instead of bringing conductors into the building [see Figures 7-20 and 7-21]. The tower, etc. should be bonded to the roof grounding system. This system then has down conductors external to the building to carry any lightning directly to ground without passing it through the building.)

This lightning protection system is tied to an approved ground electrode field, as specified in Chapter 3. Figures 7-18, 7-19, and 7-22 through 7-25 all show a ring ground for the wireless equipment, but any other approved ground system will suffice. In addition to the ring ground, a counterpoise system or grounding radials may be desirable. This will allow for better dissipation of lightning and transient currents and voltages away from the site electronic equipment. It will also limit ground potential rise in the direction of the electronic equipment structures (thereby limiting voltages and currents that can be induced in nearby metallic objects at the site).

Note: Lumen is deploying ethernet radio systems, some of which use power over ethernet (PoE) to power the remote radio heads. Section 7.23.7 covers these types of systems.

7.23.2 Bonding Lumen and Wireless Grounding Systems Together

During a lightning strike, the lightning protection system can rise to extremely high voltage potentials relative to nearby remotely grounded objects. Bonding components of the lightning protection system to nearby grounded metallic objects tends to equalize potentials and prevent hazards from step and touch potentials and flashover.

The key to whether ground systems must be tied together relates to whether humans can simultaneously contact two ground potentials that would be produced on the separate systems during a fault or lightning strike if the systems were not tied together. Similar to isolated and integrated ground planes within a building, the key is a greater than 6-foot separation between metallic objects in the separate planes because this is essentially greater than the limit of normal human "reach" (a human can stretch their arms further than this, but that requires effort), and is in keeping with intersystem bonding requirements in various Codes (such as the NEC® and NESC®).

Besides the general metal objects (such as building beams, wireless site fences, etc.), there may be up to two other metallic connections between the wireless equipment and the Lumen CO / equipment enclosure. If the wireless carrier equipment and the Lumen equipment receive AC power from the same service meter, the two ground systems must be bonded together regardless of distance ("shared AC service" is covered in greater detail in Section 7.23.4). The other metal connection may be a T1/HDSL copper interface, a DS-3 coax cable, or a Cat5/Cat6 ethernet cable carrying 10/100Base-T or GigE between the wireless provider and the Lumen CO / equipment enclosure (used by the wireless carrier for transport). Separation between the ground fields can be obtained by gas tube protectors (see Section 7.23.5 for further detail). If the wireless carrier equipment has its own "AC Service" completely separate from the Lumen AC service, and all its metal (excepting any metallic T-1/HDSL/DS-3/ethernet connection) is greater than 6 feet from any metal object related to the Lumen equipment, no connection between the ground fields is needed; and in fact, is somewhat undesirable.

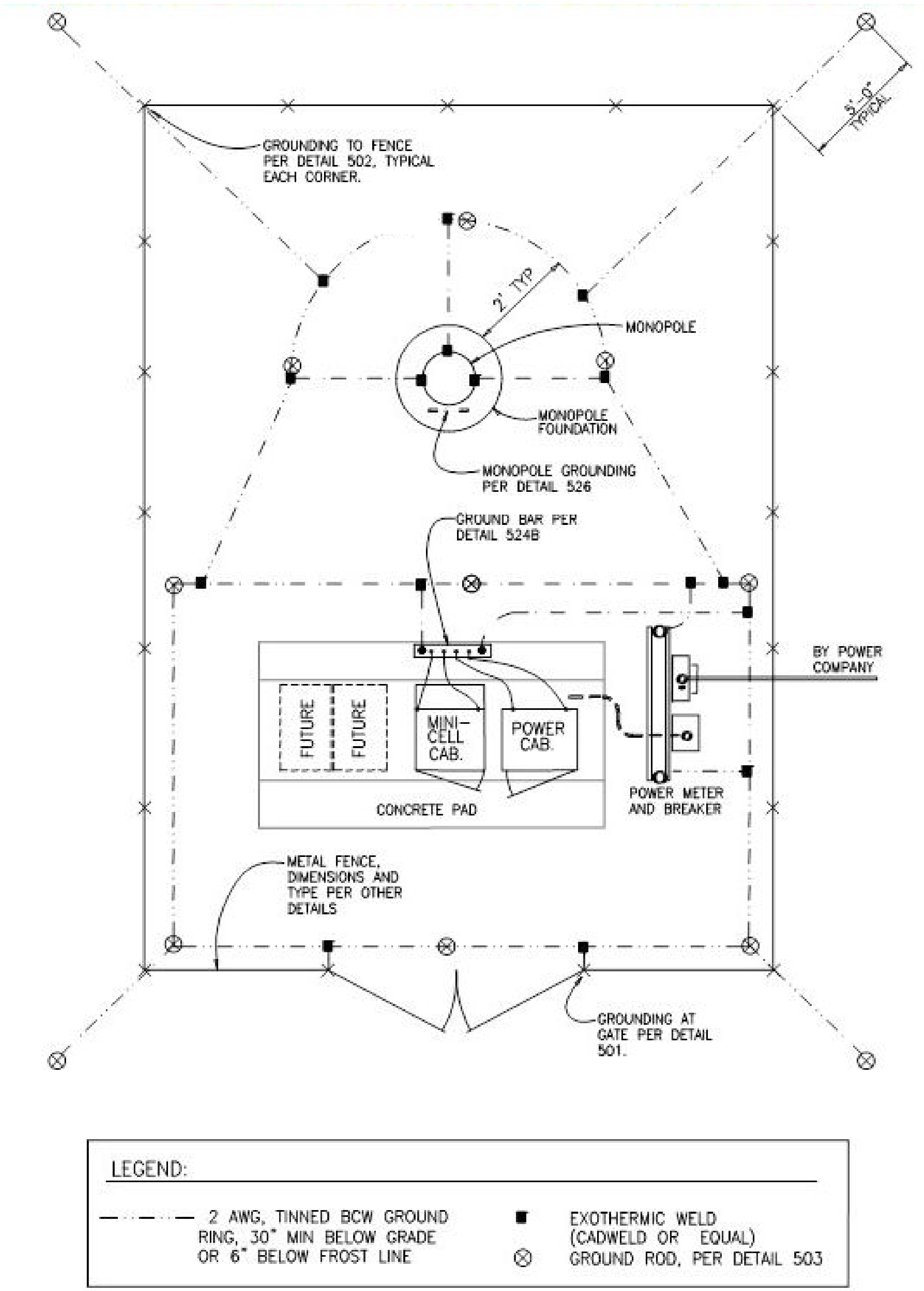
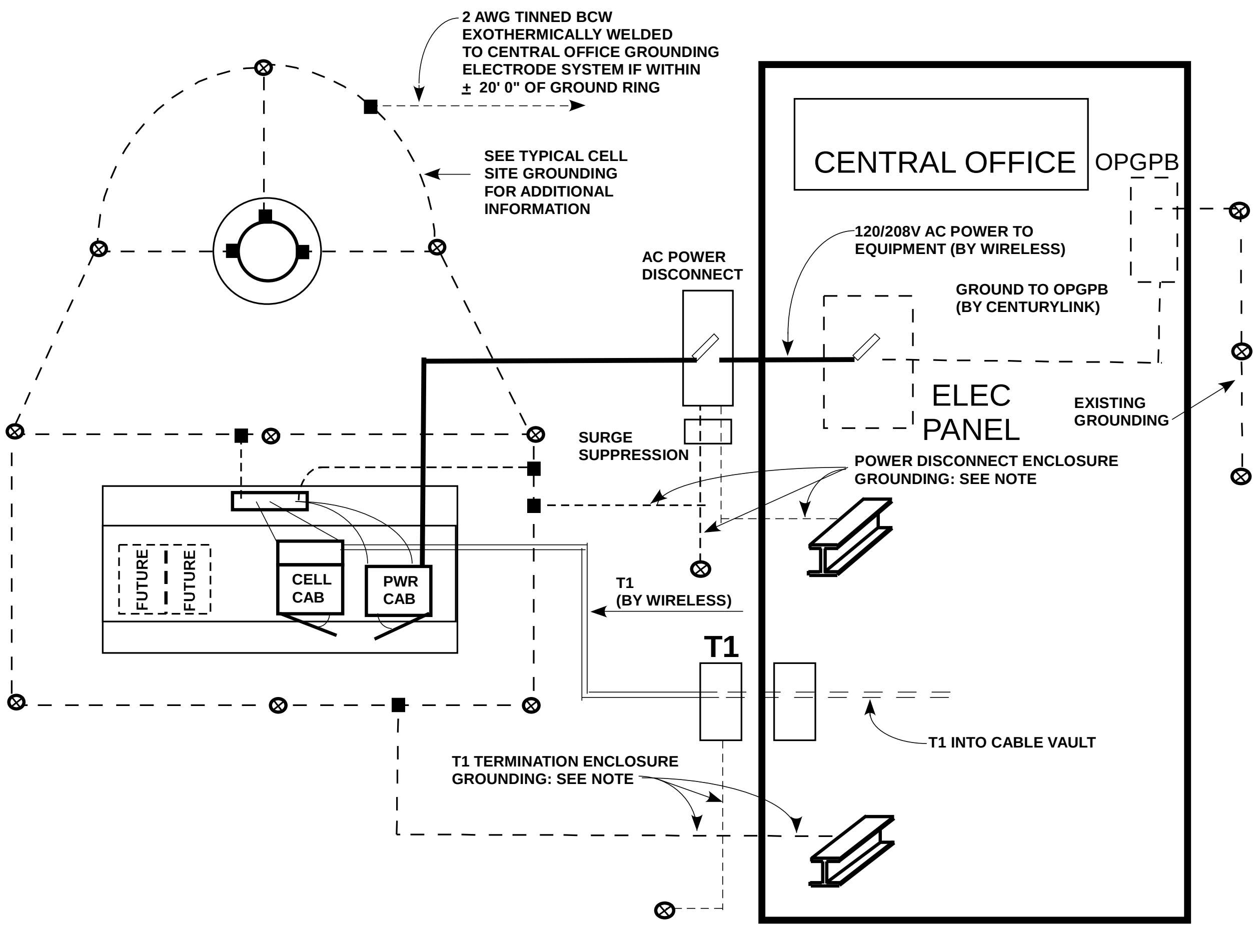


Figure 7-18: Grounding of a Typical Wireless Pole Site with a Metal Fence



T1 TERMINATION BOX & POWER DISCONNECT BOX GROUNDING

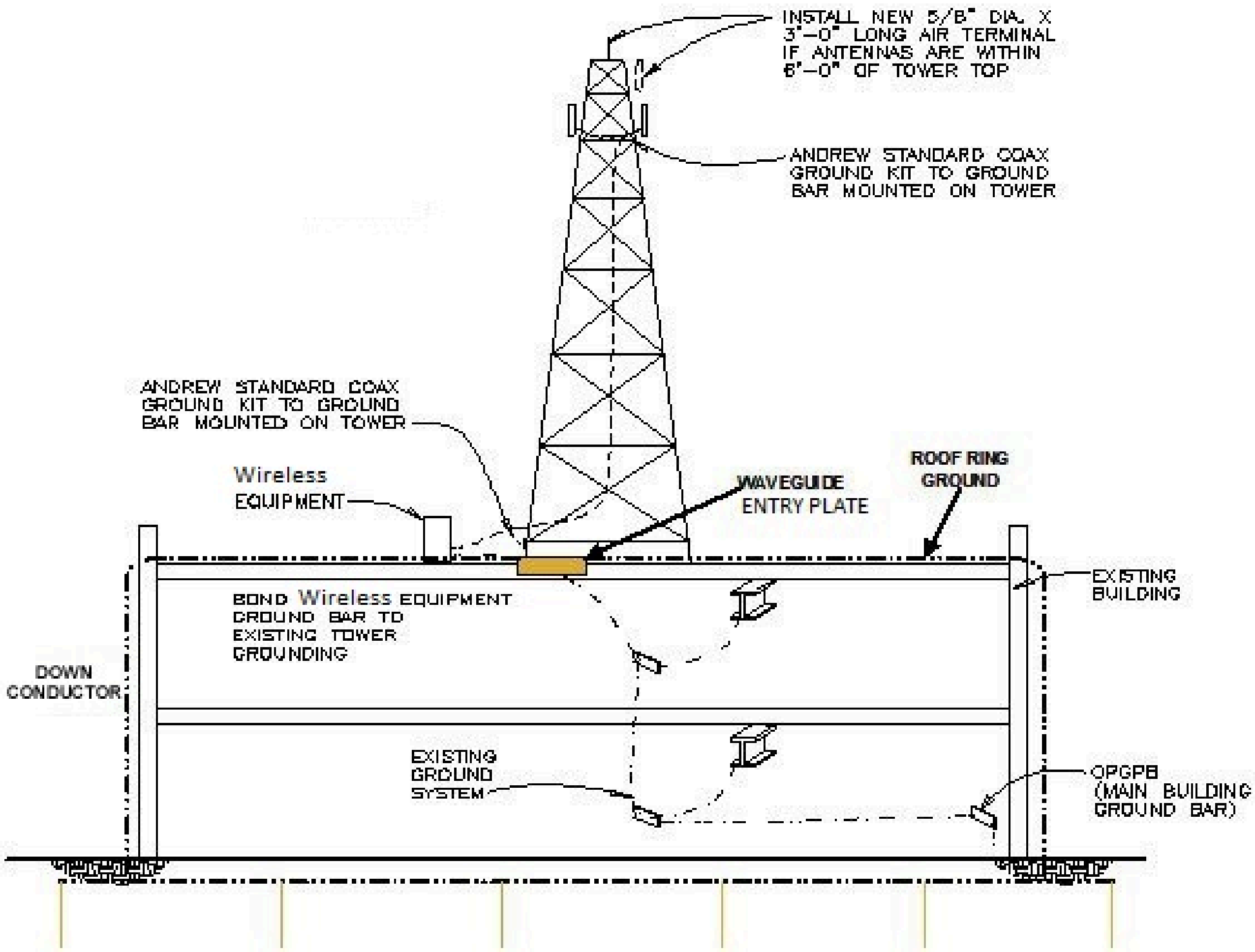
T1 TERMINATION ENCLOSURE GROUNDING AND POWER DISCONNECT ENCLOSURE GROUNDING ARE SITE SPECIFIC, BELOW ARE THE REQUIREMENTS FOR GROUNDING.

- GROUND WITH 2 AWG BCW TINNED TO CELL SITE GROUND RING
- GROUND WITH 2 AWG BCW TINNED TO BUILDING STEEL IF BUILDING IS OF STEEL FRAME CONSTRUCTION AND WITHIN ± 15' 0" OF DISCONNECT ENCLOSURE
- ADD ADDITIONAL GROUND ROD ADJACENT TO DISCONNECT ENCLOSURE IF EQUIPMENT GROUND RING IS ± 20' 0" FROM DISCONNECT ENCLOSURE

NOTE: WHEN T1 TERMINATION AND POWER DISCONNECT ENCLOSURES ARE CLOSE TO EACH OTHER, COMBINED GROUNDING CAN BE USED.

SURGE SUPPRESSION IS REQUIRED AT EACH DISCONNECT ENCLOSURE

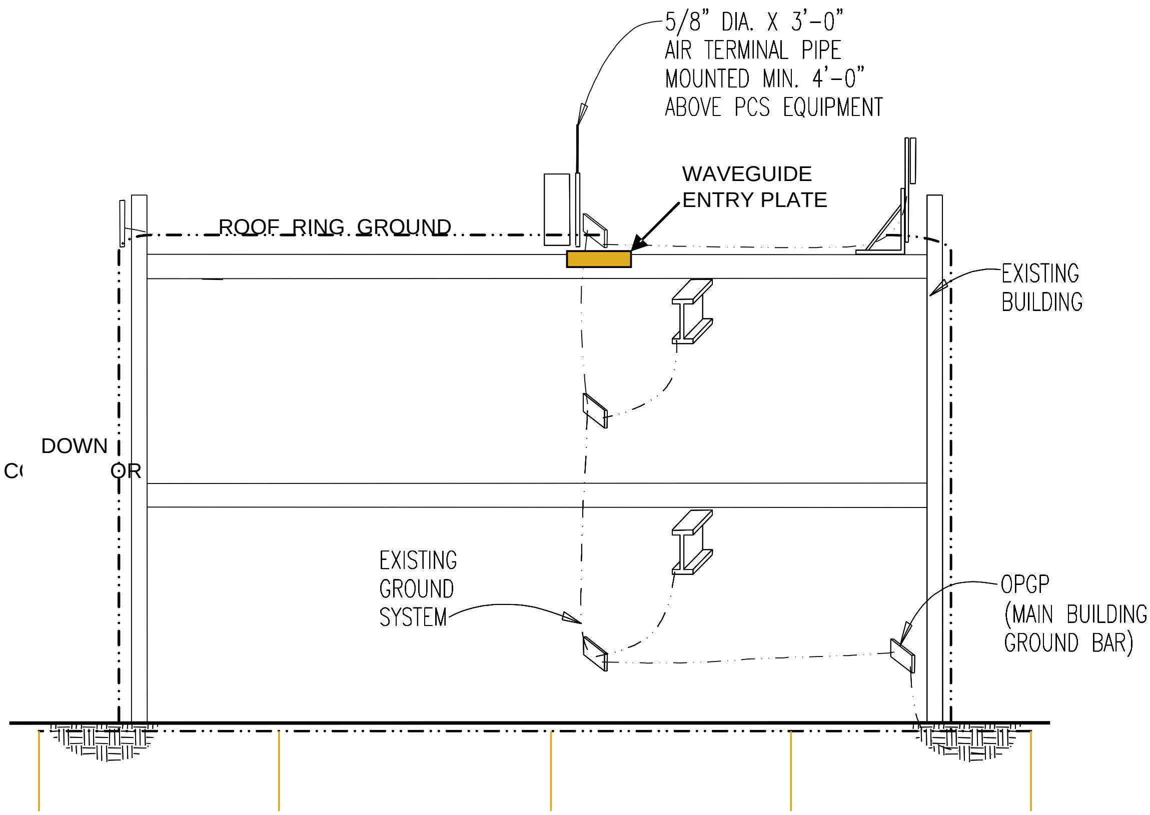
Figure 7-19: Grounding Interface between a Typical Wireless Pole Site and a CO



NOTES

1. The metal tower is grounded to a roof ring ground lightning protection system (NFPA 780® compliant), which is connected to an earth ground electrode field by down conductors coming down the side of the building
2. The cable from the tower enters through a waveguide entry plate on the roof or side of the building, which is then bonded (directly or indirectly) to an external ground electrode field; and on the inside to the nearest COGB
3. There is a lightning arrestor at the waveguide entry plate, bonded to the entry plate or its associated ground bar
4. The roof waveguide entry plate is bonded directly to the roof ring ground

Figure 7-20: Grounding of Wireless Equipment Mounted to an Existing Roof Tower



NOTES

1. If there are taller structures on the roof, there will be a roof ring ground lightning protection system (NFPA 780® compliant), which is connected to an earth ground electrode field by down conductors coming down the side of the building
2. The cable from the tower enters through a waveguide entry plate on the roof or side of the building, which is then bonded (directly or indirectly) to an external ground electrode field; and on the inside to the nearest COGB
3. There is a lightning arrestor at the waveguide entry plate, bonded to the plate or its associated ground bar
4. If there is a roof ring ground system, any roof waveguide entry plate, as well as the antenna support will be grounded to it

Figure 7-21: Typical Grounding of Wireless Equipment Mounted on a Building Roof

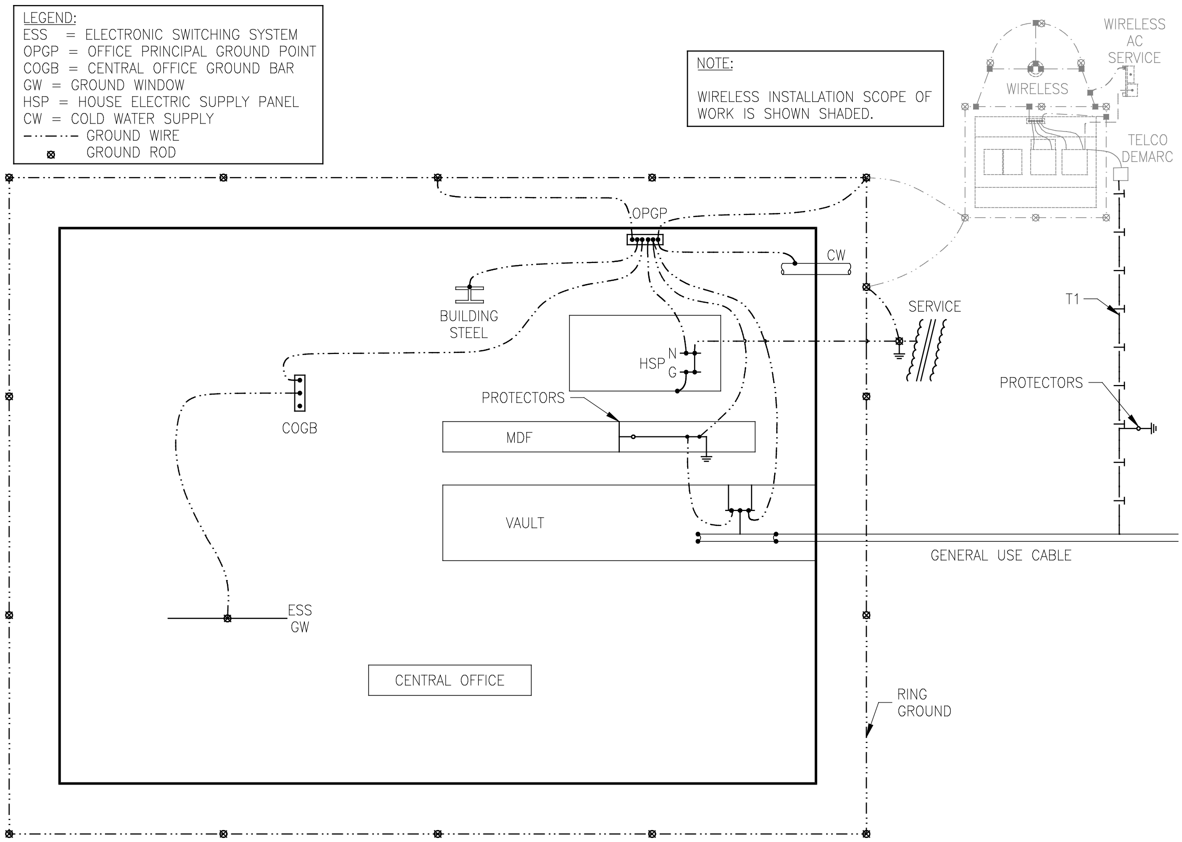


Figure 7-22: Ideal Grounding Interface Between the Ground Electrode Field of a Wireless Site and a Lumen CO Ring Ground

The wireless monopole or antenna lightning protection system is typically tied to a ground ring (or other ground electrode system) at its base (see Figures 7-18, 7-20, and 7-21). The wireless ground electrode system also needs to be bonded at two places with other nearby (within 6 feet) metal (which is all tied to the site ground electrodes) when there is the potential for touching both systems at the same time. This is easily accomplished by bonding the ground electrode systems together (preferably external to any building). Nearby metal (within 6 feet), that is not tied to a ground electrode system, should be referenced to it. (Figure 7-18 is an example of how these ground electrode systems should be tied together when there is 6 feet or less separation between the wireless ground plane and the CO ground plane. Figure 7-25 is an example of how these systems must be tied together, regardless of distance, when the Wireless equipment receives its AC/ DC power from the CO. And Figures 7-22 to 7-24 are examples of how the systems do not have to be tied together when there is greater than 6 feet of separation between the ground systems.)

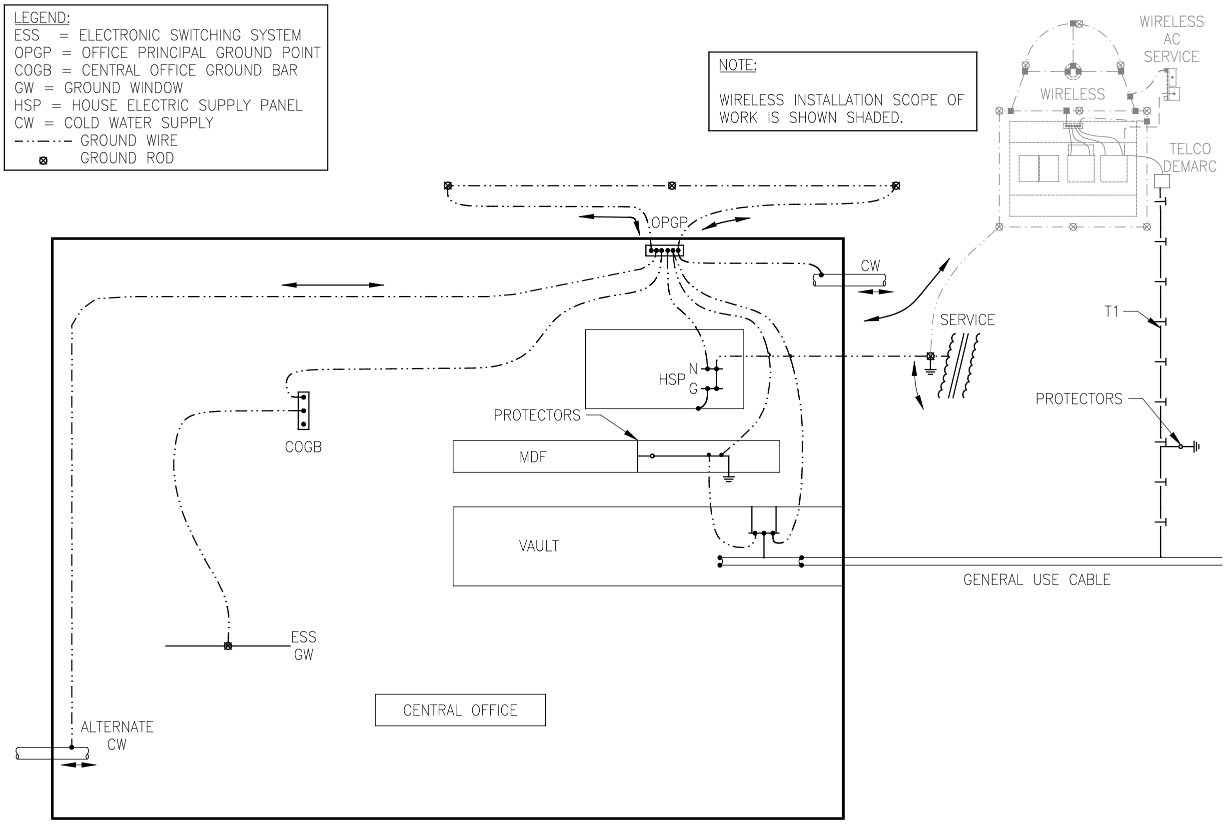


Figure 7-23: Grounding Between a Wireless Site and a Lumen CO Using a Deep Driven Rod, Counterpoise, or Chemical Ground (Ground Well) System

The existing grounding electrode system for the Lumen CO or cabinet can be any of several types discussed in Chapter 3. All are acceptable, although ground rings are preferred. Because the wireless equipment is likely to have a good ground ring, with low impedance to earth, in some cases its impedance may be lower than that of the Lumen building or cabinet ground electrode field. Or the opposite case may also be true. This poses a particular problem when wireless equipment, the OPGB, the cable entrance and the AC service entrance are not located near each other, because lightning hitting one of these components may choose to pass through the building to get to the best ground electrode field. Figure 7-22 represents the ideal situation (everything mentioned is near each other). When this situation is not possible, the guidelines of these sections and the other documents previously mentioned must be followed to avoid potential problems. In some cases, the Electrical Protection Engineer may specify upgrades to the Building Ground Electrode System to rectify potential interface problems.

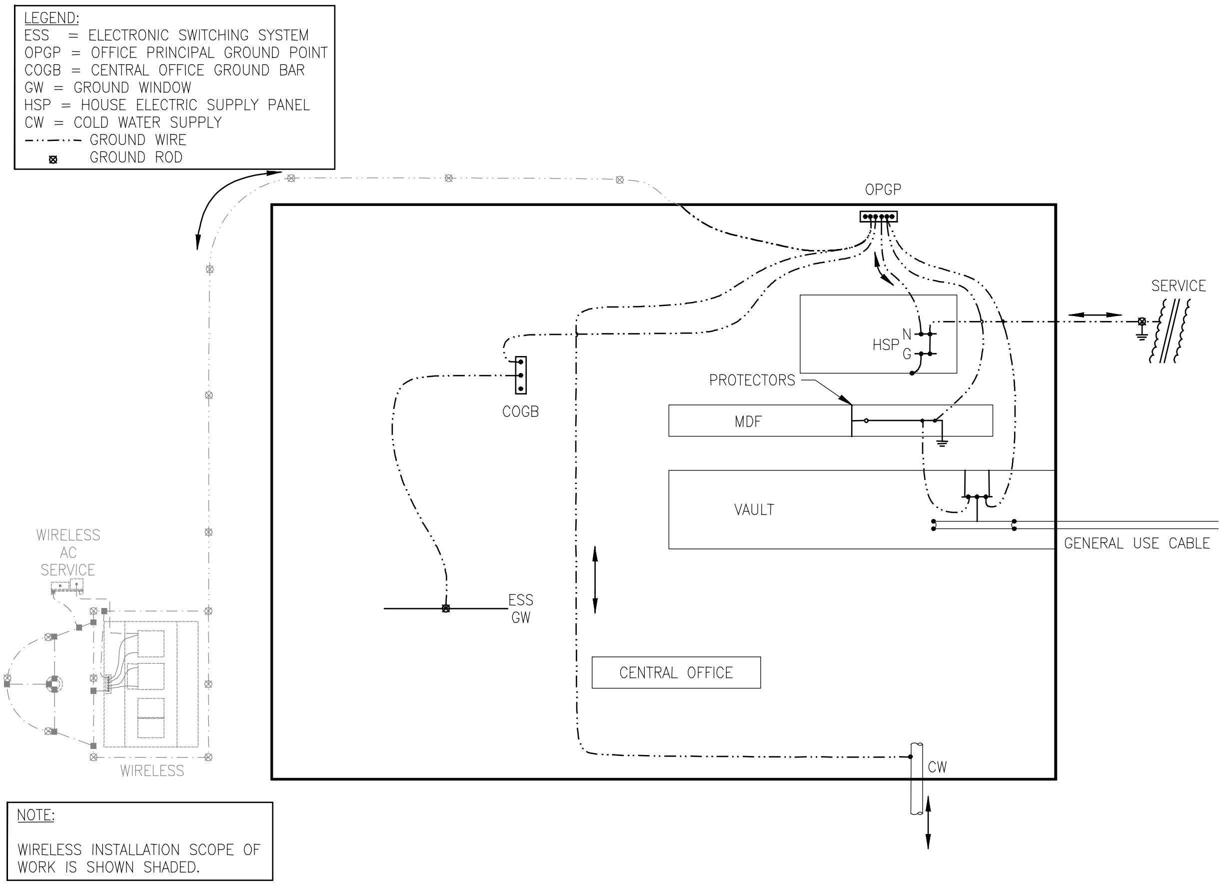


Figure 7-24: Grounding Interface Between a Wireless Site Ground Electrode Field and a Lumen CO that only has the MGN as a Ground Electrode Field

The Wireless provider is responsible for their own grounding electrode system, any bonding to the Lumen and/or Power company’s grounding electrode system(s) [although this responsibility may be jointly worked out with the Lumen engineers], and the “protection” external to the Lumen building or cabinet of any interconnects that they may have to Lumen (e.g., T1, AC feed, etc.). “External to the building” includes rooftops, as illustrated in Figures 7-20 and 7-21. For example, if placement of a wireless antenna on a building roof requires installation of certain elements of a lightning protection system (such as air terminals, down conductors, etc.), those additions are the responsibility of the wireless provider. Lumen is responsible for its own building or cabinet ground electrode system and any protection and/or grounding internal to the Lumen building or cabinet (when the wireless carrier owns the cabinet in which Lumen is collocating its backhaul equipment, refer to Tech Pub 77419 for responsibilities).

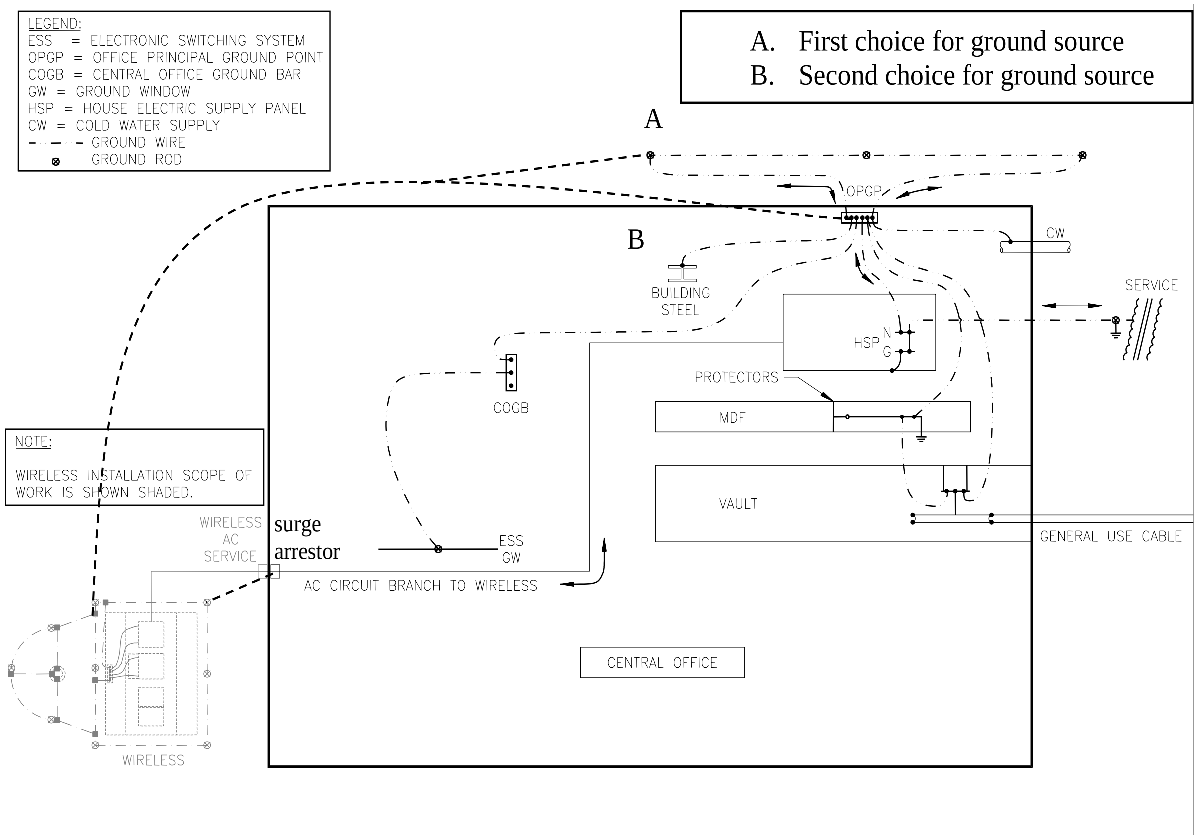


Figure 7-25: Grounding Interface Between a Wireless Site and a Lumen CO where Lumen is Providing the AC Power from Within their Building

7.23.3 Power Service Entrance Protection for Wireless Equipment

Because Lightning is likely to strike the antenna tower or monopole, the likelihood exists that lightning can be induced on to the AC service (either for the building/cabinet or for the wireless equipment). A proper surge protective device (SPD) must be installed on the AC Service Entrance to prevent excessive lightning voltages and currents from entering the equipment through the commercial AC wiring.

AC Power for wireless carrier equipment can be stand-alone (their own metered service), as exemplified in Figures 7-18, 7-19, and 7-22 through 7-24, or it can be supplied from a co-located or shared AC power distribution system, as shown in Figure 7-25.

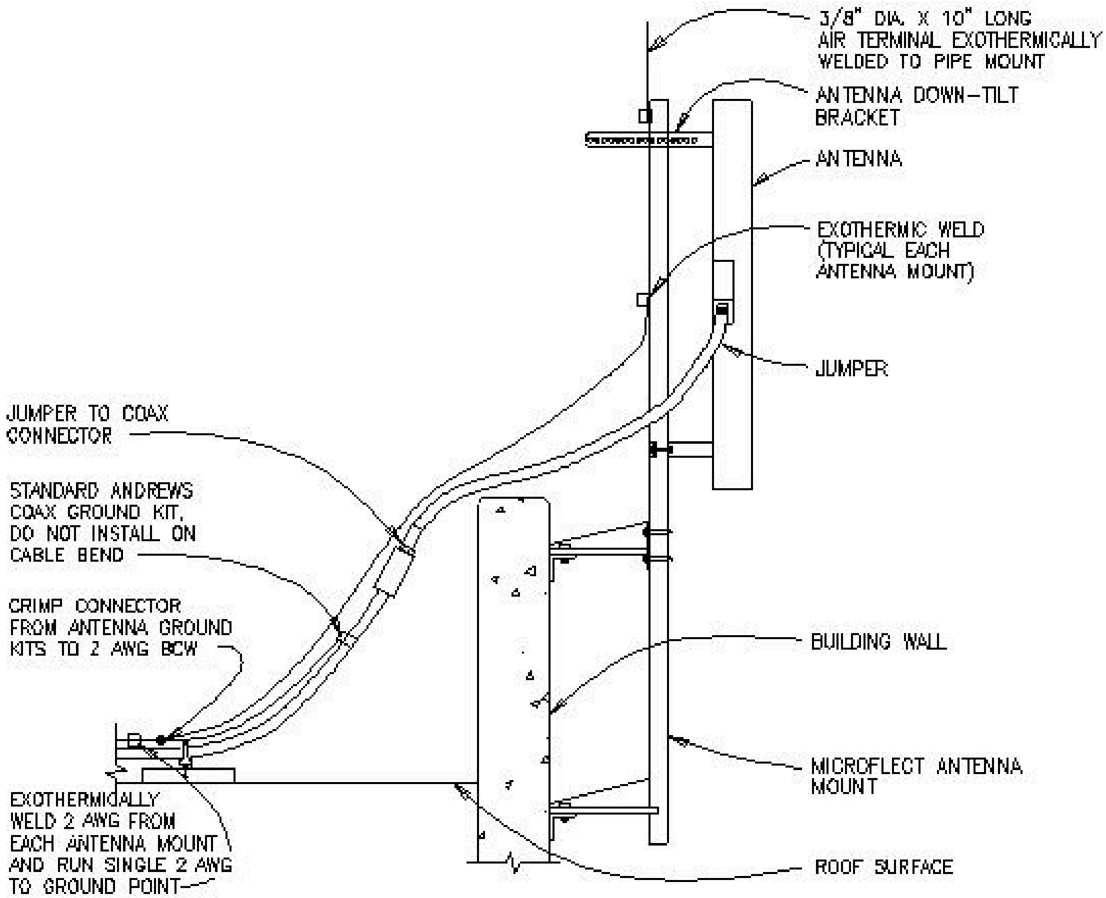


Figure 7-26: Wireless Pole Mounted Antenna Grounding Details

Transient protection must be provided to prevent lightning or other surges from reaching the wireless equipment through the AC lines. For stand-alone AC power supplies, the service entrance should be equipped with transverse SPD's. For a shared AC power distribution system (reference Figure 7-25) additional SPD's need to be installed within 5 feet (typically at the Service Disconnect) of where the AC source enters the wireless equipment (including backhaul cabinets/enclosures) that is external to the building. In these cases, both transverse and common mode SPD should be provided.

When nominal 24 or 48 VDC power is run between structures in a wireless backhaul scenario (this may be desirable in order to ensure that the backhaul has the same reserve time as the wireless equipment), surge protective devices (SPD's) rated for the correct DC voltage shall be placed on both ends of the feed(s).

Wireless equipment located internal to the Lumen building is fed from building AC and protected and grounded according to the practices specified in the rest of this Publication.

The AC Service Entrance grounding electrode must be bonded to the wireless ground electrode system as shown in Figures 7-18, 7-19, and 7-22 through 7-24. Where Lumen provides the AC power from within its building, that bond has essentially already been made internal to the building (between the HSP and the OPGP) in keeping with the requirements of Chapter 4 (see Figure 7-25).

7.23.4 Protection for a Power Interface Between Lumen and a Wireless Provider

When Lumen provides power to the external Wireless provider, precautions should be taken in addition to those mentioned in the previous subsection. Of particular concern is the ability of the AC or DC power cabling to bring lightning into the structure. Even with SPD's installed at the wireless equipment, it is also required that additional SPD's be installed at the point the AC or DC service leaves/enters the Lumen structure.

NOTE: SPD's are rated for either AC or DC voltages. When installed at a Lumen facility, the SPD's used shall be the correct voltage type and rating.

Cable routing through a CO is also a concern. If lightning does enter the building on AC feed cables going to outdoor wireless equipment, reducing the possibility of a flash over into sensitive equipment is essential. The AC feed (and any grounding conductors) leaving the building shall take the path out of the building from the AC Service Entrance that passes the least amount of equipment, even if this means that more of the AC is run outside the building than inside.

Figures 7-19 and 7-25 are poor examples of AC cable routing. It would have been better to bring the AC service directly from the House Service Panel or other nearby AC panel (towards the upper right of Figure 7-25), leave the building at that point (making the conduit electrically discontinuous by use of a non-metallic conduit section through the wall), and then run the rest of the AC service outside. While this is not always achievable , it should be done whenever possible. If AC routing through the office cannot be avoided, attempt to run it away from sensitive electronic equipment, especially ESS switches. If the AC service is being obtained from a sub-panel (as illustrated in Figure 7-25), try to choose a sub-panel whose feeder conduit (from the main House Service Panel) passes the least sensitive areas.

If AC service is provided by Lumen, as mentioned, this increases the likelihood of lightning entering the building. Because ESS switches are particularly sensitive to lightning, other surges, and/or loop currents, it is more necessary than ever that

ESS Ground Windows be properly installed, sequenced, etc. per the requirements of Chapter 8.

7.23.5 Protection for other Cabling Interfaces Between Lumen and a Wireless Services Provider

Data lines leave and enter wireless equipment and interconnect with telecom facilities. Data lines that use copper members (such as T-1) must have electrical transient protection at the interconnect points with telecommunications outside facilities or CO’s. For copper facilities interconnecting a Lumen equipment enclosure with external wireless equipment, there are basically 4 points of protection: outside the building, at the entrance to the Wireless equipment, in the cable entrance, and at the MDF protector blocks. Typically, all but the cable entrance protection involves protectors. These are usually of the “gas tube” type.

The wireless provider must provide their own protectors for copper interconnect facilities that enter their equipment. Often it is built right into the equipment.

Figure 7-19 illustrates that surge protectors must be installed on copper data circuits at a point before they enter the building or other Lumen structure (such as a cabinet or wall-mount box).

If the entrance into the Lumen CO is underground, it is preferable for the protectors to be installed before the cables enter an external manhole (the protectors can also be installed inside the manhole, although it is preferable that they be external in a pedestal) from which they come into the Cable Entrance Facility (see Figures 7-22 and 7-23). This external protection pedestal must be grounded to a ground electrode field.

Just as with any other cable with copper members, cables entering the Cable Entrance Facility (CEF) or Vault must be shield grounded as specified in Section 6 (see also Figures 7-22 and 7-23).

After leaving the CEF, the copper facilities have a presence on the MDF, DSX, or Cosmic Frame. At this point they will also be protected with a “5-pin” protector.

Oftentimes, outside cabling enters through conduit. Where possible, this conduit should be non-metallic , fire-retardant and comply with the requirements of NEC® Articles 362 and 800. Metallic conduit offers a path for transients to enter the building and shall be grounded to the closest available non-isolated ground bar.

7.23.6 Grounding for Collocated Microwave Facilities

Collocators may install microwave transmission facilities on Lumen towers/buildings. They also may or may not collocate their wireless equipment bays inside the Lumen CO or radio hut. These types of collocations deserve special mention.

When the collocator mounts their microwave antennas on a Lumen tower/pole structure, they should tie their grounds to the same grounds that Lumen already has for their own equipment. The same applies for any equipment enclosure related to the antenna (s) that the collocator may have outdoors.

When the collocator mounts their antennas s on their own structure on a Lumen roof, they shall bond to the roof ring ground if it exists. If it does not exist, they shall run a down conductor over the side of the building and tie into the Lumen external ground electrode field. The same applies to any equipment cabinets the collocator may place on the roof.

When a collocator places their own microwave antenna -supporting structure on Lumen property (but not on the roof), they shall bond their grounding system to the Lumen external ground electrode field. The same applies to any equipment cabinet they may place to support their antenna (s).

When the collocator interfaces their microwave antenna with equipment inside the Lumen CO, they must come through a waveguide entry plate and be properly bonded to that entry plate’s grounding system as specified earlier in this chapter. If the waveguide is center conductor coax, a lightning protector shall also be placed near the entry plate and bonded to its grounding system.

When the microwave collocator places equipment inside the Lumen facility, it must comply with the interior supplementary ring ground requirements of section 7.12. If the equipment is in a cage, the cage itself serves as the supplementary interior ring ground.

7.23.7 Grounding and Surge Protection for Ethernet Radio, Satellite Systems and PoE Devices Located on the Exteriors of CO’s and Huts

When satellite antennas or Ethernet radios are placed on Lumen buildings, such as Central Offices, all grounding terminations and surge protective devices shall be kept on the exterior of the building. All coaxial cables shall have their shields grounded at the point where the coax cable(s) penetrate the building exterior wall.

For ethernet radio systems, which use a PoE router or PoE power supply to provide DC voltage to power the remote radio head (RRH), there shall be a listed ethernet

SPD placed at the point where the CAT 5/6 cables penetrate the building exterior wall. The SPD shall be grounded to the sites exterior MGE. (see Figures 7-27 & 7-28).

For either system, the roof mounted antennas/ RRH shall be grounded to the roof top ground ring, where available, or a small roof top ground buss may be placed and a minimum 2 AWG down conductor placed on the building exterior. The down conductor shall be bonded to the building ground system (ring). (see Figures 7-27 & 7-28).

Remote radio heads for ethernet services may be placed on new or existing towers and utilize DC power cables to power the RRH's. For these installations, a listed surge protective device (SPD) shall be provided at the RRH location on the tower and at the point the DC power cables penetrate the building exterior wall. The SPD at the RRH's shall be bonded to the tower steel and the SPD at the structure shall be grounded to the site exterior grounding system. (see figure 7-29).

If PoE devices, such as cameras, are installed on building exteriors and are exposed to lightning, the camera mounting must be grounded with a minimum 6 AWG conductor to the site exterior grounding system. The CAT 5/6 cables shall have a listed ethernet SPD installed where the cable penetrates the exterior wall. The SPD shall be grounded to the exterior grounding system with a minimum 6 AWG grounding conductor. For Central Offices taller than single story, contact real estate for additional assistance.

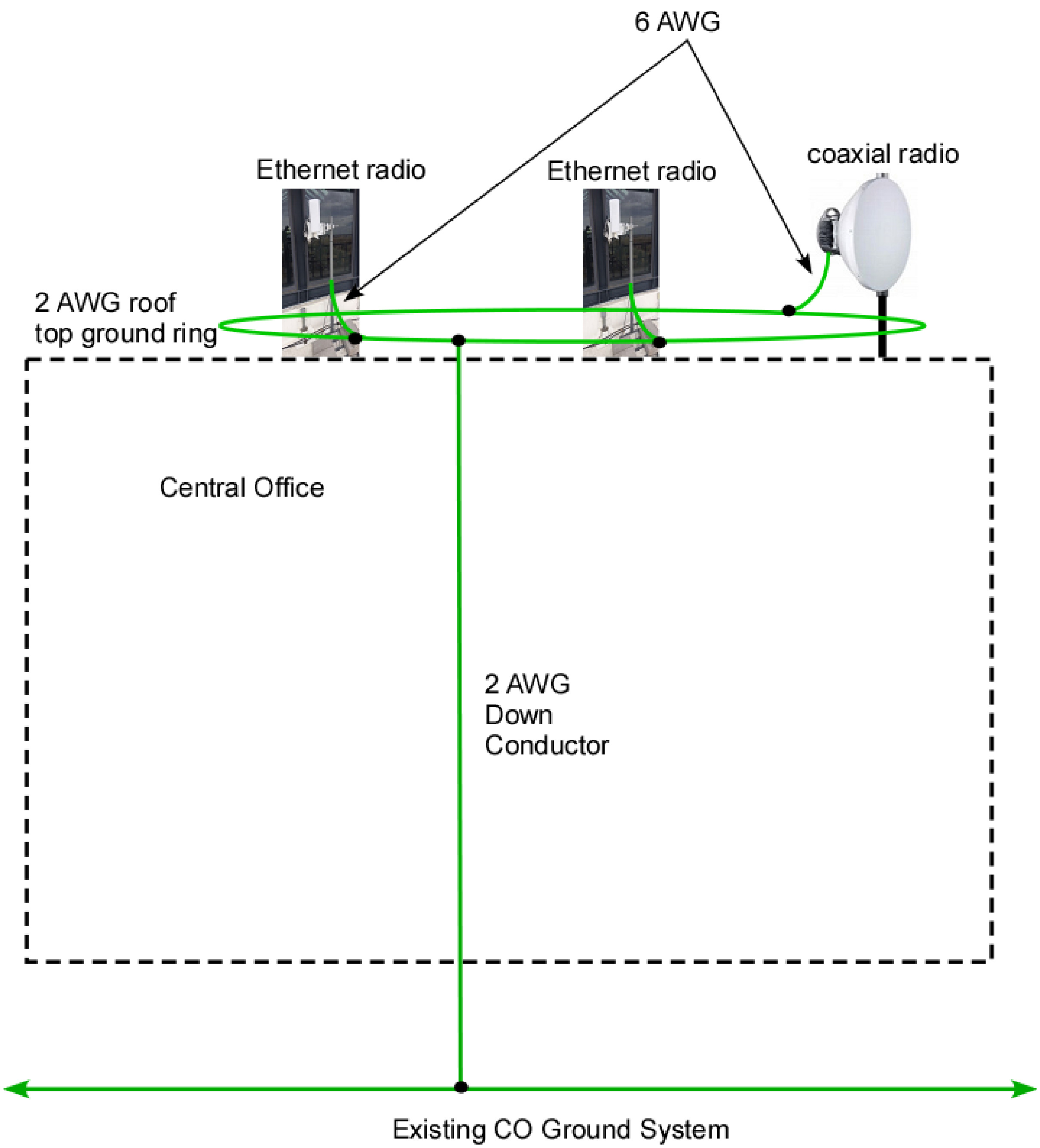


Figure 7-27: Existing Roof Top Ground Ring

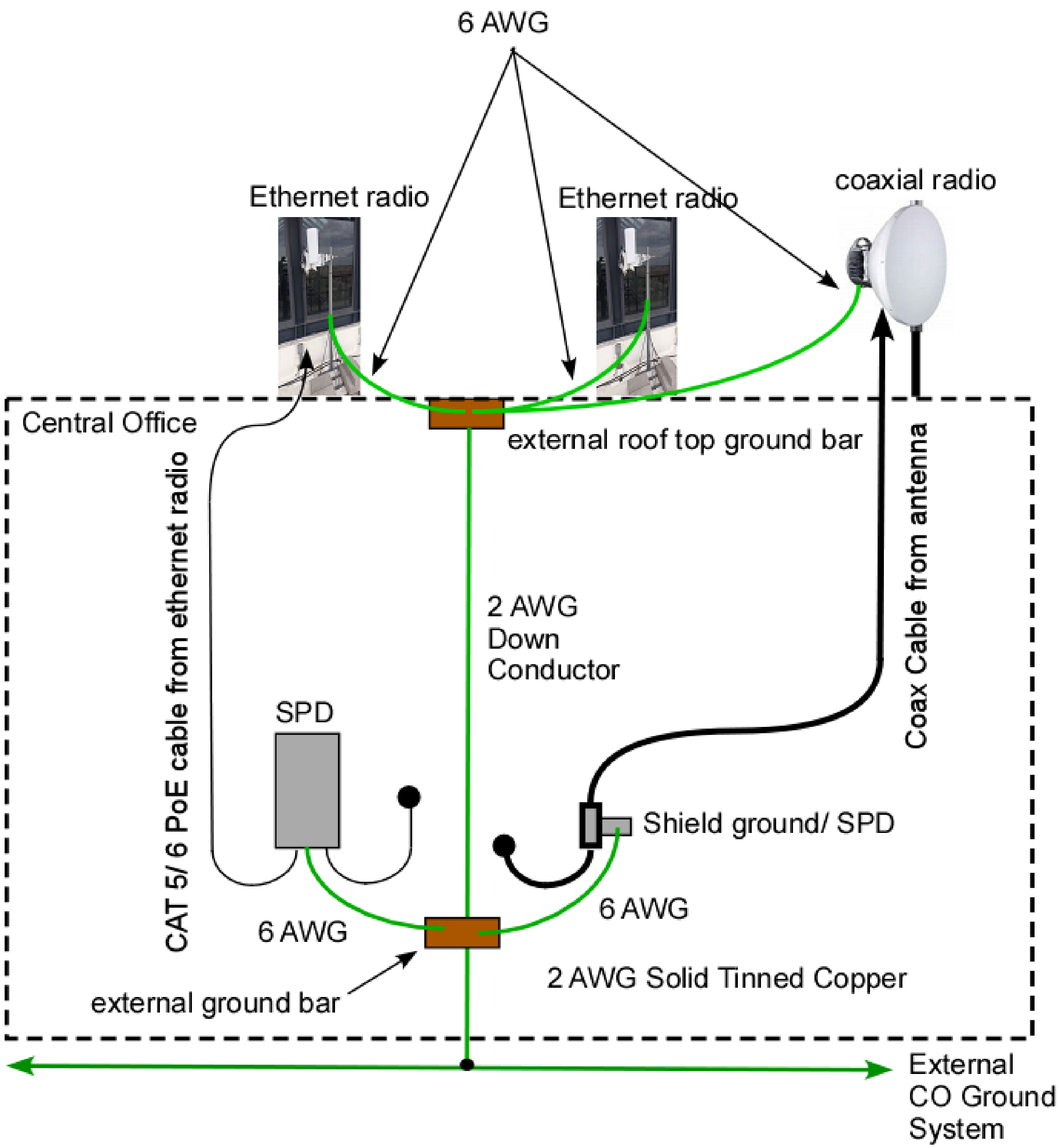


Figure 7-28: Grounding and Surge Protection Configuration

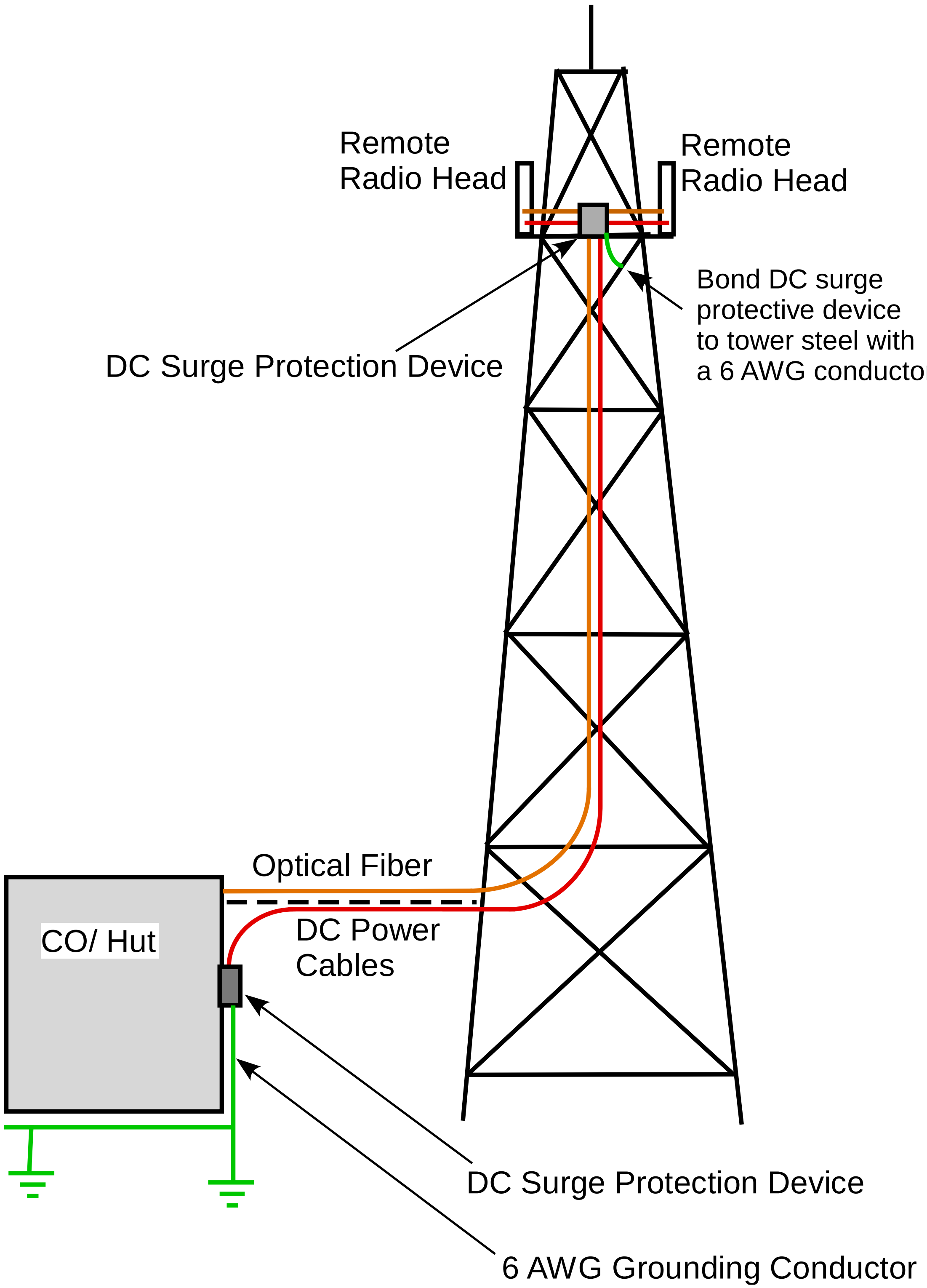


Figure 7-29: Remote Radio Head Surge Protective Device Placement

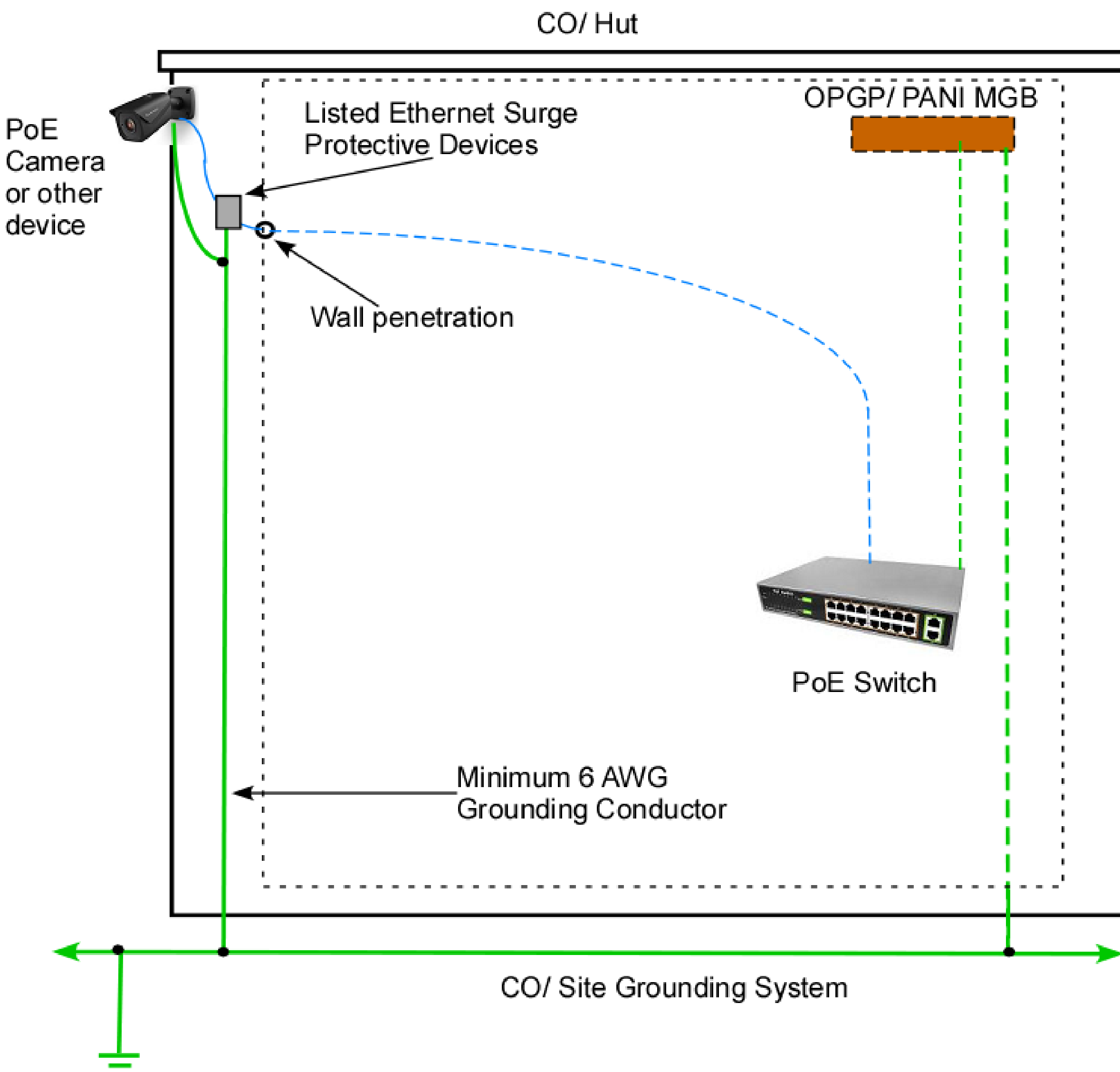


Figure 7-30: Surge Protection for PoE Devices Mounted on External Walls.

7.24 GPS/Sync Grounding Issues

Lumen installs GPS antennas on many of its buildings in order to obtain very accurate, world-standard timing (synchronization) signals from the GPS (Global Positioning System) satellite constellation. Because these GPS antennas are usually roof-mounted, and because they are sometimes placed away from other metal objects on the roof (such as HVAC systems, other antenna towers, etc.), they may provide a convenient lightning attraction point. Figure 7-31 details a typical setup for a roof-mounted GPS antenna. (Some GPS systems may not be roof-mounted.) If the antenna is mounted on an exterior wall below the roof-line and within the zone of protection of an existing lightning protection system (LPS) or steel communications tower as described in NFPA 780® , the external ground electrode field connection is not needed nor is an in-line surge arrestor required. An in-line in-building surge arrestor is still suggested, and when used, should be grounded to the nearest COGB/ FGB / OPGP / PANI- MGB or internal wall ring ground (preferably close to the point of entrance), following the rules in this chapter.

When using a metallic mast for roof mounted GPS antennas, the mast shall be grounded unless it is under the zone of protection of an LPS or taller grounded object. Also, the antenna itself feeds its signal into the equipment in the building via coaxial cable. The coax shall have an SPD ,designed for the application, installed on the CO exterior as close to the wall penetration as possible.

A metallic antenna mast should be grounded to the building roof ground ring (which is part of the lightning protection system — see Section 7.4) if one exists (this ring is then connected to the building ground electrode field by means of down conductors). If a roof ring ground does not exist, a 2 AWG solid tinned bare copper conductor can optionally be run down the side of the building (down conductor) and connected to the building ground electrode field (requirements for proper installation of down conductors is detailed elsewhere in this Chapter, and in NFPA 780®).

The connection to the mast may be accomplished by means of an exothermic weld (preferred), a pipe clamp, or a two-hole crimp connector bolted to the pipe (proper application of all these methods is detailed elsewhere in this document).

If possible, place the GPS rooftop antenna so that it is under a "zone of protection" (as defined by the NFPA 780®) of a taller grounded metal object that will not reflect the GPS radio electromagnetic field (EMF). If this cannot be accomplished, a lightning rod nearby that provides a "cone of protection" may be necessary (see Figures 7-32 and 7-33). If a lightning rod is installed it needs a minimum 2 AWG down conductor that is tied to its own driven ground rod, which must (per Code) then be bonded to an existing ground electrode field (CO grounding system).

On some early installations of GPS antennas, the coax protector was located on the antenna mast. This protector could then be grounded in similar fashion as the mast. On most later installations, the coax protector is located near the building entrance point for the coax (typically a waveguide entry plate). It is most preferable if the protector is located external to the building (to prevent lightning from ever entering the building). In this case, the protector should be grounded to the nearest entry plate or entry plate ground bar), or have a separate exterior 2 AWG solid tinned bare copper lead run to the building ground electrode field (this lead should be separated during the vertical run down the side of the building from any NFPA 780® Lightning Protection System down conductor by at least 6 feet). It is also most preferable if the coax entrance is through the cable entrance facility for the site, or a waveguide entry plate. If the protector box is mounted inside the building, it should be located as close to the coax entrance as practical. It should also be grounded to the nearest COGB/OPGP, FGB/MGB "P" section, or CEF Ground Bar (with ground cable routing as far as possible from working equipment, and as close as possible to exterior walls). It should also have a 2 AWG solid tinned bare copper conductor that immediately leaves the building and connects to an external ground electrode field (preferably the existing one). When the existing ground electrode field(s) cannot be located, tie the down conductor from the coax protector to another existing down conductor or external ground electrode conductor as close as practical to the point where that conductor enters the earth. If that cannot be done, run the new down conductor on the outside of the building to a point close to the internal OPGP / PANI- MGB, go through the wall at that point, and attach to the OPGP. This will ensure that any surges brought in on this new down conductor will immediately go back out to the existing ground electrode fields tied to the OPGP.

For sites using an outdoor GPS antenna, some further things should be done to protect equipment inside the building from potential lightning propagation coming in from the GPS antenna. In these cases (of an external GPS antenna, especially one above the roofline), the best type of inside-the-office configuration is to have the GPS timing receiver shelf separated from the clock distribution (as opposed to integrated GPS receiver / timing distribution). In the case of separate receiver and distribution shelves/bays, propagation of potential lightning ingress further into the office can be limited by bonding the shield of the cable that goes between the two shelves to only one end.

Where the GPS receiver and timing distribution are integrated, then the shields of the timing cables serving the various network elements should have their shield grounded at the network element termination end (this may conflict with some Telcordia GRs and manufacturer manuals, but is by far the best protection against lightning propagation when an external GPS antenna is involved with an "integrated" GPS receiver / timing distribution setup).

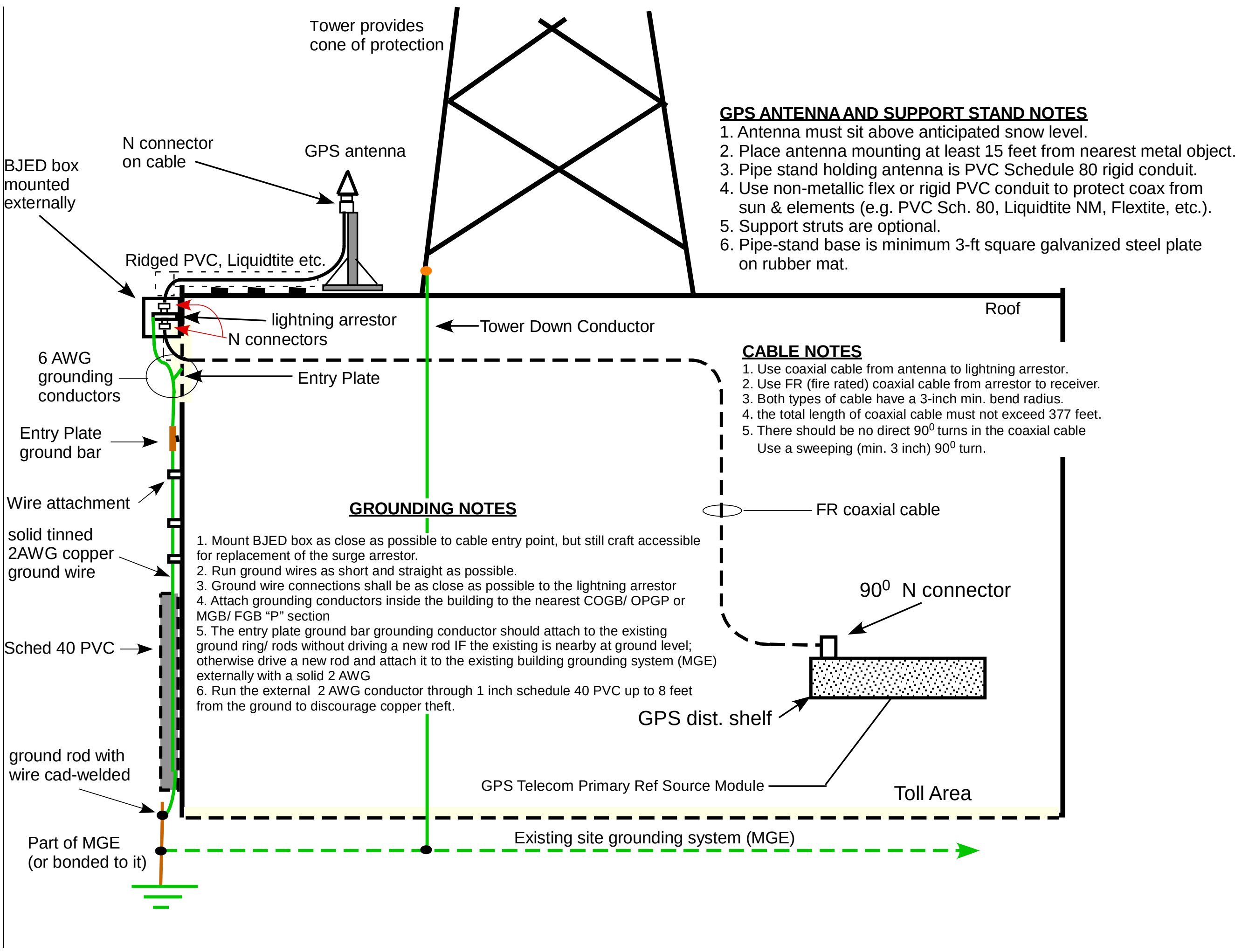


Figure 7-31: Rooftop GPS Antenna Grounding Detail

Figure 7-32: GPS Antenna Above Roofline Protected by Lightning Rod

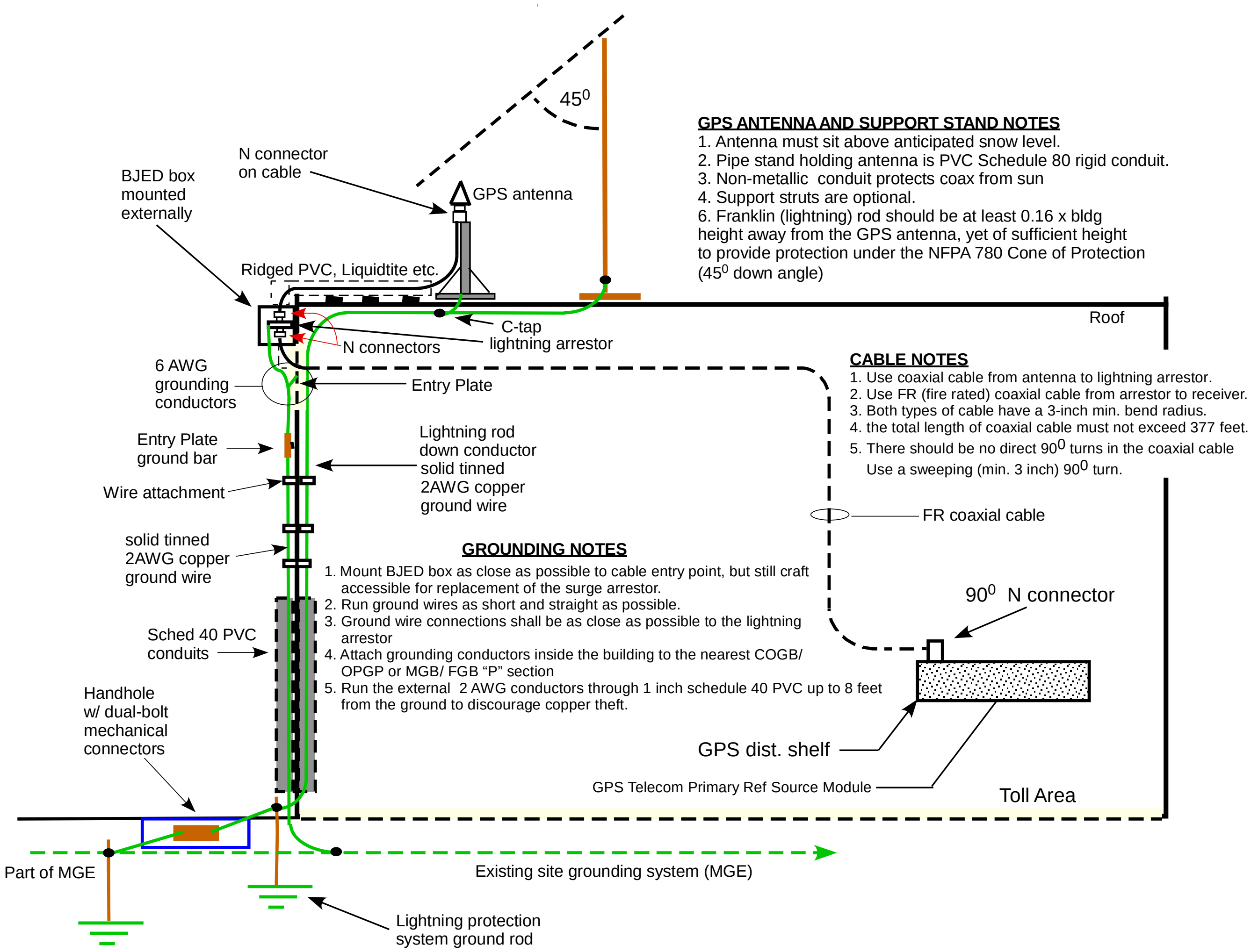


Figure 7-33: Rooftop GPS with Franklin (Lightning) Rod

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8. Isolated Ground

8.1 Isolated Ground Plane Principles

Note: Information in this chapter is generally specific to Central Offices built using the Telcordia “ground window” methodology. CO’s built using RUS “PANI” grounding standards are covered in chapter 9, section 9.9

8.1.1. Isolated Ground Plane(s)

An isolated ground plane is a set of interconnected frames that is intentionally grounded by making only one connection to a given ground reference. This plane, taken as a conductive unit with all of its metallic surfaces and grounding wires bonded together, is insulated from contact with any other grounded metalwork in the building. Current from faults in the AC or DC power systems should not circulate in the isolated ground plane because of the single-point connection. Similarly, fault current from a lightning strike should not circulate within the isolated ground plane. Some users and suppliers refer to an "isolated ground plane" as an " isolated ground zone”(IGZ) or an “isolated bonding network" (IBN).

8.1.2 Establishing a Ground Window

A ground window must be established to serve the isolated ground plane. The ground window is the interface between the building's integrated ground plane and a given isolated ground plane. It consists of a dimensional transition zone consisting of a sphere with a maximum 3 foot radius. A copper bus called the main ground bus (MGB), must be located within the ground window to provide a place for required connections. After bonding to the MGB in the "ground window", grounding conductors (not to be confused with return conductors) associated with the isolated plane are insulated from the integrated plane.(See Figure 8.1)

Three ground window plant configurations may be used with isolated ground plane(s):

A. A ground window developed from a DC plant with an insulated return bus. (See 8.1.3.4)

B. A ground window remotely located from the DC plant (remote ground window). (See 8.1.3.1.)

C. A ground window developed from a DC plant that does NOT have an insulated return bus. (See 8.1.3.5)

8.1.2.1 Dimensions

The ground window is a sphere with a maximum radius of 3 feet (a 6 foot diameter sphere which encompasses the MGB). Any connection to the main ground bus (on the integrated side) must be no greater than six conductor feet from the COGB 750 KCML integrated-isolated split point connection. (See Figure 8.1)

8.1.2.2 Location

The ground window can be located in the principal power plant as the battery return bar. It can also be located in a remote area as close as possible to the isolated ground plane it serves (remote ground window). Vertically, it must be no more than one floor from the isolated ground plane. Horizontally, the ground window must be no further than 100 feet (straight line distance) from the floor central office ground (CO GRD) or 100 feet (straight line distance) from the furthest member in the isolated plane. All equipment in the isolated ground plane must be no more than 200 conductor feet from the floor CO GRD bus.

8.1.2.3 Connections

The main ground bus must be configured to split the isolated and integrated ground connections within the ground window. Connections are based on the needs of the installation. Figure 8-1 and Table 8-1 show typical detail connections. The MGB can be thought of as the transition conductor between the integrated and isolated ground planes. The sequence of connections shown in Table 8-1 should be followed. Table 8-1 identifies conductor size and use as shown in Figure 8-1. All metallic connections between the isolated ground plane and the integrated ground plane must be made through the ground window MGB.

Note: The MGB within the ground window must be clearly identified by stenciling or other means. In addition, the MGB must be identified as to isolated and integrated ground connections.

8.1.3 Ground Window Configurations

8.1.3.1 Separate Ground Window

Requirements for this type of plant are covered in paragraphs 8.1.2.1 to 8.1.2.3 and Figures 8-9 and 8-11.

8.1.3.2 Using the Return Bus as the Ground Window

In some locations, it is practical to use the principal power plant's return bus as the ground window serving an isolated ground plane. Figures 8-10 and 8-11, respectively, show typical arrangements for insulated and non-insulated return bus plants. Three advantages can be realized:

- A plant that has a return bus connected to its frame can be used.
- The return conductors that provide power to integrated ground plane loads from a shared power plant can be run directly to the return bus because the return bus has become the ground window.
- The voltage stress that can build up between the return bus and the plant's frame is minimized when lightning or other fault currents flow in the building.

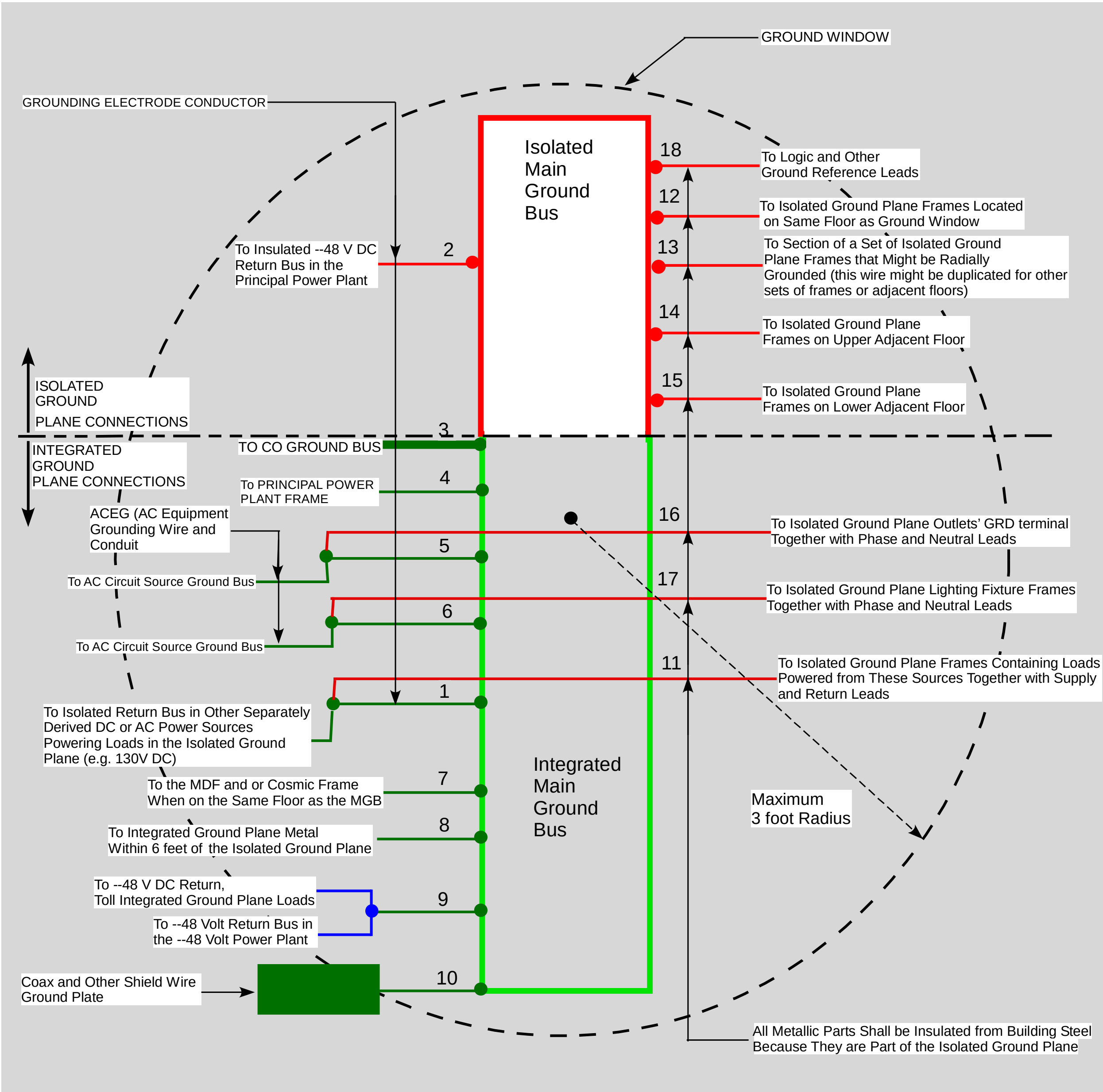
Note: Connections of battery return conductors for isolated ground plane loads are not considered to be located within the ground window.

As noted in Section 8.1.3.3 and in Figure 9-2, when the power plant return bus is used as the ground window, the plant must be located within one floor of the isolated ground plane.

8.1.3.3 Requirements for Both Kinds of Plants

The MGB must be located within 1 floor of all isolated ground planes. The location of the power plant in relation to the isolated ground plane or the MGB is unrestricted if a remote ground window is used. However, if the MGB and the plant return bus are common, the power plant must be within 1 floor of all isolated ground plane. Integrated equipment that might be powered from the same plant has no location restrictions. (See Figures 3-4 and 3-7)

In plants with a common return and charging bus, the charging leads from the rectifiers are connected to the isolated section of the bus (these connections are not shown on Figures 8-10 and 8-11).



NOTES

Lead numbers on this figure are listed in the Conductor identification column of Table 8-1.

Figure 8-1: Typical Sequence of Connections to a Separate Ground Window

Table 8-1: Tabulation of Typical Ground Window Connections

Conductor Identification (see Figure 8-6)		Can Conduct: Lightning Current		Can Conduct: Fault Current		Required in All Plants		Required in Some Plants (Yes)	Wire Size (AWG)
		Yes	No	Yes	No	Yes	No		
1	External Power Sources Grounding Conductors	x		x			x	x	6 AWG
2	Principal Power Supply Grounding Electrode Conductor		x	x		x			750 kcmil
3	Main Ground Bus to CO Ground (COGB) Connection	x		x		x			750 kcmil
4	Principal Power Plant Frame Ground Reference Wire for remote Ground Windows (tie all frames with a #6 AWG to the common conductor)	x		x		x			1/0: <50 ft 4/0: 50-100 ft 350: 100-150 ft 500: 150-200 ft 750: >200 ft
5 6	External Power Sources Grounding Conductors	x		x			x	x	12 AWG minimum 10 AWG for 2 AC ckts 6 AWG for 3 or more
7	Main Distributing Frame (MDF) and/or Cosmic Frame Protector Frames' Grounding Wires (only applies when this frame is on the same floor as the MGB)	x		x			x	x	1/0
8	Grounding Wires for integrated ground plane metal within 6 ft of isolated plane	x		x			x	x	6 AWG (for individual frames), or 2 AWG for collector bar/cable
9	Toll (Integrated Ground Plane) Loads –48V shared Return Leads	x		x			x	x	same size as load conductor (max 1/0)
10	Connection bar for coax shields and other shield wires connected to the isolated plane	x		x			x	x	6 AWG
11	Continuation of Grounding Conductor (and Conduit) from Associated External Sources		x	x				x	same size as the associated phases and neutral
12-15	Isolated Ground Plane Grounding Conductors		x	x		x			1/0 minimum
16 17	Continuation of Grounding Conductor (and Conduit) from Associated External Sources		x	x				x	same size as the associated phases and neutral
18	Logic and other "Quiet" Ground Reference Leads (sometimes required to be a continuous run)			x			x	x	per equipment vendor

NOTE: For lead 9 in Figure 8-1 and Table 8-1 (which represents multi-grounded integrated ground plane load –48 V return conductors), Table 8-1 states that the maximum bonding conductor size for these conductors (to bond them to the MGB as they pass through the ground window) is a 1/0 AWG. Due to length and load, sometimes the return conductors for a single load may be multiple cables. In the cases where there are multiple return conductors for a single load, the return conductors for that load can be H-tapped together and then bonded to the MGB with a single 1/0 (bonding jumpers do not need to be run to each return conductor of a particular feeder return).

8.1.3.4 Requirements for Plants with an Insulated Return Bus

All grounding and return conductors that can conduct lightning or fault currents should be grouped together along one section of the bus (integrated), and preferably in the sequence shown in Figure 8-1. All conductors within this section (marked on the Figure with a circular bracket as the ground window) should be 6 conductor feet or less. Return conductors that serve loads in the isolated plane should be grouped along the end of the bus (isolated side), out of the direct path of lightning or short circuit currents. Isolated DC return conductors and battery connections are technically not a part of the ground window, but because they connect to combination MGB/return buses, they are often contained within the 6 foot ground window sphere.

8.1.3.5 Requirements for Plants with a Noninsulated Return Bus

Lightning and short circuit currents can flow on the non-insulated return bus because the bus is connected to the plant's frame. If the return conductors serving the isolated plane loads were connected to this bus, dangerous voltage differences between these conductors could be generated when these currents flow.

A way to prevent this is to add an insulated auxiliary bus, and then make one connection to the return bus, as shown in Figure 8-11. This is equivalent to an insulated bus plant, because now the return conductors serving isolated loads can be connected to the new section on which no significant lightning current can flow.

Note: The single point connection between the isolated and non-insulated bus should be implemented with a bus assembly that has sufficient ampacity. If the bus assembly is impractical for some installations, paralleled conductors of equal ampacity and length assembled with abutting connectors are OK.

The sequence of conductor connections to the non-insulated and the insulated return bus is the same as described for an insulated plant.

8.1.4 Stored Program Control Frames

Most switching equipment requires an isolated ground plane. Examples include the Lucent 5 ESS®, and the Nortel DMS® family of switches. However, other switching equipment (e.g., DACS, some ATM switches, etc.) does not require an isolated ground plane. This decision is left wholly to the switch manufacturer.

However, unless it is known otherwise, it may be assumed that all of the frames that house a Stored Program Control Switching System (SPCSS) are normally treated as an isolated ground plane. Therefore, all document references to SPCSS equipment frames will normally assume that they are in an isolated ground plane (unless otherwise known).

Because an isolated ground plane switch manufacturer is most familiar with their switch and how to make it work properly, their own written requirements for grounding internal to the switch footprint supersede any Lumen requirements.

Figure 8-1 illustrates an isolated ground plane in its simplest form. A set of frames housing electronic circuits is initially insulated from all integrated ground planes. This includes building steel and all frames connected thereto. Then, a single point of connection is made through a ground window (also known as a Single-Point Connection Window or SPCW) from the electronic entity to the integrated ground plane.

When an SPCSS is treated as an isolated ground plane, external noise currents that could produce voltages, that damage and upset the system circuitry, cannot flow in the frames. Some sources of external noise currents are the following:

- Lightning strikes
- External power faults
- Filters that are connected from line to ground
- Multi-grounded AC and DC power sources
- Lightning protectors connected from line to ground
- Improper load connections

8.2 Interconnected Frames

Groups of frames within an isolated ground plane may be interconnected through the use of cross-aisle interconnections that join the frames of one frame lineup to the frames of a second frame lineup. Cross-aisle metallic cable trays, metallic power conduits, metallic cable shields, and deliberate cross-aisle bonds may be used to interconnect groups of frames within an isolated ground plane.

8.3 Serial, Radial and Mesh Grounding

Both serial (also known as Chain-IBN) and radial (also known as Star-IBN) forms of grounding in a set (or parts of a set) of frames in an isolated ground plane can be used. Judicious use of these techniques avoids the formation of loops (see Figure 8-2). Some switch manufacturers have even gone to mesh grounding within the isolated ground plane (which does create internal loops), but with a single "frame reference ground" connection back out to the ground window. This is still "single-point" or "isolated" grounding; and is within the rights of the switch manufacturer to decide how their switch must be grounded. They know what types of noise and currents to which their switch is susceptible.

8.4 Isolated Frame Grounding Methods

Figure 8-4 illustrates the overall frame grounding methods used in a typical telephone central office building and shows how the isolated ground plane fits into the total grounding plan for the building.

1. Install an Office Principal Ground Point Bus (see Office Ground Electrode in Glossary).
2. Install a vertical equalizer in the building to establish a low impedance path to earth reference. On each floor, connect a central office ground bus (CO GRD) to the vertical riser to form an effective earth reference. The distance between the vertical equalizer and the CO GRD must be 20 conductor feet or less.
3. Install the SPCSS and its associated processor as an isolated ground plane insulated from building steel. Then, make a planned earth reference to these frames by connecting grounding conductors from each set of frames to the serial, radial, or mesh bonding network that connects to the Main Ground Bus (MGB) within the ground window. Connect the MGB (also known as the Single-Point Connection Bus or SPCB) to the COGB on the same floor, completing the required connections.

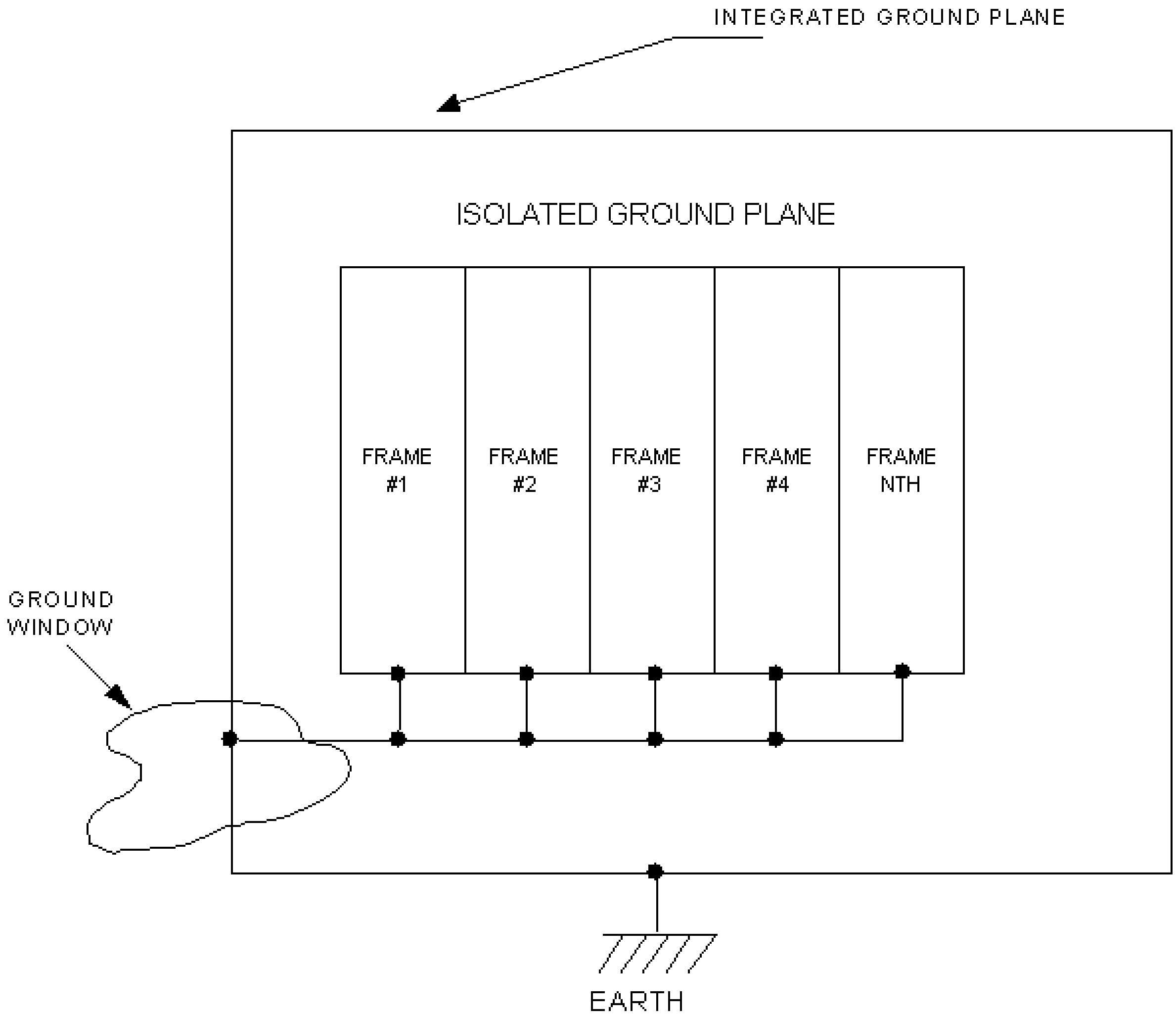


Figure 8-2: Simplified Isolated Ground Plane

When using Serial or Radial grounding (see Figure 8-3) do not add grounding conductors that would cause a direct connection between frame lineups (loop between frames). Caution must be taken to ensure that electrical connections which create loops are not inadvertently formed by grounded cable shields. In general, all low frequency (< 1 MHz) shielded wires within the CO should only be grounded at the termination end. Some older timing cables may be grounded at the source end, but it is required to ground them at the termination end (when the GPS timing receiver and the timing distribution shelf are integrated) to prevent lightning propagation into the office in sites with outdoor GPS antennas. For cables running between the isolated and integrated planes, the termination end is in the isolated plane.

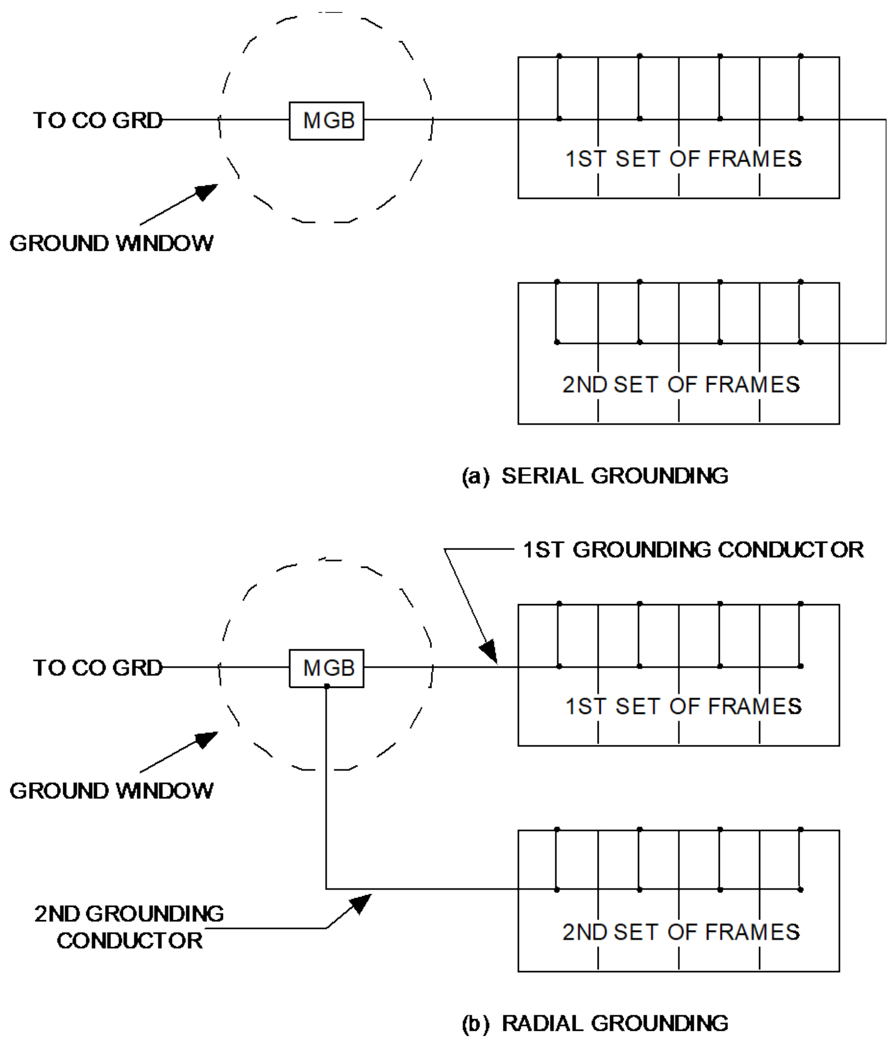


Figure 8-3: Simplified Examples of Serial and Radial Frame Grounding

Reliable frame to frame grounding connections must be made. Route a minimum 6 AWG bare (or insulated) stranded copper wire along each frame lineup. Using compression connectors, connect this "stringer" (with a similar wire) to each frame. If frames are painted, remove the paint at the point of conductor contact, clean all contact surfaces, and treat with a non-oxidizing agent. All connections to frames must be made with 2-hole copper crimp connectors (for existing, working switches that use single-hole connectors, it is not required to upgrade them to 2-hole due to the hazards that drilling could pose to the operation of the switch).

4.

Note: The principal power source serving the isolated ground plane must be associated with only one ground window. . More than one set of isolated ground plane frames may be served from a single ground window.

All ground connections from the SPCSS and processor frames going to the integrated ground plane must be routed through the ground window (the imaginary 3 foot radius sphere) and bonded (referenced) to the MGB. All metallic objects such as conduits, cable racks, armored cable sheaths, and grounding wires associated with these frames become a part of the isolated ground plane and must be isolated from the building integrated ground plane. All integrated grounds serving the isolated ground plane (AC conduit) must be routed via the ground window and bonded to the MGB. These units must be insulated from the building integrated ground plane once they have been routed via the ground window (and bonded to the MGB) toward the isolated ground plane.

The grounding cables in Fig. 8-4 provide fault current paths to permit operation of overcurrent protection devices (fuses and breakers) when ground faults occur between DC "hot" leads and the frames. They do not normally carry load current.

8.5 Power Supply Grounding Methods

Generally, all power sources serving an isolated ground plane shall be single point solidly grounded. Exceptions to this rule are as follows:

- When the principal power source has a return bus that is not insulated from the plant's frame and this bus is used as the ground window, three advantages can be realized provided that an insulated auxiliary return bus is added as shown in Figure 8-11:
  - A plant that has a return bus connected to its frame can be used if it is designated as the ground window.
  - The return conductors that provide power to integrated ground plane loads from a shared power plant can be run directly to the return bus because the return bus has become the ground window.
  - The voltage stress that can build up between the return bus and the plant's frame is minimized when lightning or other fault currents flow in the building.
- Return conductors serving integrated ground plane loads (e.g., radio and non-switched circuit equipment) from the same power plant that serves the isolated ground plane loads are permitted to multi-ground the power source at the loads housed in the integrated ground plane if those return conductors are routed through the ground window and bonded to the MGB.

8.6 Multi-grounded Power Source

Generally, multi-grounded power sources (i.e., sources with one load current carrying member grounded at more than one point in length) shall not be used to power isolated ground plane loads (see exceptions listed in paragraph 8.5).

8.7 DC Power Supplies

All DC power supplies located in an isolated ground plane shall be single point grounded.

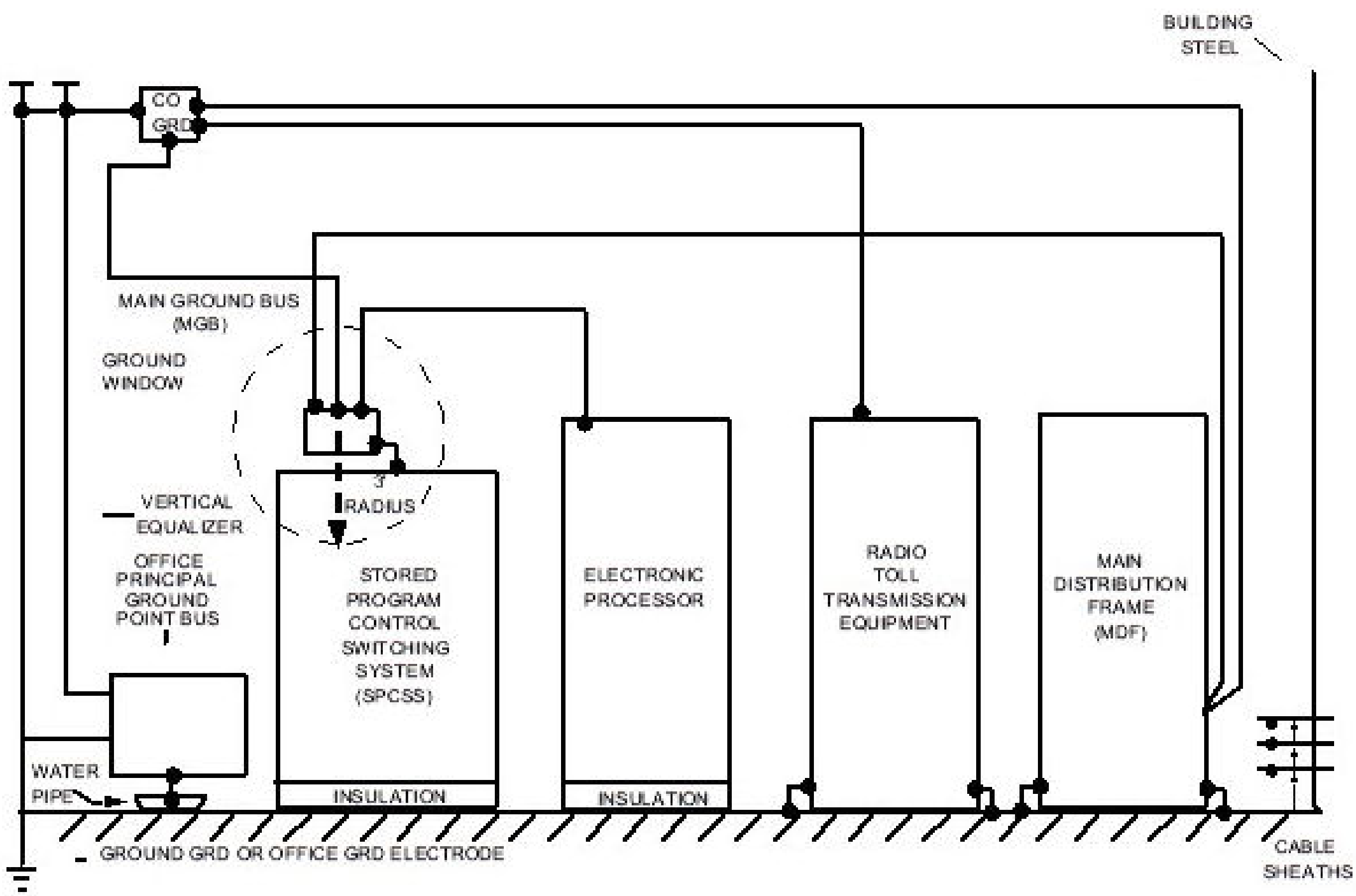


Figure 8-4: Typical Overall Frame Grounding Methods

Grounding Locations:

- The return side (usually the positive bus) of the principal power source shall be grounded to the OPGP with a separate 750 kcmil grounding conductor. Only one grounding conductor is required for each DC power system. When rectifiers are added or retrofitted to a DC power plant, it is not necessary to place an additional 750 kcmil grounding conductor. For integrated/isolated offices, the 750 kcmil conductor should terminated on the integrated ground window associated with the isolated ground plane at the point closest to the isolated ground plane. (see Figure 8.6) For PANI-MGB offices, the 750 kcmil conductor should terminate on the main DC return buss and the N portion of the PANI-MGB. For DC plants whose load is never expected to exceed 600 Amps, this reference conductor is allowed to be as small as 1/0 AWG. The principal power source is classified as an external power source. If the positive bus is designated as the ground window it must be grounded with a 750 kcmil to the CO ground bar (this reference conductor is allowed to be as small as 1/0 AWG for DC plants whose load is never expected to exceed 600 A). If the DC plant serves only integrated ground plane equipment, its return bus still needs a reference to the nearest COGB/FGB or OPGP / PANI- MGB. The sizing rules for this conductor are based on typical power plant and site size for the different types of sites. Section 5.4.1 specifies requirements for CO plants serving only integrated ground planes.
- Other external DC power sources (such as 130 volts DC) serving the isolated ground plane must be grounded only at the ground window in the same manner as the principal power source. (Other grounding requirements for DC systems over nominal 50 Volts are covered in NEC® Article 250.160.)
- Internal DC power supplies (usually DC to DC converters and rectifiers) shall be grounded at the nearest internal reference ground bus.

Return Conductors — Return conductors are the grounded conductors in DC power supplies. They shall not be used as grounding conductors.

Power Distribution Cabinets (PDCs) used to distribute DC power to the isolated ground plane loads must be part of the isolated ground plane.

8.8 AC Power Supplies

All separately derived AC power supplies shall be grounded in accordance with Article 250 of the NEC®.

Safety Requirements — All component parts used in the AC power distribution system serving the isolated ground plane system shall be listed by a National Recognized Testing Laboratory (NRTL) such as Underwriters Laboratory (UL®)and wired in accordance with the current National Electrical Code (NEC®). **Raceways** — All AC branch circuits serving the isolated ground plane shall be housed in metallic raceways from source to load. Each raceway shall be joined to form a continuously electrically conductive grounding path. This rule applies to circuits that have metallic contact with isolated ground plane frames, not those that pass within 6 feet of the isolated plane (foreign object grounds). However, because of the number of integrated ground plane members the AC raceways (and other FOG raceways) pass, and the fact that they are typically out of human reach (up in the overhead racking area), it is not necessary to FOG ground all of the integrated members that an AC raceway attached to a FOG ground passes while in the integrated area.

AC Equipment Grounding (ACEG) Conductor — An ACEG conductor shall be provided in all raceways housing AC circuits from source to load. This conductor shall be insulated and identified with a green color.
<u>ACEG Requirements</u>:

- All grounding conductors and metallic raceways associated with external AC power that feed loads within the isolated ground plane must be routed through the ground window and bonded to the MGB.
- All grounding conductors shall be electrically connected to each junction box that they pass through, and to those on which they terminate.
- Mechanical connectors are not allowed for ACEG conductors inside the isolated equipment.

  Note: A junction box refers to a pull-box outlet/receptacle box, or any similar metallic enclosure.

Single Point Grounding of AC Power Supplies — All separately derived AC power systems shall be grounded at their immediate outputs and only at that one point. Beyond the immediate output, the grounded conductor (usually called the neutral) shall not be grounded at any other point along its entire length.

General Purpose Outlets — Every outlet (receptacle) mounted in the isolated ground plane and intended for general use shall be the standard type that connects its grounding terminal to its frame. Isolation outlets (marked isolated or orange colored, or with an orange triangle, as described in NEC® 406.3 (D) (1) and (2)), are prohibited except when extending from an existing isolation outlet.

8.9 General Isolated Grounding Conductor Requirements

Grounding conductors shall be used only to ground power supplies and frames. They shall not be connected in parallel with battery return conductors unless it is an expansion of an older existing Class 4 or Class 5 SPCSS that was designed that way. The size of the grounding conductors shall be as specified by the SPCSS supplier. In no case should the DC grounding conductors be smaller than a 6 AWG wire or equivalent. DC grounding conductors used to ground frame members of the isolated ground plane can be bare or insulated. All other conductors must be insulated.

Generally, DC grounding conductors may be run near each other regardless of the equipment they are grounding. However, in rare cases, a switch manufacturer may specify that certain grounding conductors in the isolated ground plane be segregated. In these cases, the switch manufacturer and the installation vendor must clearly mark those runs that must be segregated for noise or other reasons.

Armored cable containing a bare bonding strip to decrease sheath resistance shall not be used as an equipment ground conductor.

8.10 Induction Effects

Induction effects on the isolated ground plane should be minimized by avoiding the formation of inductive loops and by routing lightning and fault current carrying members in paths that are as far away as practical from the isolated ground plane.

8.10.1 Loops in the Isolated Ground Plane

Paragraphs 8.4 and 8.11.5 must be followed to avoid forming large area inductive loops (see Figure 8-5) among the grounding conductors of the isolated plane. Do not use the so-called "-48 V return horizontal equalizing conductors" where the -48 V return bus in each DC distribution cabinet (PDC) is sequentially connected from PDC-to-PDC to form a completed inductive loop, with the last PDC bus connected to the first.

In an integrated ground plane, loops may be unintentionally formed. If a switch manufacturer does not require an isolated ground plane, loops are allowable. Internal loops in the isolated plane are also allowable if the switch manufacturer has specified mesh bonding of their frames. Follow the switch manufacturer’s guidelines for internal grounding.

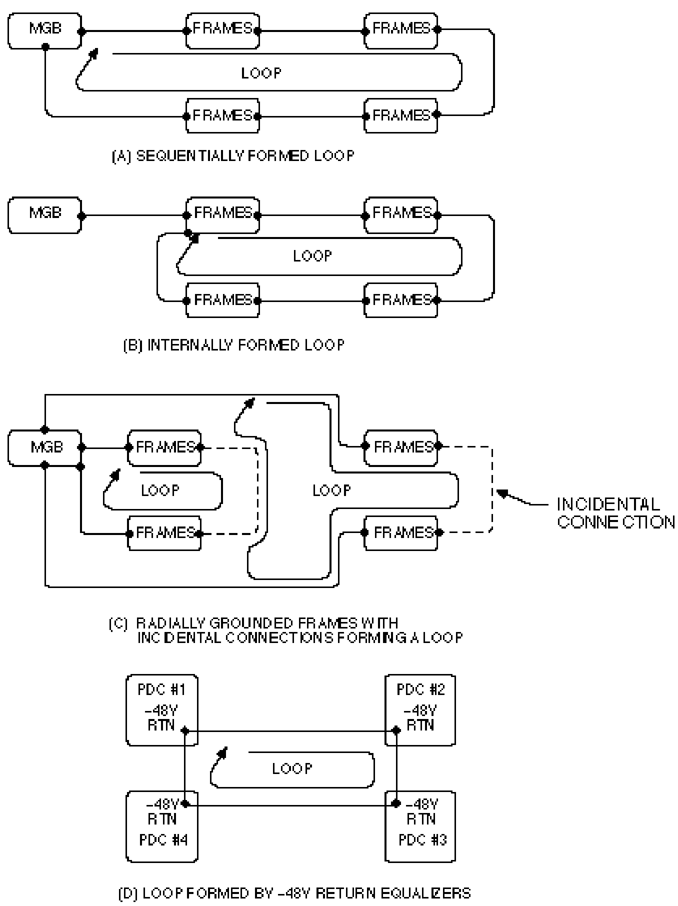


Figure 8-5: Loops (Isolated Ground Plane)

8.10.2 Lightning and Fault Current Carrying Members

The following types of conductors must be routed a minimum of six feet from the boundaries of the isolated ground plane:

* The grounding conductors from the ground window and the CO GRD to the main distributing frame (see Figure 8-4).
* Wave guides and coaxial cables from tower mounted antennas.
* Metallic raceways from other systems.
* Cables coming from other external antennas (such as GPS, wireless, etc.).

8.10.3 Nearby Integrated Ground Plane Frames

All integrated ground plane conductive members located within six feet of the isolated plane shall be bonded to the integrated collection bar (ICB)/foreign object ground (FOG) to reduce shock hazards to personnel and minimize surge potential differences between members of the two planes. Equipment frames may also be bonded to the CO GRD system, although this is not required; nor is it required to individually connect each equipment frame to the ICB/FOG system. A connection to a lineup stringer is sufficient. This includes structures supporting the ICB/FOG.

In the RUS PANI concept, door frames within 6 feet of an isolated ground plane (including MAP rooms) are grounded to the "N" section of the MGB. (see Figure 8-6)

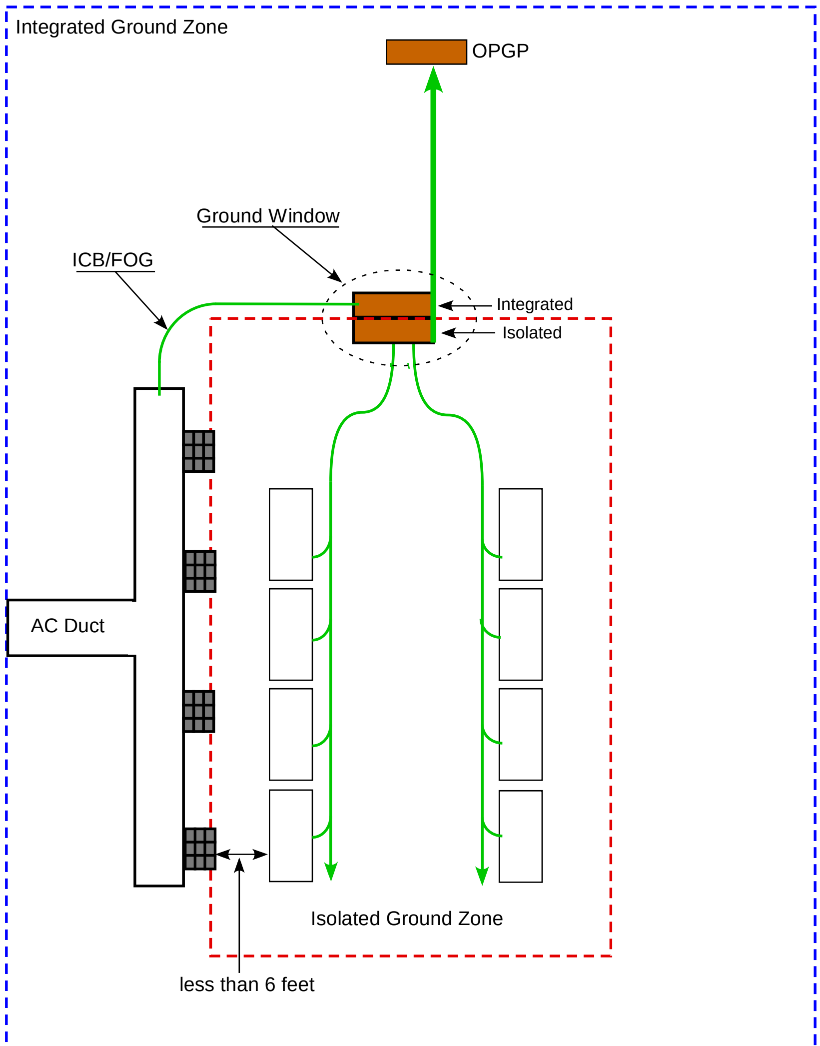


Figure 8-6 ICB/FOG Grounding

The bond to the ground window (integrated section) can be accomplished by running a minimum 2 AWG to the area and bonding all metallic components with 6 AWG, or by installing a collector bar (FOG, ICB) where bonding of all components can be accomplished.

Such frames include:

- Metallic stands and desks
- Plug in Card (PIC) cabinets (Additional information for PIC cabinet grounding can be found in section 9.11)
- Equipment frames
- Miscellaneous Iron (auxiliary framing, metal conduits, air-conditioning duct, cable racks, etc.); which can achieve continuity between separate parts by incidental metal-to-metal contact (e.g., sheet metal screws are OK as long as the resistance between connections is less than 0.1 ohms — otherwise remove the paint/galvanization, etc.)
- Lighting fixtures that are not part of the isolated ground plane
- Air ducts
- Metallic raceways from other systems

8.11 Isolating Ground Plane Frames (Specific Requirements)

8.11.1 Specific Requirements

The set of frames designated as the isolated ground plane must be one conductive unit. All of its metallic surfaces and grounding conductors must be bonded together with planned electrical connections. Incidental grounds are not permissible. Lighting frames, receptacle housings, end guards, raceways, and other peripheral parts of the isolated ground plane must be part of the one conductive unit.

8.11.2 Insulation Resistance

All frames that are part of the isolated plane must be installed in a way that insulates them from the integrated plane (building steel and other metallic parts attached to it). Before any ground window or power connections are made to the isolated ground plane, and after all fastening hardware is installed, the insulation resistance between the isolated and integrated ground planes must be verified to be 100,000 ohms or more (see Section 8.20.3 for isolation test methods), and preferably greater than 2 megohms. The isolated ground plane must be isolated from the building's integrated ground plane. Insulators must be installed between metalwork and concrete which are common to the integrated ground plane and the isolated ground plane . Typical fastening points include the following:

- **Anchor Bolts** — Isolated ground plane anchor bolts might touch grounded structural metal in the floor. Therefore, these bolts must be insulated from the isolated ground plane.

- **Bottom of Frames** — If there is any possibility that the bottom of the frames in the isolated ground plane come in contact with structural metal, concrete floors, or floor tiles, insulating material must be placed between the frames and floor.
- **Superstructure Supports** — Superstructure supports to the isolated ground plane, where used, must be insulated.
- **Lighting Fixtures, etc.** — Lighting fixtures, raceways, and cable racks that are part of the isolated plane must be insulated from the integrated ground plane.

8.11.3 Frame to Frame Connections

Reliable frame to frame bonding connections can be made in several ways. Two typical ways are described here:

- Route a minimum 6 AWG bare or insulated stranded copper wire along each frame lineup. Using crimp type connectors, connect the bonding wire to the lug supplied on each frame.
- Some SPCSS utilize a bare copper bus connected to each frame, interconnect each bus section with a crimped, braided strap. The cross sectional area of the bus and the braid must be equal to or greater than 6 AWG stranded copper conductor (about 0.027 square inches).

8.11.4 Grounding Among Groups of Frames

It is possible to ground a group of frames in an isolated ground plane by either of two basic methods:

1. The preferred method deliberately avoids the formation of frame ground loops within the isolated ground plane.
2. A method that deliberately permits the interconnection of groups of frames in such a way that numerous frame ground loops are formed.

NOTE: Unless specified by the equipment manufacturer, ground loops must be avoided in the isolated ground plain.

The size of the grounding wire used between groups of frames and the MGB must be a minimum of 1/0 AWG.

8.11.5 Serial and Radial Connections Within the Isolated Plane

Both serial and radial grounding connections are permitted from the ground window to sets of frames within an isolated ground plane. When the radial grounding technique is used, the following criteria must be met:

- No additional grounding wire connections that would cause an inductive loop to be formed should be made between the radially grounded sets (see Figure 8-5).
- If digital carrier transmitter or receiver circuits are within the respective radially grounded sets of frames, then these circuits should have their outputs isolated to avoid closing an inductive loop.
- Electrostatic shields that might be used to enclose interconnecting wires between radially grounded sets should be grounded to the frame at only one end
- Magnetic shields that may be used to enclose interconnecting wires between radially grounded sets should be run close to the frame grounding conductor. The shield itself should pass through and be connected to the ground window.

8.11.6 Limits on the Number of Floors an Isolated Ground Plane can Occupy

Limits on the number of floors an isolated ground plane can occupy is as follows:

- A given isolated ground plane must not occupy more than three adjacent floors.
- Each isolated ground plane must only be served by one ground window and one power plant. The ground window must be located in the middle floor of the three consecutive floor configurations.

8.11.7 Peripheral Equipment Frame Grounding

Peripheral metallic equipment frames (e.g., printers, metallic desks, video and hard copy terminals, etc.) should be connected with grounding conductor(s) to the isolated ground plane (see Section 8.10.3 for a more complete list) and should be treated as if they were an integral part of the isolated ground plane.

- AC or DC power for these loads must come from sources within the isolated ground plane or from sources routed through the ground window, as per paragraph 8.16.
- The grounding conductors associated with these power sources must be used to extend ground reference to the peripheral equipment's frame without contacting the integrated ground plane.
- Peripheral equipment grounded in this manner must be within one floor of the ground window serving the isolated ground plane.
- Peripheral equipment located more than one floor away from the ground window serving the isolated ground plane must not have any metallic grounding connections to the isolated ground plane members.
- If this type of equipment must be treated as an isolated ground plane, it is desirable to power it from the same principal power source through input/output isolated DC-to-DC converters.

- A second ground window on the "secondary" side of the DC-to-DC converters can then be established to ground the peripheral equipment frames. This second ground window must be located within one floor of the peripheral equipment, but the ground windows must not be bonded together within the isolated ground plane.

Note: It is desirable that isolation techniques, such as optical fiber or back-to-back modems be used between the peripheral equipment and the isolated ground plane frames, thus enabling the peripheral equipment to be grounded as part of the integrated ground plane and to be powered from commercial AC.

8.12 Principal Power Plant Grounding Requirements

The power plant frame serving an isolated ground plane is not part of the isolated ground plane it serves.

8.12.1 The Return Bus

In most cases, the return bus (usually the positive polarity side of the system) in the power plant is insulated from the plant's frame.

Note: The return bus referred to in this publication is sometimes called the -48 volt return bus, the battery return bus, or the ground return bus. For an exception to this rule, refer to paragraph 8.19.5, Requirements for Plant with a Noninsulated Return Bus.

8.12.2 Grounding the Return Bus

The return bus in the power plant must be grounded to the MGB (isolated) within the ground window with a 750 kcmil conductor.

8.12.3 Grounding the Plant's Frame(s)

For personnel safety, the plant's steel framework (distribution and rectifier bays) shall be grounded at the nearest ground reference (often the CO GRD located on the same floor) with a grounding conductor sized per section 5.4.1. Where a remote ground window is used, an additional frame-grounding conductor shall be installed between the plant's framework (all distribution and rectifier bays) and the main ground bus within the remote ground window. This conductor must follow the path of the plant's ground reference conductor for remote ground windows (see Figures 8-8 and 8-9).

A single conductor can be used for bonding multiple frames of the power plant (similar to aisle stringers). A separate single conductor may be used to reference all the DC plant PBD frames. Both grounding conductors should be terminated on the integrated side of the MGB in the ground window per Figures 8-8 and 8-9. However, they should both be independent from the ground reference conductor for the return bus (per NEC® 250.168).

8.12.4 Location of the Power Plant

The location of the power plant with respect to the isolated ground plane is not restricted providing the -48 volt return bus in the plant is not used as a ground window (see paragraph 8.19.2).

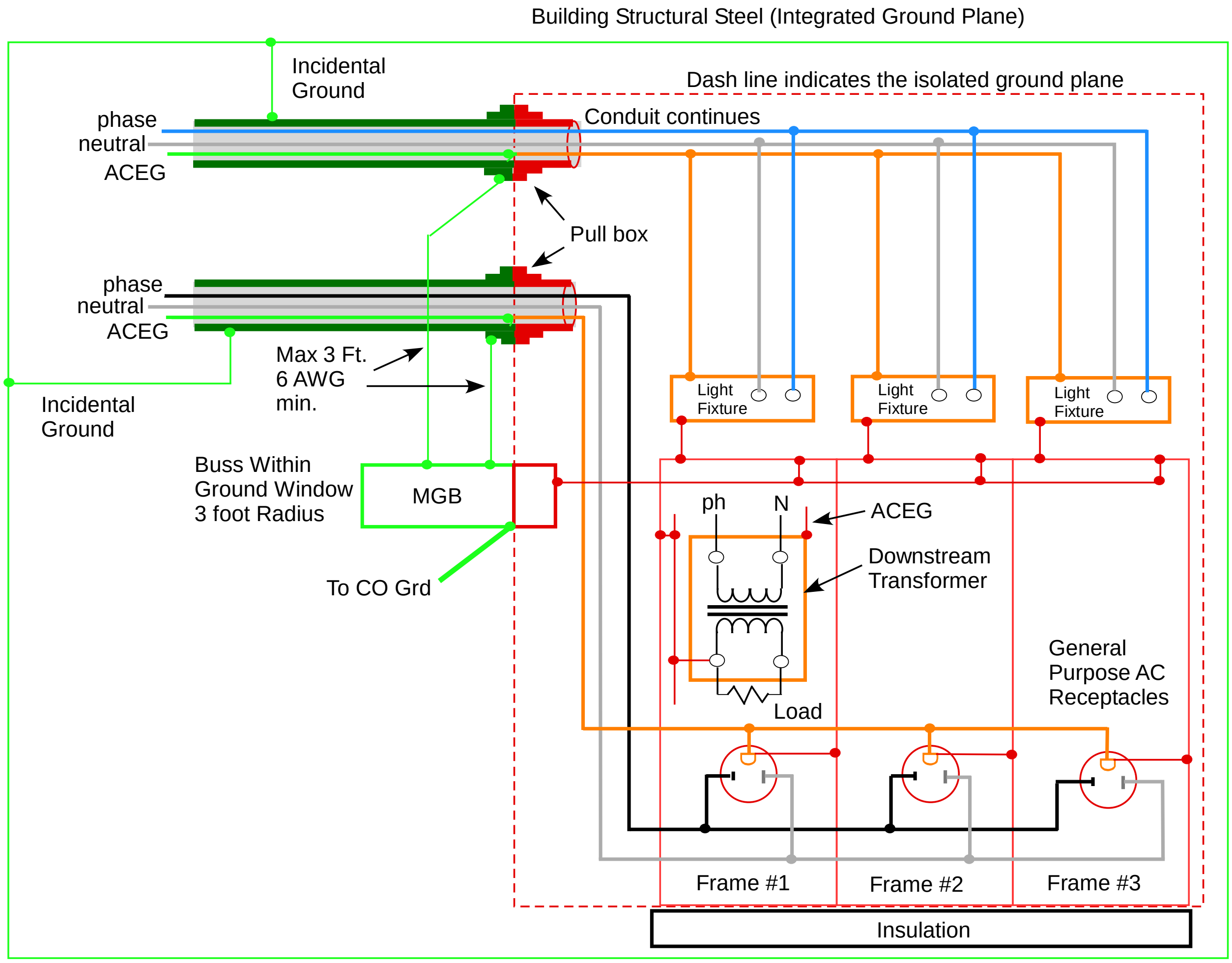
8.12.5 Power Feeders to the Isolated Ground Plane Equipment

The power feeds from the principal power source should be run to each PDC (or equivalent since different switch manufacturers give this secondary distribution point different names). The power conductors must be routed in close proximity to each other along with the plant's grounding electrode conductor and frame grounding conductor. At the PDC, the "hot" conductor and the return conductor shall be insulated from the frames. The return conductors must be run directly to the main DC return buss and must not be terminated on the remote ground window.

Power feeders to integrated ground plane loads, run from a power plant that serves both isolated and integrated ground planes, must have the return conductors pass through a remote ground window and be bonded to the MGB (see Figure 8-8 and Table 8-1). For this situation, special exceptions to the pairing rule mentioned in the previous paragraph are allowed (see Lumen/ CenturyLink Technical Publication 77385, Section 8.6 for further detail).

Note: In the case where a remote ground window is used, the downstream equipment or BDFB return is also bonded to the nearest COGB.

In addition, exceptions to this rule are allowed for separately derived (isolated) power sources. For example, the return conductor of DC feeds to isolated output DC-DC converter plants, inverters, and ring plants do not have to be bonded to a remote ground window.



NOTES

(1) Light fixtures are shown as part of the isolated ground plane for illustration purposes only. It is recommended that light fixtures be part of the integrated ground plane.

(2) Often, all AC conduits entering the isolated plane run through a common junction box near the MGB, necessitating only one connection from this box to the MGB.

Figure 8-7: Typical Grounding and AC Power Feed to an Isolated Ground Plane

8.13 Integrated Ground Plane Loads

Integrated ground plane loads fed from the same principal DC power source that supplies the isolated ground plane loads must be examined to determine if powering such loads adds multiple grounds to the battery return conductor. If the battery return conductor is multi-grounded at the distribution point or at the loads themselves, it must then be routed via the ground window and bonded to the main ground bus (MGB) before it is run to the return bus within the power plant. The length of the bonding conductor must be no longer than three feet (the size of the bonding conductor is specified in Table 8-1). The battery and return conductors must be paired to the greatest extent practicable between the power plant and the equipment being powered (see the previous section 8.12.5 for additional information on pairing and bonding of integrated ground plane loads fed from a plant that also serves isolated ground plane loads).

Note: In some older installations, the return conductors actually terminated on and/or passed through the MGB instead of being bonded to it. In these cases, it must be ensured that the cable between the MGB and the –48V plant return bus is the 750 kcmil conductor specified in Table 8-1. If this cable is carrying excess current (greater than 300 A) or is hotter than 115°F, more cables may need to be added.

Note: Multi-grounding occurs if the return conductors to these loads have not been insulated from the integrated ground plane frames along their entire length.

Examples:

- A local power distribution bay in the integrated ground plane whose return bus is connected to its frame and ground referenced to CO Ground (BDFBs will normally be multi-grounded).
- Loads in the integrated ground plane that have a common return connected to the frame in which they are mounted.
- Wiring options in plugs and connectors that interconnect the case and the return conductor

If the power conductor serving integrated ground plane loads is not multi-grounded anywhere along its length or at the load, it must not pass through the ground window or be connected to the MGB.

Example: The input power feed to separately derived power supplies, such as 130 volt converters or 120-volt inverters whose output serves integrated ground plane loads.

Note: Inverters installed in the isolated ground plane must not power loads outside the isolated plane.

8.14 Loads Fed from Internal Power Sources

Power distribution sources within the isolated ground plane, typically only power isolated ground plane loads; and powering of integrated ground plane loads from these sources is usually strongly discouraged. However, when integrated ground plane loads, fed from power sources internal to the isolated ground plane, multi-ground the return conductors, these return conductors must be routed through and connected to the MGB within the ground window before they are connected to the power source return bus.

8.15 Grounding Internal DC and AC Power Supplies Within the Isolated Ground Plane

Separately derived AC and DC power supplies shall be single-point grounded by making a connection from the conductor on the output that is designated to be grounded to the nearest appropriate ground reference bus. This grounding conductor shall not be used to conduct normal load current. The grounding location shall be at the immediate output of the power supply. Loads should be powered with separate pairs of conductors, and the frames containing the loads shall be grounded.

Note: The grounded conductor of the input power to a separately derived source (e.g. the AC neutral or the -48 volt return lead) must not be connected to any frame. This violates the single-point ground of these power sources.

8.16 Grounding the External AC and DC Power Supplies Feeding Isolated Ground Plane Loads (Other Than the Principal Power Source)

8.16.1 DC Power Supplies

These power supplies shall be grounded in the same manner as the principal power source. That is, a separate grounding conductor (sized correctly as shown in Figure 8-1 and Table 8-1) shall be run from the grounded side of the supply's output to the MGB within the ground window. Load conductors must be run in pairs and be closely coupled.

8.16.2 AC Power Supplies

AC power supplies, grounded at the source as described in paragraph 8.15, must be routed through the ground window. Each grounding conductor and raceway associated with each supply must be connected to the MGB within the ground window with a conductor that is no longer than three feet (these connections and wire sizes are shown in Figures 8-7 and 8-9).

All AC raceways running beyond the ground window toward the isolated ground plane shall be insulated from the integrated ground plane and from any incidental grounds. Where required, a separately derived dedicated AC power supply located and grounded at the ground window may be used.

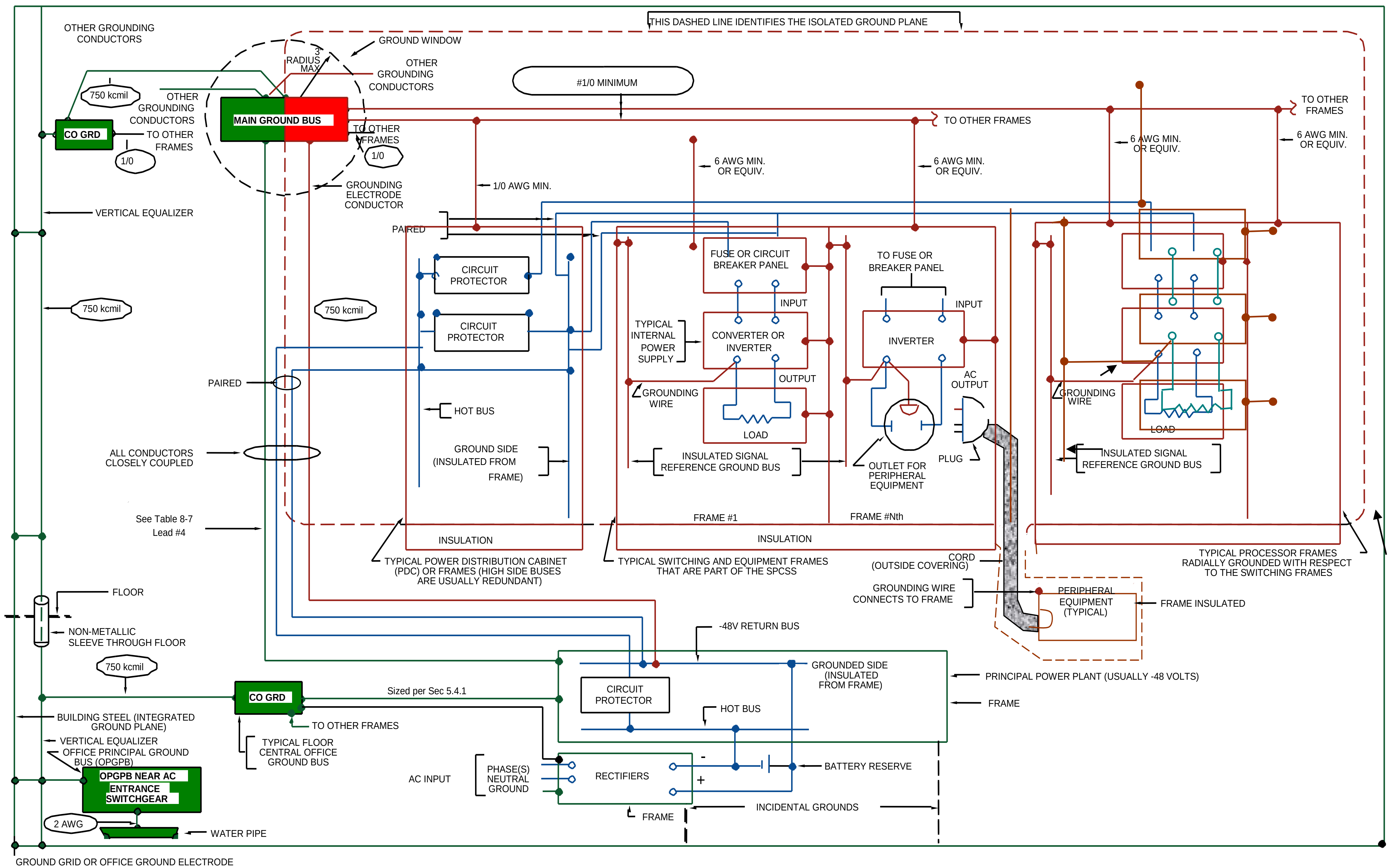
8.16.3 Treatment of the AC Conductors

The AC neutral shall not be connected to the MGB. Within the isolated ground plane, AC power conductors shall be run in separate metallic raceways that do not contain DC conductors.

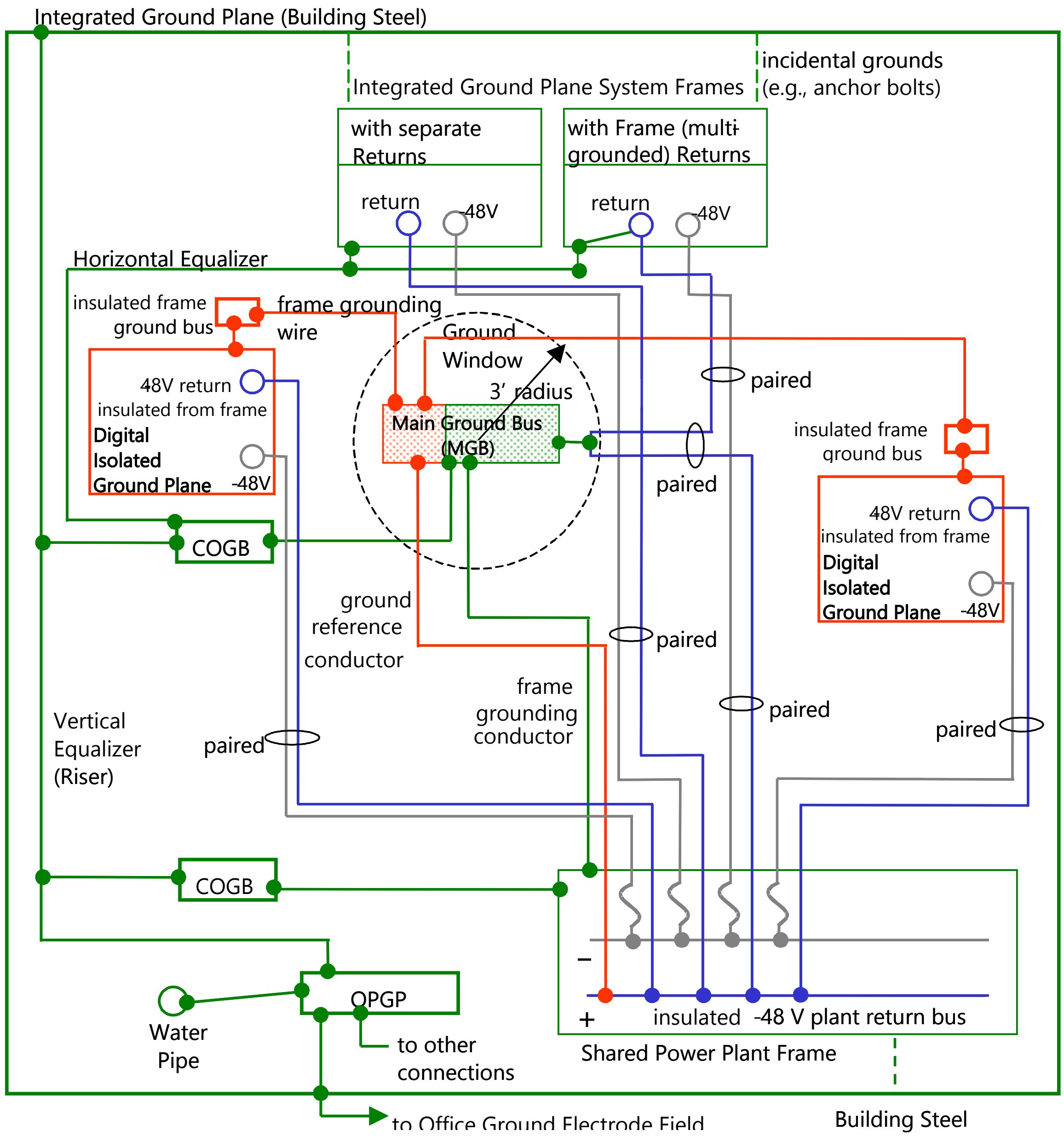
8.17 Specific Examples of AC and DC Grounding Principles for Isolated Ground Planes

Figures 8-7 and 8-10 illustrate the AC and DC grounding requirements of this document. The dashed line in each of the figures identifies the boundaries of the isolated ground plane. The figures show the grounding of frames and power sources and indicate grounding conductor sizes. They also show AC and DC power distribution to the extent that it relates to meeting the grounding requirements. Power to loads that are not part of the integrated ground plane, such as lighting fixtures, are not shown.

Figure 8-8: Typical Grounding and Power Feed from a DC Power



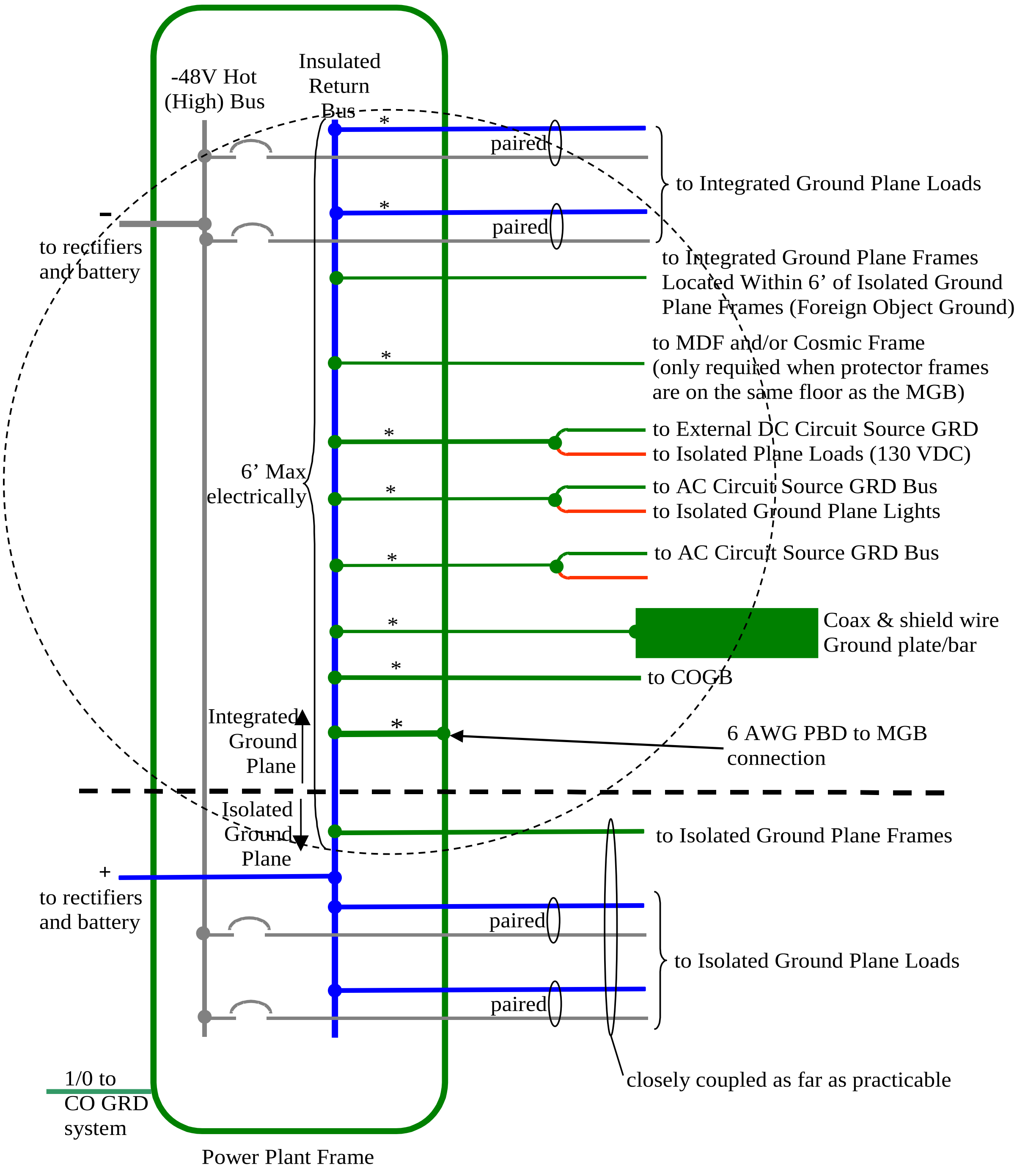
Plant Powering Isolated Ground Plane Loads



NOTE:

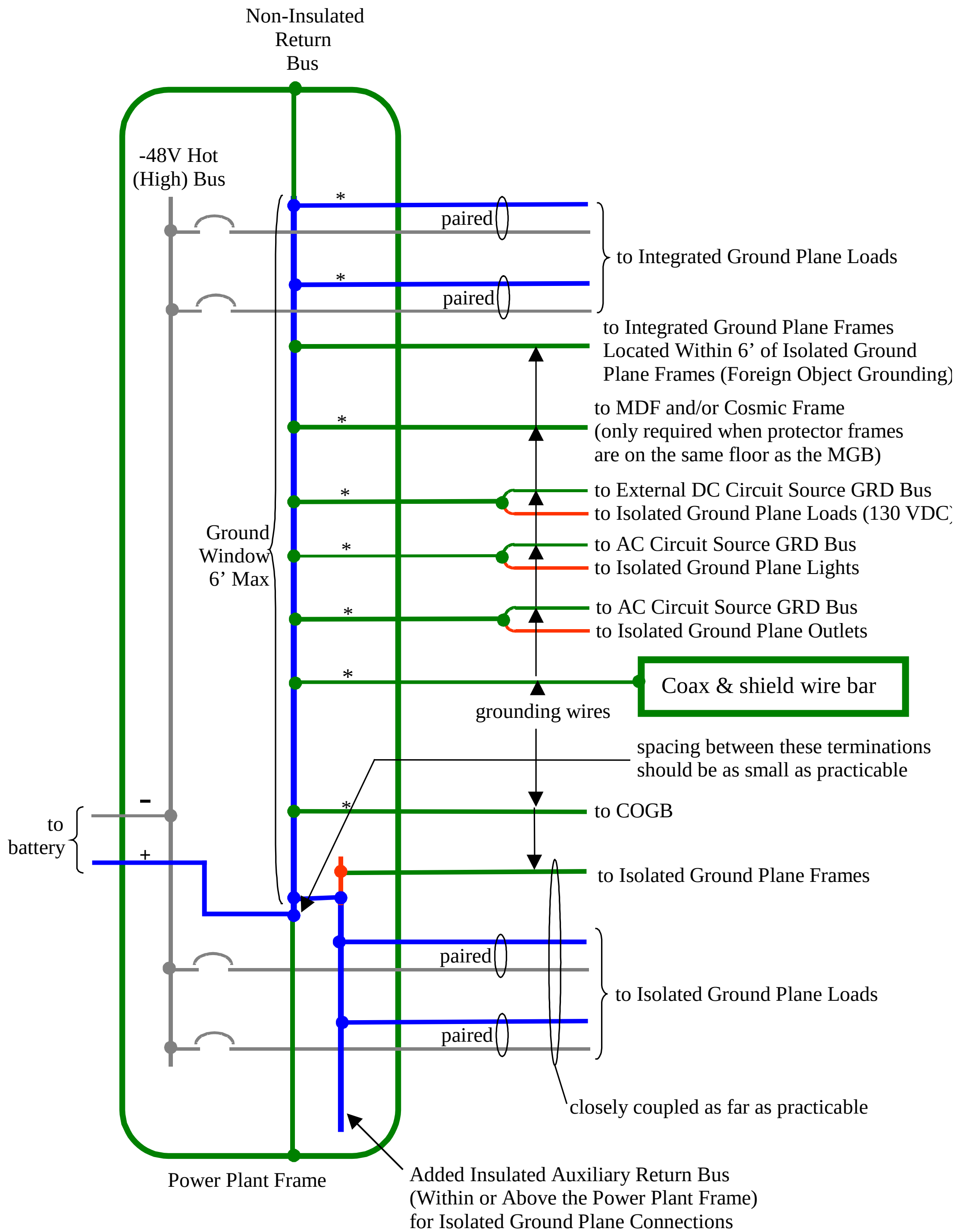
All Isolated Ground Planes Must Be Within One Floor of the Ground Window

Figure 8-9: Grounding for Integrated and Isolated Ground Planes Powered from a Common Power Plant



* Indicates Wires that Can Conduct Lightning or Fault Currents Into and Out of the Ground Window

Figure 8-10: Using an Insulated Return Bus as the Ground Window



* Indicates Wires that Can Conduct Lightning or Fault Currents Into and Out of the Ground Window

Figure 8-11: Using a Noninsulated Return Bus as the Ground Window

8.18 Outline for Establishing an Isolated Ground Plane

The procedures listed below must be followed to meet the objectives of this publication:

- Install and assemble the isolated ground plane frames as a single conductive unit.
- Test the insulation resistance between the installed frame assemblies and the building integrated ground plane before making any external connections. Resistance must equate to 100,000 ohms or more when 500 volts DC is applied.
- Establish a ground window within one floor of the isolated ground plane.
- Make all required connections to the MGB within the ground window that involve grounding of external power supplies, grounding of frames, connections to certain return conductors, and connections to AC power grounding conductors. (Also, connect all integrated ground plane members within 6 feet of the isolated plane to the MGB per the guidelines in Section 8.10.3.)
- Run paired power leads from the principal power plant to each PDC (or equivalent) in the isolated ground plane that are closely coupled to the plant's frame and system grounding conductors. Do not connect return conductors to the main ground bus in the ground window unless the power return bus is used as the ground window.
- Run other required external sources of power to the isolated ground plane. The grounding conductors associated with each of these sources must be routed through the ground window and bonded (tap-connected) to the MGB.
- Ground the output of all internal power supplies and frames as required herein.
- Connect peripheral equipment to the isolated plane as required per this document.
- Run required pre-power tests.
- , Do not power up the equipment. until all these conditions have been satisfied

8.19 Performance Verification and Test Procedures

Note: All instrumentation used in the tests described in this section must have a readout accuracy within a tolerance of 5 percent.

8.19.1 Visual Test

Visually inspect the isolated ground plane for observable violations such as loose connections, improper conductor sizes, and improper or poor connections.

Conduits and cable racks that have become part of the isolated ground plane by being routed through the ground window and connected to the MGB must not be in contact with any other metallic elements of the integrated ground plane.

Peripheral equipment frames that are part of the isolated ground plane must not be in contact with any metallic elements of the integrated ground plane.

Peripheral equipment that is part of the isolated ground plane must be powered from sources within the isolated ground plane.

Internal and external power supplies shall be checked to see that they are grounded as required.

8.19.2 External Power Supplies

All DC power supplies serving an isolated ground plane switch must be grounded at the MGB within the ground window.

All separately-derived AC power supplies originating outside an isolated plane, but serving an isolated plane must:

- be grounded at their immediate output
- have ACEG and metallic conduit bonded to the ground window MGB integrated side.
- have metallic conduit isolated within the isolated ground plane.

Isolating (orange triangle-marked) receptacles are prohibited unless it is an extension of an existing isolating orange-triangle convenience outlet system.

8.19.3 Internal Power Supplies

All internal power supplies shall be grounded at the signal reference bus (see paragraph 8.15)

Ground Window Conductors - Verify that all required conductors are connected to the ground window per Figure 8-1 and Table 8-1.

Confirm the following:

- Wire size
- Two-holed crimp connectors
- Tightness of connections
- Conductors are stranded copper
- Application of a conductive anti-oxidant compound
- Condition of the connecting surface
- Separation of integrated and isolated ground connections

Note: Not all anti-corrosion compounds are conductive. Only products that are listed as conductive are acceptable to use where an anti-oxidant compound is required.

Listed Label and Wiring - Each AC power system component (i.e. inverters and AC equipment) in the isolated ground plane must be checked to ensure that it is listed by a Nationally Recognized Testing Laboratory and labeled. All AC wiring must be in accordance with the NEC®.

Internal Power Supply Loads - Check to determine that the load conductors are properly paired and that the return conductor is not connected to the MGB within the ground window.

Continuity Test - Check all raceway fittings and frame parts for continuity. Insulated fittings in raceways and painted connection surfaces are not permitted.

Inverters in the isolated plane shall only feed loads in isolated ground planes.

8.19.4 Insulation Test

Each frame (or group of frames) that is part of the isolated ground plane must undergo the following insulation tests after being secured to the floor. This must be done before connecting any power or grounding conductors to the isolated ground plane. These tests ensure that the necessary isolation has been achieved . When growth frames are added, these tests must be done before the frame is connected to the adjacent frame or overhead cable rack system.

Low-Voltage Resistance Test - Connect a low-voltage ohmmeter between each frame (or group of frames) and the MGB within the designated ground window. Measure the resistance. The resistance reading must be 100,000 ohms or greater.

High-Voltage Resistance Test - If the frames pass the low-voltage resistance test, connect a 500-volt megohm meter between the lower part of each frame (or group of frames) and the MGB within the designated ground window to measure the resistance. The resistance must be 100,000 ohms or greater, and preferably greater than 2 megohms. Test the lower part of the frame instead of the upper part to prevent equipment damage if the insulation breaks down.

The “isolation” and insulation of an existing isolated ground plane can alternatively be tested with a clamp-on resistance meter (CORM). Using procedures found in Telcordia BR 802-010-100® (or the CORM manufacturer's documentation), radial conductors to the isolated frames can be tested. They should read high resistance (open circuit). This method can even be used on individual frames that are not mesh bonded.

8.20 Isolated Ground Plane Noise Circuit Test

8.20.1 Abnormal Current Flow in Grounding Wires and Frames

While the telecommunications systems are operating, clamp-on ammeters that can detect AC and DC current flow (in the range of milliamps to Amperes) may be used to search for and help eliminate noise current flow in all grounding conductors and reference buses. As a general rule, no more than 5 A DC or 100 mA AC total should be flowing to or from isolated switch frame grounds (in aggregate) or logic grounds, and it should normally be much less than that (no more than 1 A DC on any individual lead). Older switches were usually radially frame and logic grounded, whereas with modern switches, the frames (or logic) grounds are often mesh bonded within the isolated plane. When testing for current in a mesh bonding isolated system, care must be taken to ensure that each frame or logic ground conductor going to the MGB is measured.

8.20.2 Correctly Wired Circuit Arrangements

To meet Federal Communications Commission (FCC), Electro-Magnetic Interference (EMI), and Radio Frequency Interference (RFI) requirements, various types of filters (from feed-through capacitors to complicated pi-connected types) are used. All or part of each filter is often connected from the line to a frame, completing a circuit that causes current to flow in the frames. To avoid such currents, it is desirable to connect these devices from line-to-return conductor rather than line-to-frame.

If portions of the filter still must be connected from line-to-frame to meet FCC requirements, the shunting devices to the frame should be closely inspected to determine the highest impedance it can have while still performing the filtering functions.

A single filter must not inject more than 3.5 milliamperes (AC or DC) into a frame.

8.20.3 Testing Improperly Wired Circuit Arrangements

The following circuit arrangements must not exist within the isolated ground plane:

- Multi-grounded AC and DC power sources – This test concerns downstream interconnections between the AC neutral and the ACEG, or between the -48 volt DC return and the equipment frame.
- This test will help determine if the source(s) are multi-grounded by making a low-voltage measurement on an operating circuit between the neutral/ return conductor of the source and a nearby frame downstream from the point at which the power source has been properly grounded. If the AC/DC voltage measured is less than 0.1 V, multi-grounding generally exists. If the voltage measured is greater than 0.1 V, then it is unlikely that multi-grounding exists. This test should be performed at the following locations:
    - **Testing AC Circuits:**
        - At selected general-purpose receptacles on the frame
        - At the AC input to lighting fixtures that are part of the isolated plane
    - **Testing DC Circuits:**
        - At the PDC
        - At the input to a converter
        - At the input to an inverter
        - At connector wiring that permits connecting a strap between the -48 volt return conductor and the frame ground

8.20.4 Overvoltage Protectors

All AC and DC overvoltage protectors should be connected from the supply to the neutral/ return conductor(s). When an overvoltage protector is incorrectly connected from the supply-to-frame, current is injected into the isolated ground plane. Therefore, the supply to-frame connection shall not be used.

In cases where downstream circuit insulation could be stressed by overvoltage conditions that appear between the return conductor and the frame, an additional protector should be placed between the return conductor and the frame. Thus, with two protectors connected, one from supply-to-neutral/return and the other from neutral/return to frame, no current is injected into the isolated ground plane.

8.20.5 Improper Load Connections

DC Loads that are wired between line and ground (rather than between line and return conductor) inject large amounts of DC current into the isolated ground plane. (see section 3.8 for a description of DC-C) This type of load wiring shall not be used.

When any AC or DC current is found flowing in any of the grounding conductors, it is an objective that the above circuit violations be investigated, located, and corrected.

8.21 Distributed DC Power Plants in the Isolated Ground Plane

Small, distributed DC power plants may be placed in the isolated ground plane switch footprint instead of power distribution cabinet (PDC)s. There are 3 cases where this can be done:

1) small switch needing only 1 PDC or distributed power plant
2) large new switch with multiple PDCs or distributed power plants
3) existing switch with multiple PDCs and a remote ground window

NOTE: In very unique circumstances, a distributed DC power plant may be used within the isolated ground plane, however, this practice is not recommended.

If the switch is small enough to need only one distributed power plant, the distributed plant can be placed and function like a PDC.

- It must be isolated from the floor like any isolated ground plane bay.
- The plant should be equipped with an external return bus (tied to the internal returns) functioning as a ground window.
- The external AC feeds for the rectifiers must run through the window and have the conduits and ACEG conductors bonded to the integrated side of the MGB.
- Nearby (within 6 feet) metallic objects that are part of the integrated plane must also be bonded to the integrated side of the MGB.
- The frame ground of the plant is a 1/0 conductor terminated on the isolated side of the MGB.

Just like all other MGBs, this one is connected to the nearest COGB with a 750 kcmil cable. No frame ground should be run directly to a COGB (the fault path must be through the MGB).

If a small switch fed from a distributed plant outgrows its capacity, or a large switch is placed to be fed from distributed power:

- Only the first plant has an external ground window.
- Each successive distributed plant in that isolated ground plane does not have an external return. Instead, its internal return bus is ground referenced to the original MGB (isolated side) with a 1/0 cable (in addition to the frame ground 1/0 that must also be run from this bay to the MGB).
- The AC conduits and ACEGs feeding the additional distributed power plants must be run through the ground window and bonded to its integrated side. After that point, the conduits must be insulated from contact with integrated ground plane members as they travel towards their power plant in the isolated plane.
- Existing switches fed from centralized DC plants should generally not use distributed power plants for growth. More importantly, they cannot be used at all unless there is a remote ground window. In those cases, the new distributed plant will not have its own external return bar but will connect to the existing remote ground window (isolated side) from their return bar with a 1/0 conductor (in addition to the frame ground 1/0).
- Feeding AC conduits and ACEGs must also be bonded to the MGB integrated side.

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9. Grounding Methods

9.1 Frame Grounding

Figure 8-4 illustrates the typical overall frame grounding methods used in a digital and/or remote central office building. It shows how the isolated ground plane fits into the total grounding plan for the building. The following framework grounding arrangements, detailed below, are applicable to all digital installations:

- All isolated ground plane equipment frameworks must be insulated from contact with integrated ground plane conductive elements in the building. This includes, but is not limited to, metallic objects, floors, and walls.
- The Power Distributing (PD) cabinets (these have different names depending on switch manufacturer; such as PDF, PDC, etc.) shall be bonded directly to the MGB within the ground window with a 1/0 conductor (this does not mean that each individual PD frame must have its own direct connection to the MGB — they can be simply connected to a 1/0 serial or radial stringer).
- All other equipment frames or cabinets must be bonded by a 6 AWG copper conductor to a grounding conductor that is routed along the top of each equipment lineup.
- Isolated ground plane equipment lineups must be interconnected with a minimum 6 AWG copper conductor to a frame ground bar or a grounding copper conductor (typically a 2 AWG lineup feeder or “stringer") which are bonded to the MGB within the ground window.

9.2 Conductor and Connection Requirements

Grounding conductors are not intended to carry load currents. They shall conduct line to ground fault and lightning currents only. The impedance of any particular grounding conductor path shall be low enough to permit at least ten times the rated current of the circuit's associated protective device (See NEC® 240.21 (C) (2)) to flow when line-to-frame faults occur. The calculations that determine the impedance that meets this condition shall be based on the longest possible fault current path and the lowest working circuit voltage applied. All fault-path conductors must be large enough to carry the required fault current without thermal damage to the conductor.

The grounding conductors must be routed in paths that are as short and straight as possible, without any sharp changes in directions. If the direction must change, it must do so gradually with a minimum bend radius of 8 inches (12 inches is desirable) and a bend radius not exceeding 90 degrees. The grounding conductors must be run exposed (visible and accessible).

Connections to grounding conductors should be made, as shown in Figure 9.1 , so that any fault current on the conductor flows toward the ground source wherever possible. See NEC® 250.4 (A) (5)

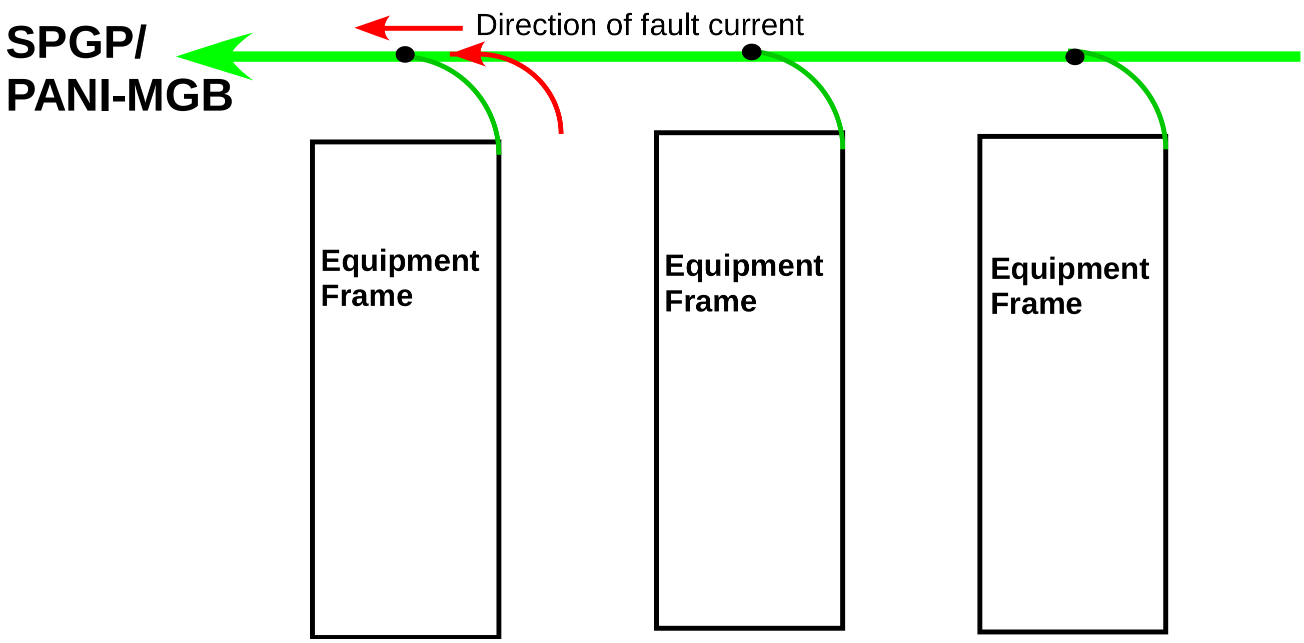


Figure 9.1 Preferred Grounding Conductor Installation for Fault Current

Single grounding conductors (conductors that do not have associated phase [hot] or neutral [return] leads) shall not be run in metallic enclosures. Furthermore, the metallic clamps used to hold down grounding conductors shall not completely surround the wire (some exceptions are allowed — see Section 9.2.1). Examples of this type of conductor are vertical equalizers (illustrated in Figure 8-4) and the AC power grounding electrode conductor (illustrated in Figure 8-8). These types of conductors passing through the floor of a building must be enclosed in nonmetallic sleeves for mechanical insulation and fire prevention.

DC Grounding conductors (as opposed to the grounded return conductors) must not be run on cable racks. Cables 1/0 and smaller may be secured to the side of cable racks, run on hangars, or any other approved method that makes them visible, as detailed in section 5.7 of Lumen/ CenturyLink Technical Publication 77350. Generally, DC grounding conductors may be run near each other regardless of the equipment they are grounding, unless specifically prohibited by an equipment manufacturer.

All ACEG conductors shall be insulated and identified with a green color. The size of the ACEG shall be in accordance with NEC® Tables 250.66 (for ground electrode conductors) and NEC® 250.122 (for equipment grounding conductors). It is preferable that ACEG splices are done with compression connections; however, they are governed by the NEC®, and not held to the same strict standards as the DC grounding system.

All splices, joints and the free ends of conductors shall be covered with an insulation equivalent to that of the conductors or with an insulating device suitable for the purpose. Non-conductive coatings (such as paint, lacquer, and enamel) on equipment to be grounded must be removed from threads and other contact surfaces to assure good electrical continuity.

Conductors must be lightly coated with an appropriate conductive anti-oxidant compound before crimp connections are made. All un-plated connectors, braided strap, and busbars must be brought to a bright finish (bringing a busbar to a "bright finish" includes removing any oxidation by lightly cleaning it with a non-conductive abrasive product). Tinned or silver-plated connectors and other connection surfaces do not have to be cleaned in this manner. All raceway fittings shall be tightened to provide a permanent low impedance path.

Note: Not all anti-corrosion compounds are conductive. Only products that are listed as conductive are acceptable to use where an anti-oxidant compound is required.

Multiple conductors are permitted only in a bus arrangement when two single conductors are placed on opposing sides of the busbar using a 2-hole bolted connection. The stacking of two or more connections under the same bolt assembly and on the same side of a busbar is prohibited.

9.2.1 Girdling

Girdling refers to the encirclement of single grounding conductors by a ring of ferromagnetic metal. This occurs in these typical situations:

- Steel frames and cover plates used where conductors pass through holes in floors
- Steel cable-hole liners and conduit used where conductors pass through floors or walls
- Steel conduit used for physical protection of conductors
- Steel rings used for supporting conductors

An induced voltage appears along the length of conductors when they carry lightning surge currents. Ferromagnetic girdling contributes an additional (undesired) induced voltage; however, new calculations, which include this effect, indicate that the increase in magnitude of the induced voltage is much less than previously thought. Experiments support this result.

The recommendations pertaining to girdling are as follows:

- Steel frames (up to 6 inches high), and cover plates used at floor or wall penetrations (where the frame is less than 8 inches in depth into the wall or floor) contribute negligibly to induced voltage and may be used without restriction.
- At locations where grounding conductors pass through walls and floors, nonmetallic liners or conduits are preferred. If metallic liners are used, aluminum is the preferred material. Steel liners and conduit, in lengths up to 3 feet, may be used where necessary. Where grounding conductors in conduit greater than 3 feet already exist, conduits must be end-bonded. "End-bonds" between the conduit and the conductor must be made and the bond jumper size must equal the size of the enclosed conductor per NEC® 250.64E, 250.66, and 250.104C. Because of their larger diameter, metallic liners contribute less induced voltage than conduit, so bonding to liners is not required. Where fire codes require metallic liners, a metallic liner with an insulating gap is preferred.
- Applications where a steel conduit encloses a single grounding conductor should be avoided, nevertheless, bonding of the conduit to the grounding conductor at both ends is still required for conduits greater than 3 feet. Bond using a pipe clamp and a conductor sized the same as the enclosed conductor or having an equivalent cross-sectional area as the conduit metal).
- Fully closed steel supporting rings may cause significant induced voltage when the rings are closely spaced (e.g., at 12-inch intervals), therefore steel rings must be avoided unless gapped with a fiber bolt. Rings of nonmagnetic material are preferred. Fiber rings, PVC rings, Steel J-hooks or other similar devices are acceptable grounding conductor supports.

9.3 DC Power System Grounding for Power Distributing Centers (PDC's)

The battery return busbar(s) of the PDC cabinet(s) (or similarly named switch secondary distribution points) is electrically isolated from the PDC framework. Splice plates located above the PDC's may serve as a convenient terminating point for the DC power return leads, which are generally large, since they are governed by voltage drop restrictions. A number of smaller leads, sized for ampacity, may be run directly to the individual discharge apparatus within the PDC frame. The use of splice plates is not a requirement. For small installations in which the power plant is located in close proximity to the digital switch, the primary battery distribution feeders may be run in pairs directly to the PDC frame. For installations which require two or more PDC's or where the power plant is located at a distance, which makes it necessary to use large or multiple conductors to meet voltage drop constraints, splice plates are required.

9.4 Power Plants located in the Isolated Ground Plane Which Power Equipment in the Integrated Ground Plane

The following is required when an isolated battery return (DC-I) DC power plant

(located in the isolated ground plane) is used to power both the Digital switch and transmission and miscellaneous equipment that is located in the integrated ground plane:

- A ground window should be established at a convenient location for connecting both the AC conduit serving the isolated ground plane and the DC distributing return leads serving the integrated ground plane equipment. There should be no more than one floor separation between the ground window and the digital switch (see Figure 8-9).
- A physical separation of 6 feet should be maintained between isolated ground plane frameworks and the frameworks of integrated ground system equipment, when possible, to avoid the possibility of personnel contact between the two.
- A grounding conductor must be connected (referenced) between the digital switch framework and the MGB within the ground window.
- A dedicated 750 kcmil grounding electrode conductor shall connect the power plant battery return bus to the MGB within the ground window. The primary battery distribution feeders shall be run in pairs and closely coupled directly to the PD(C)s of the digital switch.
- The Main Ground Bus of the ground window must be bonded to the CO GRD bus or OPGP (whichever is easier) on the same floor with a 750 kcmil conductor.
- The DC power plant framework, metallic battery stands, miscellaneous frames in the PBD lineup, and rectifier cabinets must be bonded to the CO Ground bus on the same floor. The power plant framework must also be connected to the MGB within the ground window
- To assure positive operation of overcurrent protection devices within the DC power plant, in the event of a battery plant frame fault, sizing of the conductors will vary depending on the length and ampacity and should run directly from each DC distribution frame to the MGB within the ground window (refer to Figure 9-2).

9.5 Ground Window

The ground window (also known as the Single-Point Connection Window or SPCW; or in the case of some Lumen Consumer or Enterprise sites, a GWB extension from the I section of the PANI master ground bar) is a dimensional transition zone consisting of a sphere with a maximum 3 foot radius. This is the interface between the building's integrated ground plane and a given isolated plane. It is the point where all AC and DC grounding conductors (including metallic raceways) serving an isolated ground plane have their last connection to the building's integrated ground plane before they are connected to the isolated ground plane frames. Any bond or connection to the main ground bus (MGB) must be within three conductor feet of the center point of the sphere (see Figure 8-7). Any number of individual isolated equipment subsystems may exist in an isolated plane and can be referenced to a single ground window. After passing through the "window" and being bonded to the MGB, all of the grounding conductors (not to be confused with return conductors) associated with the isolated plane are insulated from the integrated plane because they have electrically become a part of the isolated plane. Conductors serving integrated ground planes that utilize a common return side of the principal power source (DC-C) and are powered from the isolated power plant serving the isolated plane must be routed through and connected to the MGB within the ground window. See Section 8.1.2 through 8.1.4 for detailed instructions regarding ground windows.

Figure 9-2 illustrates the maximum number of floors over which one or more isolated switches served by a common DC power plant may be located. It also shows a method of bonding used to form a common ground plane that is isolated from the integrated plane, except for a single bond connection to the CO GRD bus on the center floor.

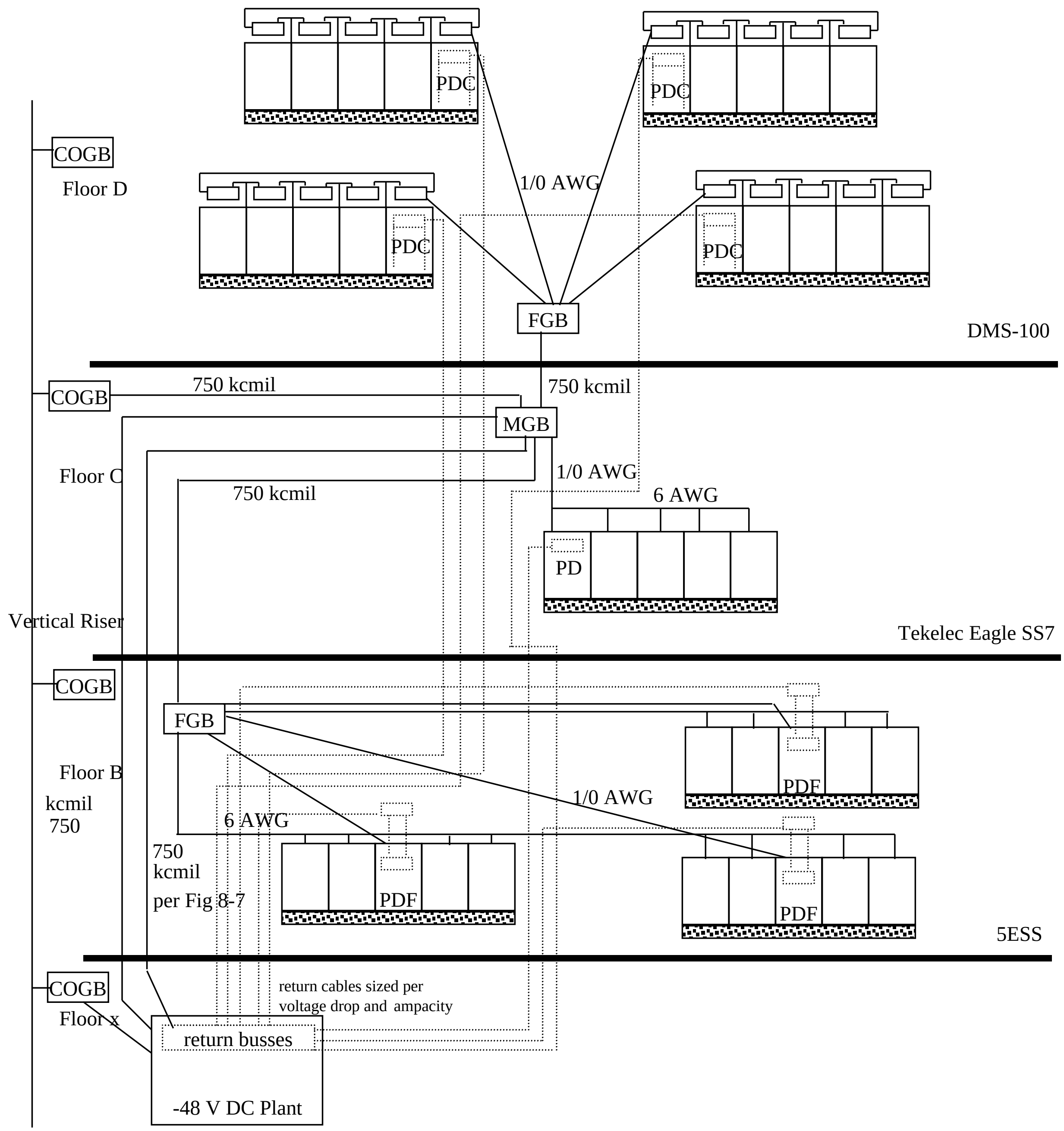
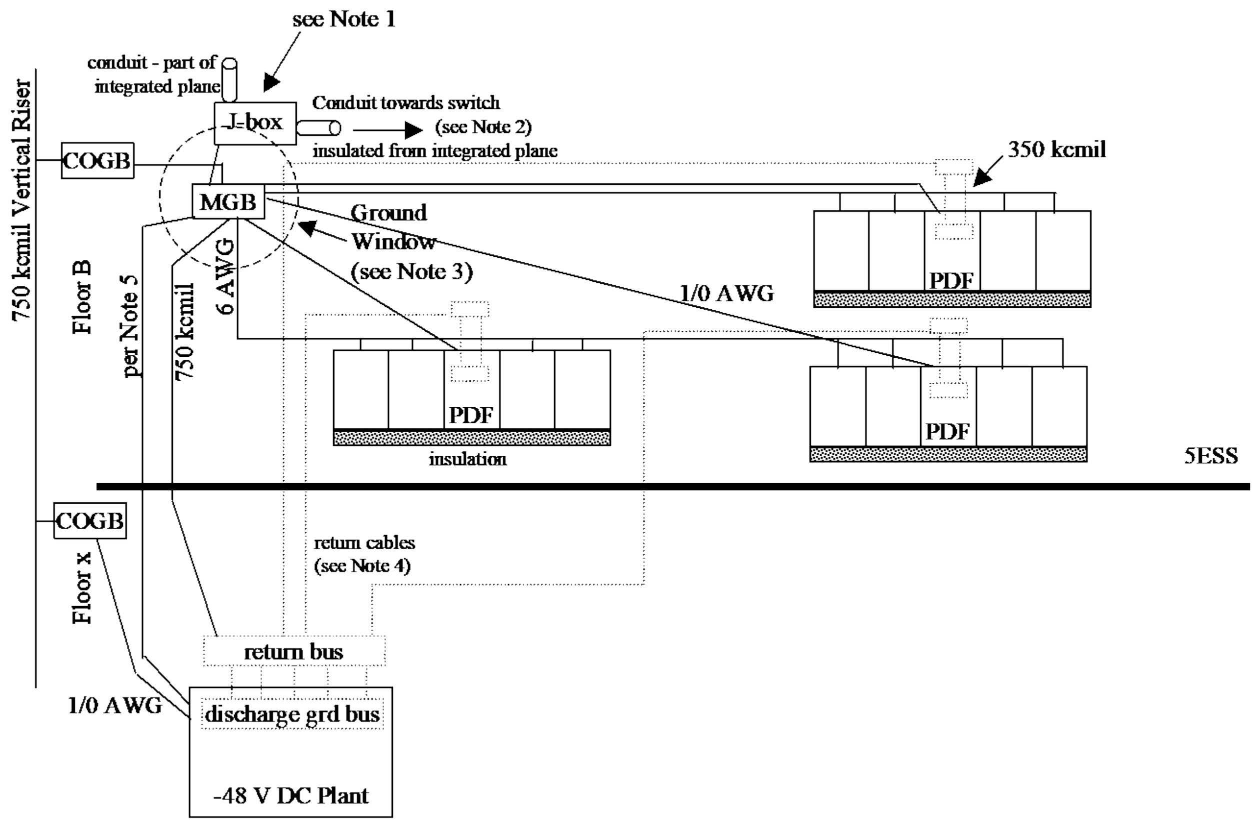


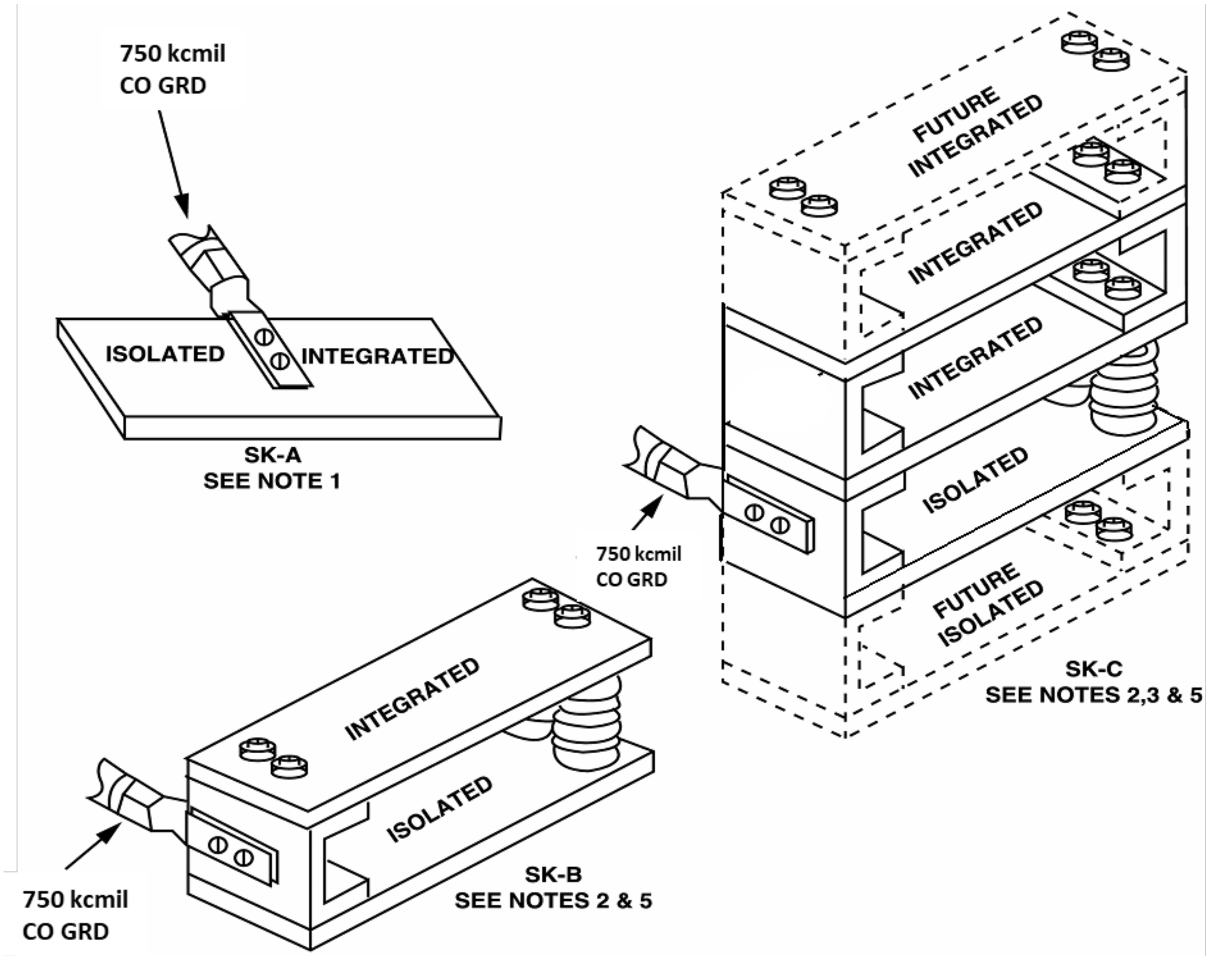
Figure 9-2: Maximum Multifloored Ground Plane Spread Using a Single Power Plant



Notes:

1. ACEG (Green Wire) and its metallic raceway must be connected to the Ground Window and treated as part of the Isolated Ground Plane downstream from the Ground Window.
2. Conduit must be insulated from the Integrated Ground Plane from this point on and be electrically continuous from the source of the loads.
3. The Ground Window must be located as closely as possible to the Isolated Ground Plane(s) it serves. Vertically, it must be no more than one floor from the Isolated Ground Plane.
4. The Plant Discharge Feeders (-48 V Return) are sized to meet system requirements and are run paired with the –48 V feeders.
5. The conductor between the MGB and the Power Plant Frame should be a minimum of 1/0 AWG up to 50 ft, 4/0 from 50 ft to 100 ft, 350 kcmil from 100-150 ft, 500 kcmil from 150-200 ft, and 750 kcmil for longer distances.

Figure 9-3: Digital Switch Isolated Power Plant Application



Notes:

1. The 750 kcmil grounding conductor attachment to the bar may be located at any point, so long as the isolated and integrated connections are on opposite sides of the 750 kcmil.
2. When 2 or more bars are used for the MGB in the ground window, the 750 kcmil conductor should be installed on the copper channel bus as shown in SK-B and SK-C.
3. When the MGB is installed in the ground window, space should be provided for future growth when it is anticipated that 3 or more bars will be used.
4. Each bar must be identified as to whether it is in the isolated or integrated zone.
6. When the battery return bus is used as the ground window, the copper channel bus must be sized to meet the power plant ampacity.
7. Although SK-C shows copper channel on both sides (excepting the area of isolated/integrated zone division), it is not necessary that it be done in this manner. It is also permissible to set up the bar in an “E” configuration (i.e., insulators would be installed on the opposite side of the bar from the 750 kcmil). This allows the integrated side (which is limited to 6 linear feet) to be stacked up to 3 feet high with 3-foot bars.

Figure 9-4: Ground Window Busbar Configurations

The following restrictions are necessary to protect solid state components and printed circuit boards from possible damage in case of a lightning strike on or near the building or other voltage disturbances originating outside the equipment area served by the isolated ground plane:

- Only one single point ground may be utilized with an isolated ground plane.
- A Stored Program Control Switch System (SPCSS) framework, that comprises a portion of the isolated ground plane, must not be more than one floor away from the ground window.
- These restrictions limit the installation of the SPCSS equipment to a maximum of three adjacent floors when the ground window is established on the middle floor. As shown in Figure 9-2, the SPCSS ground reference is extended between floors only by means of a 750 kcmil vertical equalizer conductor. There is no continuity, except through the ground window, between the isolated ground plane on the upper and lower SPCSS floors. On the middle floor, only one bond connects the isolated ground plane to the integrated ground plane. This is shown as a 750 kcmil conductor between the CO GRD bus and the MGB within the ground window.
- The single point connection integrates the isolated ground plane with the integrated plane for the purpose of equalizing voltage between the otherwise isolated planes. The single point restricts current generated by a lightning strike on the building from flowing through SPCSS frame members to earth. Additionally, current spikes generated by equipment operation or malfunction in systems that are not connected to the isolated ground plane cannot flow through that plane since at least two connections are required to complete a circuit.
- The ground window may be located in a position other than that described in paragraph 9.4. In a single floor SPCSS layout, establish the ground window in a location that would facilitate routing of conduits or power ground feeders that must pass through the ground window. It may be mounted on cable rack, a column or a wall or other positions accessible for cabling.

  Note: For conduits and ACEG leads serving the SPCSS equipment See sections 8.1.2 – 8.1.4

- If space for termination of ground leads on the MGB has been exhausted, supplementary ground buses may be installed. This bus must be located within the 6-foot sphere of the ground window (i.e., within three feet of the MGB) and must be connected with a copper channel bus (preferable) or 750 kcmil conductor(s) or. Any ground leads that are normally connected to the main ground bus may be terminated on the supplementary ground bus. A supplementary ground bus should not be used unless necessary.

  NOTES:

  - Under normal conditions at a remote ground window only one 750 kcmil is required between the MGB and the supplemental bus
  - If the MGB is also the power plant return bus, enough 750 kcmil conductors must be used to connect external bus to ensure that the required ampacity can flow through it

The ground window with supplementary buses is constructed as follows:

- The main ground bus must be the bus which contains the connection to the CO ground bar.
- Supplementary ground buses must be connected to the MGB with 750 kcmil conductors or a copper channel bus (see Figure 9-4).
- When open-ended supplementary buses are used, the distance from the ground window “center” to the open end bus must be limited to 3 conductor feet (see Figure 9-4).
- Supplementary buses must be configured so as to preserve the conductor segregation as specified in Figure 9-4.

9.6 Establishing a Separate Ground Window

A ground window, as previously covered in chapter 8, must be established to serve the isolated ground plane. A copper bus (or buses) called the main ground bus (MGB), must be located within the ground window to provide a place where various required connections can be made. The MGB must not be mounted on any of the isolated ground plane frames (see paragraph 8.1.3.2 for requirements when the principal power plants return bus is used as a ground window).

Note: The MGB in the ground window must be clearly identified by stenciling or other means. The MGB isolated and integrated sections must also be identified.

To prevent lightning and fault currents from flowing through the MGB, the MGB shall be mounted on insulators so as to insulate it from the building's integrated ground plane.

The principal power source serving the isolated ground plane must be associated with only one ground window. However, more than one isolated equipment subsystem may exist in an isolated ground plane and can be served by a single ground window (see paragraph 8.1.3.2).

Note: Additional information regarding ground windows can be found in Sections 8.1.2 through 8.1.4.

9.7 Separation of Isolated Plane from Integrated Plane

Isolation of SPCSS equipment is accomplished by the use of insulators between points where metal work common to integrated plane must be fastened to metal work common to the isolated plane. Such points include:

- **Anchor bolts** — An insulator must be used to separate studs and bolt heads from frame metal.
- **Bottom of frames** — Place insulating material between frames and the floor.
- **Shelves from frames** — When a relay rack is integrated (non-isolated), but a particular shelf needs to be isolated, nylon washers (and possibly nylon bolts) or equivalent must be used to provide isolation.
- **Superstructure supports** — This includes brackets extended above frames to support Unistrut® channels that support fluorescent lighting fixtures, conduits, and power cable racks that are part of the integrated ground plane. Insulators must be placed on top of the support brackets to isolate the SPCSS (analog or digital) switch from the integrated ground plane.
- **Conduits** — Conduit (or other raceway) connected to analog or digital ground plane equipment (SPCSS) and supported from Unistrut® lighting support channels are insulated by means of fiber sheeting wrapped around the conduit or other appropriate insulating material at points of support.

When 500 V minimum rated insulation is not used, conductive members of differing potentials or different ground planes must be separated by at least 2 inches of air space.

When isolated, quiet ground, or logic grounding conductors 6 AWG and larger share the same cable rack hangers as integrated (non-isolated) grounding conductors, they should be marked so that they do not get used for integrated grounding. Acceptable methods of marking the isolated/quiet/logic grounding conductor include:

- tagging the isolated/quiet/logic grounding conductor(s) at 3 foot intervals.
- green insulation with a continuous yellow stripe,

- marking the isolated/quiet/logic grounding conductor with yellow tape at 3 foot intervals,

9.8 Typical Bonds from the Ground Window Bus

The MGB/GWB within the ground window serves as the interface point between the isolated ground plane and the building integrated ground plane. In addition to a connection to the floor CO GRD bus, direct bonds of minimal practical length are required from the main ground bus to points on different objects comprising a part of the integrated ground plane ("foreign" object grounds). Use of such bonds ensures that the voltage difference between members of the two planes will be equalized to the greatest extent possible. Such equalization tends to reduce the incidence of sparkover between the two planes and possibility of shock hazard to personnel in contact with both planes.

In a typical SPCSS installation, the main ground bus is bonded directly to:

- The floor CO GRD bus (see Figures 8-7 and 9-3)
- Main Distributing Frame when on same floor as the ground window (see Figure 8-7)
- AC conduit and AC equipment ground conductors (ACEG) that serve the isolated ground plane (see Figure 8-7)
- Foreign object grounds within 6 feet of the SPCSS equipment
- Grounded conductors of power supplies to non-SPCSS equipment

Connection between the Main Ground Bus and the CO GRD bus is made with a green 750 kcmil insulated stranded copper conductor.

It is advantageous to keep the interbonding conductor at a minimum length. Where practical, the CO GRD bus and the main ground bus should be located close together.

Note: Sharp turns or bends should be avoided in grounding systems. Minimum bending radius is 8 inches. Bend radius less than 8 inches reduces the overall effectiveness of the grounding system.

9.9 Rural Utilities Service PANI Concept

In some NNS (Lumen), and Legacy CenturyTel and Embarq (CenturyLink) facilities, the USDA Rural Utilities Service (RUS) PANI (**P**roducers, “**A**bsorbers”, **N**on Isolated, and **I**solated conductors) concept, as described in this section and RUS Bulletin 1751F-810, is used (and does not have to be changed). In offices that utilize the PANI concept, there is only one master grounding bar (MGB) used in these sites, regardless of label. The MGB serves as a combination of the OPGP, COGB, and Ground Window system described elsewhere in this document. In multi-story buildings, there is a main OPGP/MGB, as well as individual floor FGB/COGB bars. Each of these bars in an office built to RUS standards is split into sections (PANI). The sequence of connections can be reversed (INAP) if needed. An example is shown in Figure 9-5.

The MGB **PANI** sections are:

- **P**roducers- Different sources of surge energy include local lightning strikes, local commercial power surges, electrostatic discharges (ESD) from within the building, or any combination directed into the building on commercial AC service entrance conductors, telephone cables/pairs, coaxial cables, or radio antenna wave guides.
- **A**bsorber conductors are designed to provide a low impedance path for lightning or power fault surge currents to ground. Absorbers include the MGE, MGN, metallic water line, building steel etc.
- **N**on-Isolated (ground zone)- any equipment and metallic structure in the facility that does not reside in the isolated ground zone.
- **I**solated (ground zone)- all equipment and metallic structures in the facility that are isolated from all but one path to the MGB and ground (TDM Switch).

In the RUS PANI concept, in addition to Class 4 and Class 5 switches (Isolated Ground Zone (IGZ) 1), some toll/transport frames may also be isolated and considered as their own network element isolated ground zone (IGZ 2). In these cases, there are usually at least two different ground window bars (GWB) that connect back to the Isolated section of the MGB. Some of the non-isolated ground zone (non-IGZ) equipment may be isolated in the RUS PANI concept.
Sometimes (depending on the switch manufacturer's design) a GWB bar (such as an FGB) is placed near the switch for connection of all switch frames, and the GWB is connected to the "I" section of the MGB with a minimum 2/0 copper conductor having a maximum resistance of 0.005 Ohms. The switch manufacturer determines the size of the ground conductors from the GWB to the individual equipment frames.

When no GWB is used, a collector cable (minimum 2/0) may be run to the switch area from the "I" section of the MGB, with individual switch lineups/frames tapped to it, or multiple cables are run from the "I" section of the MGB to the switch area (once again, dependent on switch manufacturer design). Non-isolated ground plane metal within 6 feet of the IGZ (see Section 8.10.3 for further detail) should be connected to the "N" section of the MGB (it may be first connected to a collection bar, such as a foreign object ground (FOG) or integrated collection bar (ICB)) on the same floor.

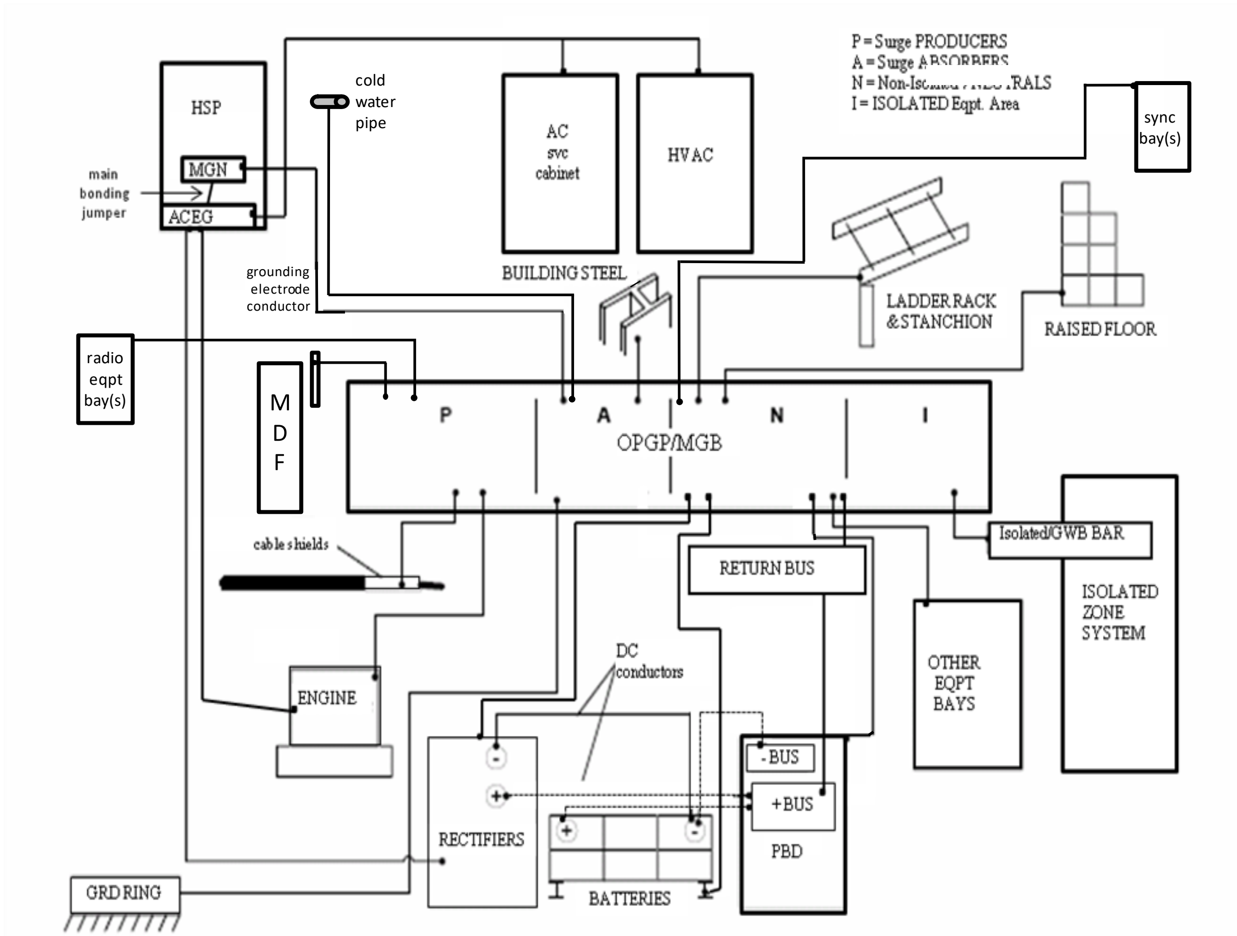


Figure 9-5: PANI Concept Grounding Conductor Layout

Table 9-1: Tabulation of Typical PANI Bar Connections

Section	Lead Types
P	Radio Equipment Cabinets [R]
P	Cable Entrance Ground Bar (CEGB) [C]
P	MDF Ground Bar [M]
P	MDF Ironwork (when not isolated from the MDFGB)
P	Engine-Alternator Frame/Room
A	Central Office Ground Electrode Field(s) (COGF) [L]
A	MGN or delta neutral (or power company rod for ungrounded secondary deltas) [N]
A	Water Pipe [W]
A	Building Steel [B]
A	Vertical & Horizontal Equalizers (including feeds to collocator's) and FGBs
N	Timing Source Receiver RR or Chassis (must be first connection of N section)
N	MDF Ironwork (when isolated from the MDFGB)
N	Collocation Ground Bars on the same floor
N	PICS Cabinet
N	Battery Racks
N	Power Bay Equipment (PBDs), including stand-alone Rectifiers [G]
N	non-IGZ Equipment [N^2]
N	Cable Rack and other miscellaneous metal
N	Battery Return Bus [N^1]
I	Ground Window Bus (GWB) for non-Switch isolated ground zone (IGZ 2,3,4 etc.) [I^2]
I	GWB or conductor(s) for Switch isolated ground plane (IGZ 1) [I^1] (must be last connection of I section)

In order to minimize electrical noise particularly on high-speed circuits, network elements may be placed in Isolated Ground Zones. This may include equipment for transport, transmission, and DLC/DSLAMs. The equipment frame / relay rack must be isolated from the floor and other CO metal (including cable racks and metallic conduit). In most cases there is a GWB for each IGZ (2,3,4 etc.) which is connected to the "I" section of the MGB with a minimum 2/0 conductor. The aisle stringers for each lineup are a minimum 2/0. A GWB is not required for single lineups, and the aisle stringer can connect directly to the MGB.

It is desirable that each isolated ground zone be marked on the floor with orange tape.

In the Non-IGZ, each lineup is typically connected to the "N" section of the MGB with a 2/0 aisle stringer or a horizontal equalizer. Non-IGZ equipment not classified as switch, sync/timing, or radio is also typically connected to the "N" section.

Network sync/timing receiver equipment is metallically connected to almost all other intelligent network elements (most of which are connected to the “N” or “I” sections of the MGB) to provide timing. GPS sync/timing receiver equipment in the PANI concept:

- may reside in an isolated relay rack.
- should be separately connected to the MGB “N” section with a 2/0 copper insulated conductor.

GPS sync/timing receiver antenna cabling can bring a surge into the office similar to “P” equipment but is connected to the “N” section of the MGB adjacent to the “A” section (the first conductor in the “N” section).

NOTE: See section 7.24 for guidance on grounding of GPS antennas.

In circumstances where space is not available to place the timing receivers in a separate rack, isolate the timing receivers from the relay rack framework, and separately ground the chassis to the “N” section of the MGB. An isolated ground bar, specific to the GPS timing receiver, can be placed at the top of the rack where the GPS equipment is mounted. A 2/0 grounding conductor must be placed from the isolated bar to the MGB as described previously. The GPS equipment must be bonded to the isolated ground bar with a minimum 6 AWG green insulated copper conductor.

In a site built to RUS PANI standards, CO ground electrode systems, as described in Chapter 3, are typically tied to the MGB “A” section with a minimum of two, 2 AWG solid tinned bare copper conductors. In cases where these conductors are brought into the cable vault instead, and tied to the CEGB, it is acceptable as long as a 750 kcmil conductor connects the CEGB to the MGB.

The MGN at the service entrance is connected to the “A” section of the MGB. This should be a minimum of 2/0, to ensure the RUS standard of 0.005 ohms for this connection is met. (see Chapter 4).

Building steel must be bonded to the MGB “A” section.

In the Non-IGZ, cable racks may or may not be isolated from building structure, supports, relay racks and metallic AC conduit. Cable racking (including foreign object grounds [FOG or ICB] near the switch) must be connected to the MGB “N” section with minimum 6 AWG green-insulated copper conductor

In sites designed to RUS standards; radio equipment usually resides in isolated relay racks connected to the “P” section of the MGB with a 2/0 copper insulated lead. Coax and waveguides are grounded as described in Chapter 7, both inside and outside the building at the waveguide entry plate.

Cable entrance facilities (CEF) in sites designed to RUS standards will have a cable entrance ground bar/bus (CEGB) (see Chapter 6 for additional information). This bus is either tied directly to the COGF with two 2 AWG solid tinned copper conductors or to the MGB "P" section with a 2/0 insulated conductor. When a solid copper bus bar is not used, a 2/0 or larger cable is run from the MGB "P" section and extended the length of the cable entrance facility to serve as a pseudo-"bus". Each cable shield is bonded to the bus using a 6 AWG conductor or equivalent.

Main distribution frame grounding:

- The main distribution frame (MDF) ground bar (MDFGB) and the MDF ironwork (when isolated from each other) are connected to the MGB with 2/0 cables (MDFGB to the "P" section and MDF ironwork to the "N" section).
- When the MDFGB and or the protector block ground points are not isolated from the ironwork of the MDF, a single 2/0 green-insulated cable is run from the MDFGB to the "P" section of the MGB. MDF ironwork must be isolated from other overhead ironwork in the site.
- When the MDFGB and the protector block ground points are isolated from the ironwork of the MDF , each vertical set of protector block grounds are typically daisy-chained to the MDFGB with 6 AWG with two-hole lugs where equipment design allows for it.

In very small sites (including those with a pedestal CEF), the MDFGB may double as the MGB.

In-building engine rooms are typically bonded to the MGB in the "P" section (see Section 4.9 for further information on engine room grounding).

Absorbers and Producers should generally be routed as far away from Network equipment and signal-carrying cables as possible (for example, it is recommended that radio bays be located at least 10 feet away from a switch) to avoid flashover and induced noise. It is also acceptable to have the Producers and Absorbers on a bar that is separate from the Non-Isolated and Isolated bar, as long as the two bars are bonded together with a 750 kcmil conductor. The split bars should be placed as close to each other as practical but no more than 20 feet. See figure 9.6

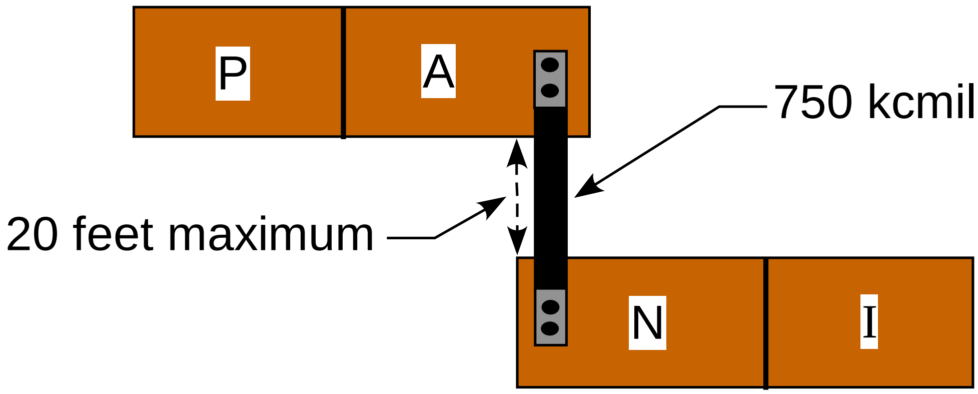


Figure 9.6: Split PANI Bus Bar

9.10 3-Wire DC Equipment Grounding

Almost all North American telecommunications equipment uses what the NEC® calls a 3-wire DC system: hot, return, and frame ground (see Figure 9-7). In almost all modern telecommunications equipment the green-wire frame ground is not a normal current-carrying conductor (it is there to carry fault current). International grounding standards refer to this configuration (where the green wire ground is only for fault current) as DC-I (the DC return is isolated from the frame ground).

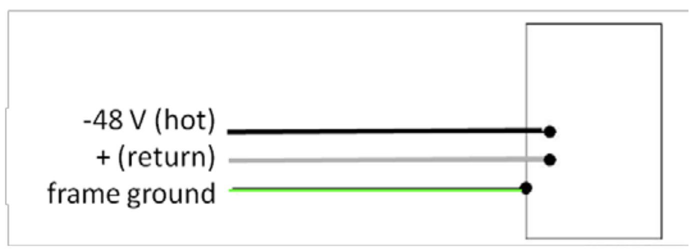


Figure 9-7: Traditional Modern North American 3-Wire DC-I System

As mentioned in Chapter 3, some telecommunications equipment has the return bonded to the frame within the equipment, so that return current is shared between the green-wire frame ground and the return conductor(s) of the 3-wire DC system. This system is commonly called DC-C (in other words, frame ground and DC return are made Common within the equipment).

Some European 2-Wire DC-C equipment is being introduced in North America. 2-wire systems are recognized by the NEC® but are not as common in North America. These systems only have hot and return conductors (no frame ground, thus the 2-wire designation). When deployed in America, some telecommunications carriers have chosen to deploy them as a true 2-wire system. Other carriers, including Lumen, choose to deploy them similar to the older DC-C equipment as a modified 3-wire DC system (see Figure 9-8). In the modified configuration, a green-wire frame ground is added to the design so that both return and fault current are shared between the return conductor(s) and the green-wire frame ground.

Note: Existing grounding conductors may be a color other than green.

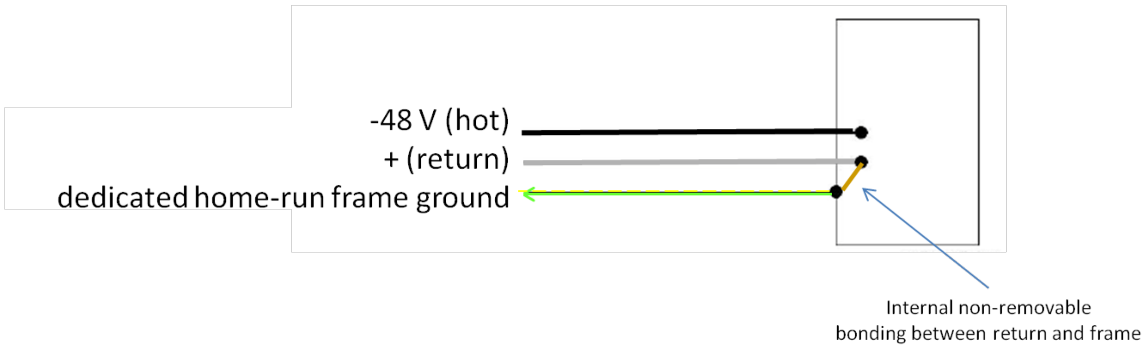


Figure 9-8: Lumen Grounding Design for New European 2-Wire DC-C Systems

Modern equipment, typically deployed in Lumen sites, is DC-I where there is very little DC current (if any) normally flowing on the green-wire frame grounds. Because the modified 2-wire DC systems will carry current on the green wire conductor, several special rules need to be followed.

- Frame(s) of the 2-wire system must be isolated from the floor .
- Frame(s) of the 2-wire system need to be isolated from any standard 3-wire DC equipment frames and any other grounded metal object by a minimum 3 inch air gap.

  NOTE: If this is not possible, due to space restrictions in the site, insulating material (such as fiber paper) needs to be used to provide the isolation.
- A "green"-wire ground, dedicated to the 2-wire equipment frame(s), needs to be home-run to the same OPGP / PANI- MGB or COGB that the DC plant feeding the equipment derives its ground reference. Multiple 2-wire equipment frames may be bonded to the same green-wire grounding conductor.

  NOTE: Three-wire DC grounding systems may not use the green-wire ground, dedicated to the 2-wire equipment frame(s)

  NOTE: For isolated-integrated ground plane sites, where the frames are installed in [or within 6 feet of] the isolated plane of a Class 4 or Class 5 voice switch, this conductor must be run to the integrated side of the MGB in the ground window

- The green-wire ground cable(s) must have a DC resistance of less than 0.03 Ω (see Table 5-4).
- The dedicated grounding conductor is required to have green insulation with a yellow stripe, or be standard green insulation marked with encircling yellow electrical tape at intervals not to exceed 3 feet.

  NOTE: Existing dedicated grounding conductors are exempt from special marking.

- In addition, within 18 inches of the termination points, and at intervals not to exceed 10 feet, the conductor must be marked with standard labels stating that "*this is a dedicated 2-wire DC system grounding conductor that is not to be shared*". (for labeling standards, see Lumen/ CenturyLink Technical Publication 77350)

In cases where 2-wire DC equipment resides in more than one relay rack, the green-wire grounding conductor is allowed to be shared between relay racks. However, when the current in the green-wire grounding conductor exceeds (or is expected to exceed) 65 A DC , an additional green-wire conductor must be added in parallel, sized and labeled as noted in the preceding paragraph. When 2-wire system relay racks are powered from different power plants, they must be separately isolated and must have their own green-yellow ground conductor.

9.11 Plug-In (Circuit) Cards (PICs) Storage Cabinet Grounding

PICS storage cabinets must be grounded with a minimum 6 AWG grounding conductor to help dissipate static electricity (ESD). Resistance requirements and conductor length requirements mentioned in Chapter 5 are waived for PICs cabinet grounding conductors.

PICs cabinet grounds:

- May connect to existing integrated (non-isolated) ground plane conductors that are carrying less than 5 A.
- Must follow the rules for foreign object grounding if nearby metal is in an isolated plane.
- May be daisy-chain grounded, as long as 2-hole compression lugs are used and paint is removed at the connection point.
- May use bolting hardware to tie cabinets together in lieu of direct grounding conductor connection to each cabinet or daisy chaining as long as resistance between cabinets can be measured to be less than 1 Ω.

- Metal door frames of storerooms in which PICS cabinets are located should also be grounded.

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10. Outside Plant Equipment Enclosures

10.1 Controlled Environmental Vaults (CEVs)

For CEVs, a driven ground electrode system (MGE) as specified in Chapter 3 shall be installed (and possibly pre-engineered using soil resistivity measurements). After installing the ground electrode, the system should be tested and recorded prior to connecting the system to other ground electrodes. The resistance of the ground electrode system measured with an earth resistance test set should be 5 ohms or less. A clamp-on resistance meter should generally not be used for this measurement — see the guidelines in Section 3.1. If a 5-ohm impedance cannot be obtained, contact the regional Lumen Electrical Protection Engineer for assistance.

Note:
When OSP Electronic Equipment Enclosures [EEEs] such as CEVs, huts, or RT cabinets are placed within a quarter mile of an electrical substation, special grounding precautions may need to take place. Contact the Lumen Electrical Protection Engineer assigned to the region for assistance in determining ground potential rise, high voltage isolation needs, and ground system considerations.

The preferred CEV grounding method is to install a driven ground rod system adjacent to the CEV in undisturbed soil (see Figures 10-1 and 10-2). See chapter 3 for MGE requirements. After the CEV is set in place, route the MGE 2 AWG grounding conductors through the designated PVC conduits cast into the CEV wall. Place a moisture proof dam around the end of the conduits and the 2 AWG conductors to prevent moisture from entering the CEV.

A ground bar must be installed inside the CEV at a convenient location for ease of grounding of all equipment framework (some existing CEVs have an interior halo ground and upgrading to a main ground bar is not necessary). This ground bar will be the site principle ground point bar (SPGPB). The MGE 2 AWG grounding conductors must be connected to the SPGPB using 2 hole compression lugs.

After the CEV is assembled, bond the two housings together with a minimum 2 AWG copper conductor or equivalent. Exothermic weld or crimp a two-hole compression lug at each end and connect to the CEV ground plates with two bolts. Apply a conductive non-oxidizing compound to all mechanical ground connections (see Figure 10-3).

Bond the CEV ground plates to the SPGP ground bar or interior halo ground with a minimum 2 AWG copper conductor.

10.1.1 New CEV's

For new installations, the ground connections required inside the CEV are:

(see also Figures 10-2 and 10-4)

- Add a bonding jumper from the AC panel neutral bar at the service entrance, sized per the NEC® 250.28 (D) (1) through (D) (2), and terminate it on the AC panel ground bar. Before doing this, ensure there is no MGN-ACEG bonding jumper in the power pedestal serving the CEV.

  Note: If additional electronic equipment is added external to the CEV, the MGN-ACEG bonding jumper may need to be relocated.
- Add a 2 AWG stranded copper conductor interior halo ring ground on the inside wall just above the cable rack level or run, from the site principle ground bar (SPGB), individual 2 AWG stringers down each equipment aisle.
- Bond the 2 AWG interior halo ring ground (or aisle stringer(s)) to each ground plate of both the upper and lower sections of the CEV.
- Bond the SPGB or halo ring ground to the AC panel ground bar at the service entrance with a conductor sized per Article 250 of the NEC®.
- Ground the power plant's positive (+) battery return bar to the aisle stringer or halo ring ground using a 2 AWG stranded conductor.
- Add a 6 AWG ground conductor for grounding the power plant framework (this can be connected directly to the SPGB, halo ring ground or to the lineup "stringer".)
- Ground each equipment frame to the aisle stringer or interior halo ground ring with a 6 AWG stranded wire using H-taps or C-taps and two-hole crimp connectors.
- Ground the protector frame cabinet and the cable splice cabinet with a 2 AWG conductor.
- Add a 6 AWG ground conductor from the entrance ladder to the site ground system if the two sections of the ladder are bonded together with a 6 AWG jumper. (Alternately, connect upper and lower sections of the entrance ladder to the 2 AWG halo conductor with individual 6 AWG conductors)

When a made ground electrode (MGE) is installed, bring two conductors from the MGE into the CEV at two points on opposite sides and connect to either a ground bar or to the interior ring ground. Two holes should be drilled through the upper section of the CEV for access . These holes must be sleeved and properly sealed to prevent moisture from entering the CEV. See figures 10-1 and 10-2

NOTE: All grounding conductors need to be placed as short and straight as practicable. Where bends are required, the bend radius should be a minimum of 8 inches and no greater than 90^0.

10.1.2 Existing CEVs

Existing CEVs can be upgraded by installing an external made ground electrode system and bringing the inside grounding up to current grounding requirements. (Some of the oldest CEVs were Ufer grounded, but it was discovered that without a sealant on the concrete, there was water seepage.) Consider the following items, and Figure 10-5:

- If the existing CEV does not have an external grounding electrode system, one must be added. Add a grounding electrode system per Figure 10-2, depending on the site. When a made ground electrode (MGE) is installed, bring two conductors from the MGE into the CEV at two points on opposite sides and connect to either a ground bar or to the interior ring ground. Two holes should be drilled through the upper section of the CEV for access . These holes must be sleeved and properly sealed to prevent moisture from entering the CEV.

After completing a thorough grounding and bonding audit, make appropriate changes/ additions to the CEV grounding per the following checklist.

As needed:

- Add a 2 AWG stranded copper conductor interior halo ring ground on the inside wall just above the cable rack level or run, from the site principle ground bar (SPGB), individual 2 AWG stringers down each equipment aisle.
- Bond the 2 AWG interior halo ring ground (or aisle stringer(s)) to each ground plate of both the upper and lower sections of the CEV.
- Bond the SPGB or halo ring ground to the AC panel ground bar at the service entrance with a conductor sized per Article 250 of the NEC®.
- Ground the power plant’s positive (+) battery return bar to the aisle stringer or halo ring ground using a 2 AWG stranded conductor.
- Add a 6 AWG ground conductor for grounding the power plant framework (this can be connected directly to the SPGB, halo ring ground or to the lineup “stringer”.)
- Ground each equipment frame to the aisle stringer or interior halo ground ring with a 6 AWG stranded wire using H-taps or C-taps and two-hole crimp connectors.
- Ground the protector frame cabinet and the cable splice cabinet with a 2 AWG conductor.

- Add a 6 AWG ground conductor from the entrance ladder to the site ground system if the two sections of the ladder are bonded together with a 6 AWG jumper. (Alternately, connect upper and lower sections of the entrance ladder to the 2 AWG halo conductor with individual 6 AWG conductors)

NOTE: All grounding conductors need to be placed as short and straight as practicable. Where bends are required, the bend radius should be a minimum of 8 inches and no greater than 90^0.

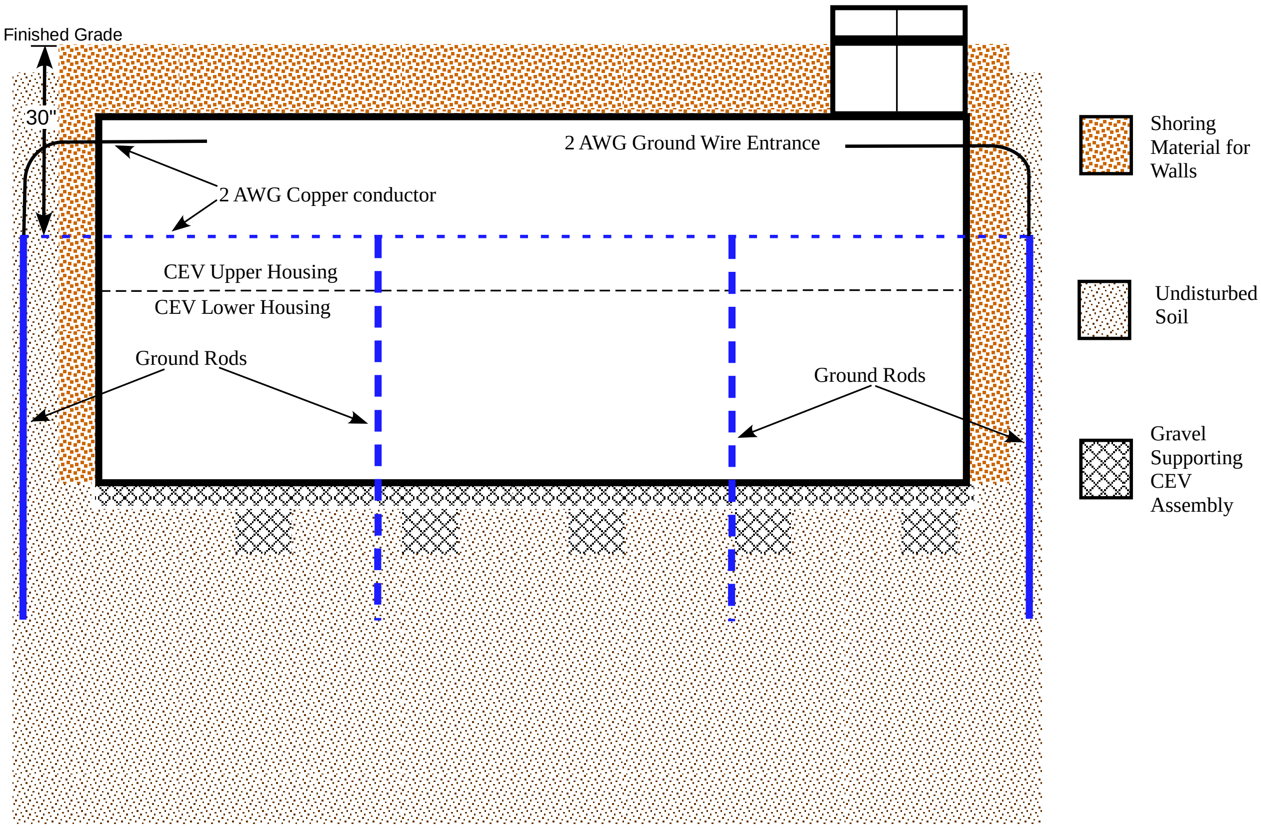


Figure 10-1: CEV Sectional View of Excavation and Ground Rod Installation

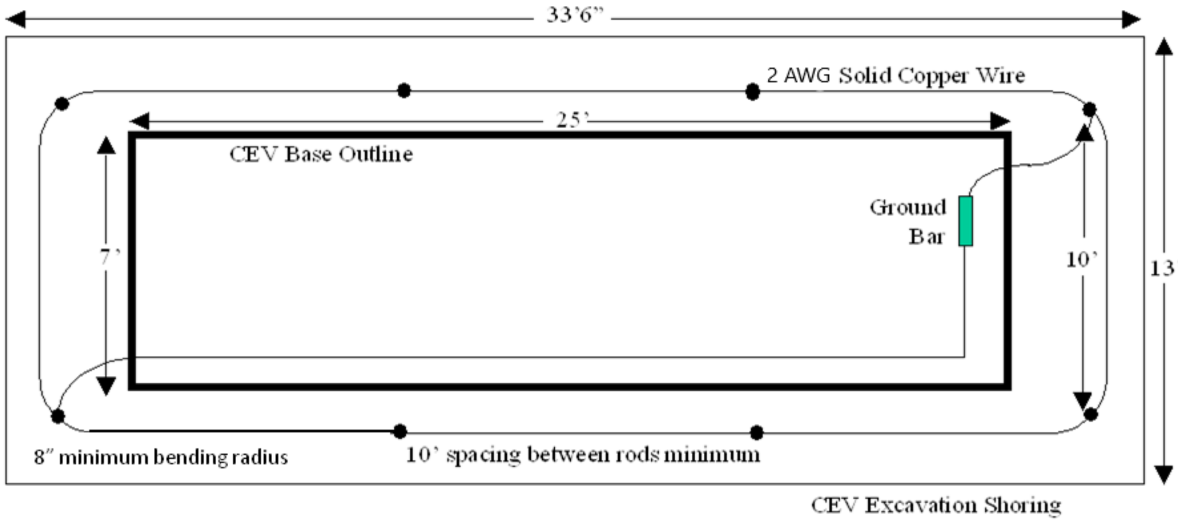


Figure 10-2: Typical CEV Excavation and Driven Ground Rod System

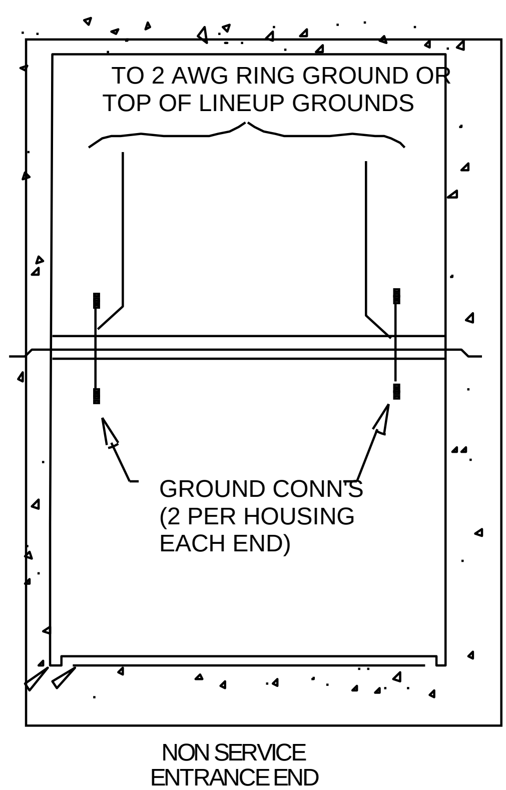
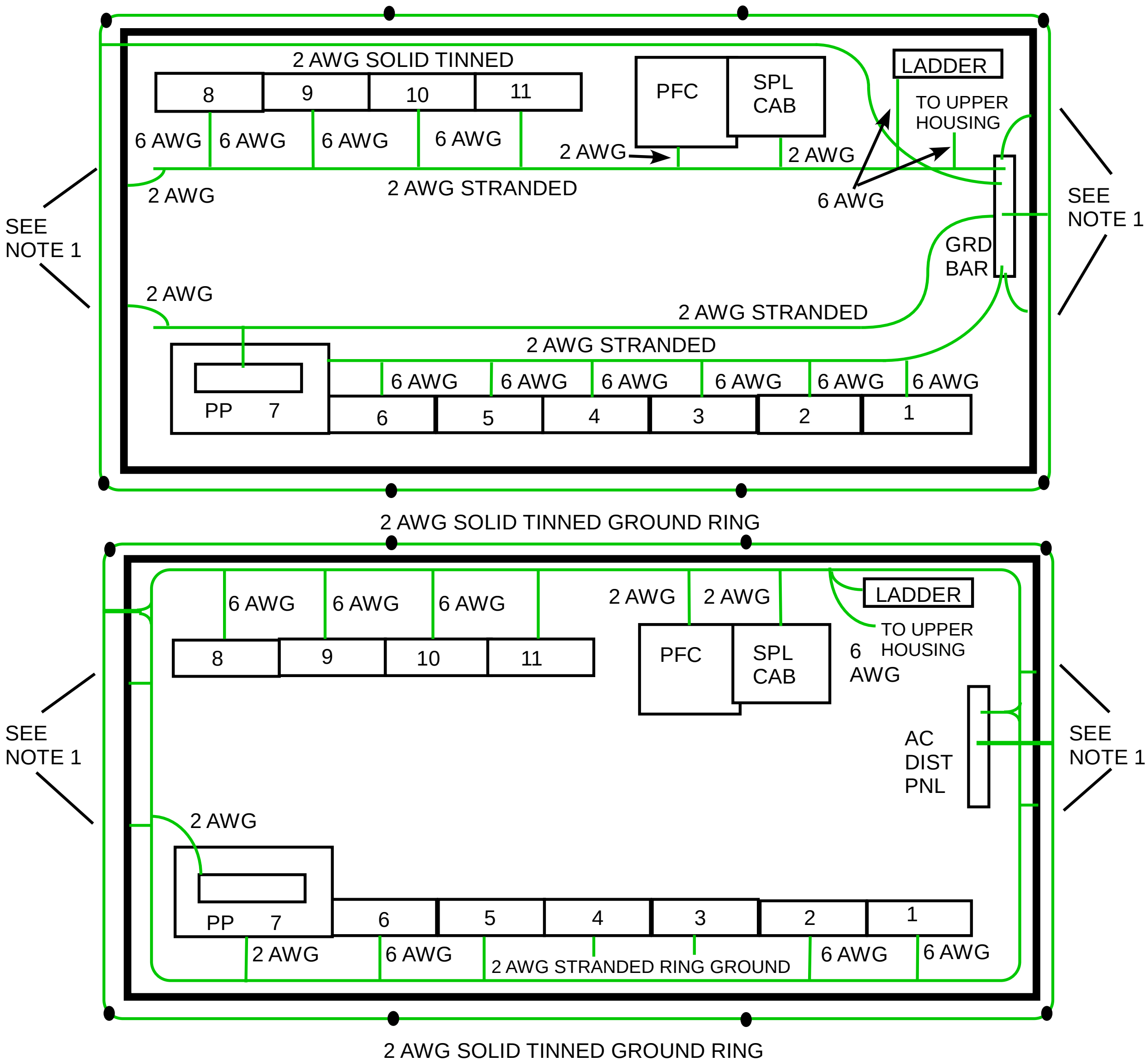


Figure 10-3: Typical CEV Bonding of Upper and Lower Housings



Note 1: Connect to upper housing ground plate.

Figure 10-4: Typical Inside Grounding for CEVs

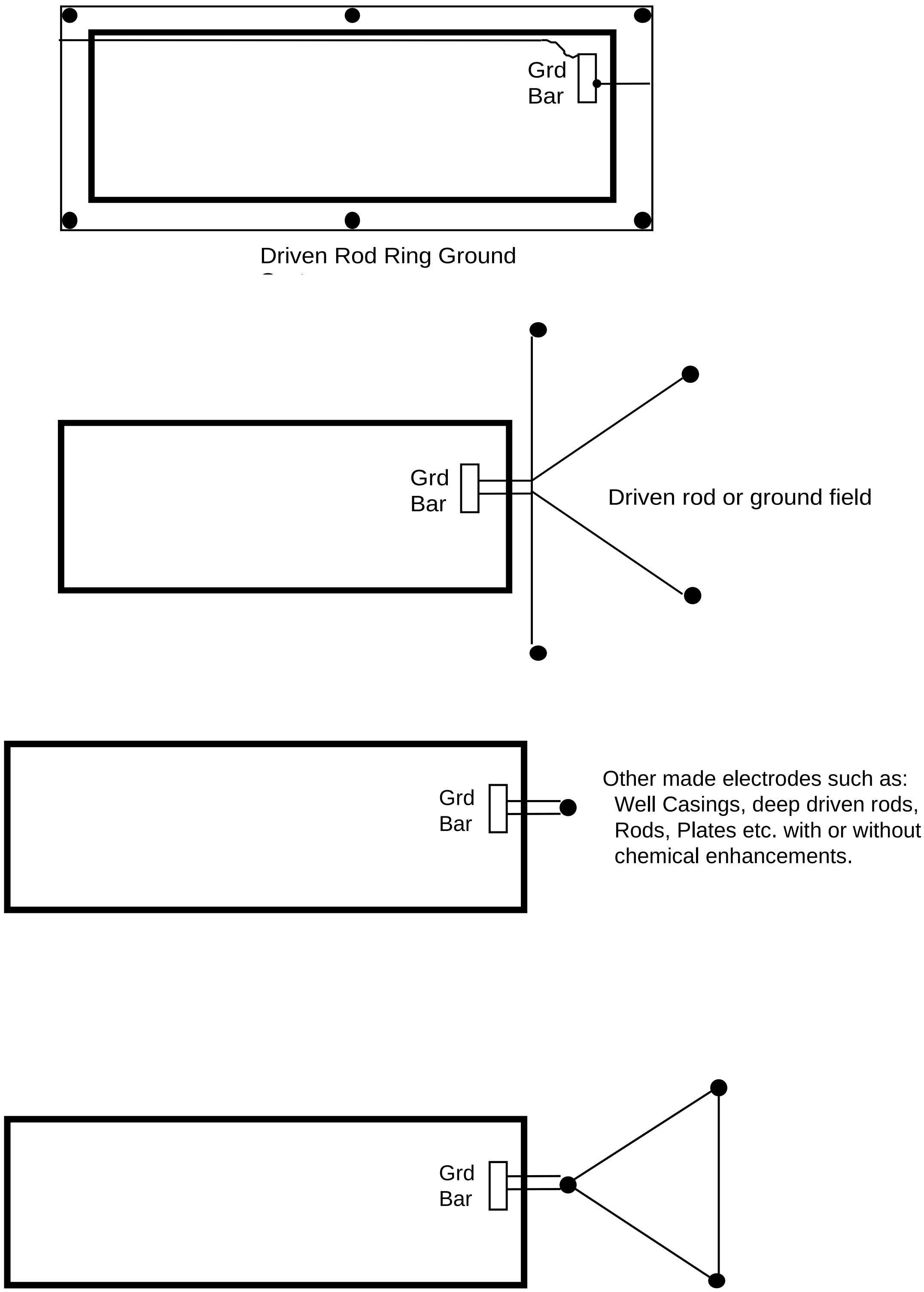


Figure 10-5: Examples of Grounding Schemes for Existing CEVs

10.2 Other Controlled Environment OSP Enclosures (huts, CECs, UEs, etc.)

A CEC™ or UE™ is similar to a CEV except it is not fully buried in the ground. The grounding requirements of a CEC or UE are very similar to those of a CEV and are mostly covered in Section 10.1. The main differences are that a CEC comes in one piece (although a UE is still in two pieces), so there is no need for bonding of upper and lower halves in a CEC; and typically, the grounding leads to connect the inner and outer ground rings go through the above-ground cable entrance.

Huts (including ROW sites) are similar in size and structure to CEVs, CECs, UEs, and Radio sites. Grounding requirements from Section 10.1 or 7.21 must be used. Portable buildings are often used as huts. A building raised above the ground on some kind of skid structure may not be at earth potential. For these reasons, care should be taken to bond and ground all metallic components (including metal skids, metal doorframes, metallic entrance conduits, etc.) to the MGE. In rare cases, a hut may contain a Class 5 switch. In those cases, follow the isolated ground plane guidelines found in Chapters 8 and 9.

10.2.1 Optical Fiber Regeneration (REGEN) Sites

Fiber regen sites may be single buildings similar to a small Central Office, Multiple buildings in a campus environment or several huts/buildings placed end to end with a common made ground electrode (MGE) system, DC power plant and AC power distribution. For single building locations, see section 9.9 for grounding details. For multiple buildings in a campus environment, if there are no shared facilities, grounding should follow section 10. 2. If there are shared facilities e.g. armored optical fiber or copper communications cables placed between each building, each building MGE should be bonded together with a minimum of 2- 2AWG solid tinned copper conductors. Where several huts/buildings are placed end to end with a common MGE system, each building should have a dedicated ground bar and one of these ground bars should be used as the MGB for the connection to the site MGE. Place a continuous, 2/0 minimum, grounding conductor (horizontal equalizer) between each building ground bar to maintain electrical potential between the buildings. (SEE Figure 10-6)

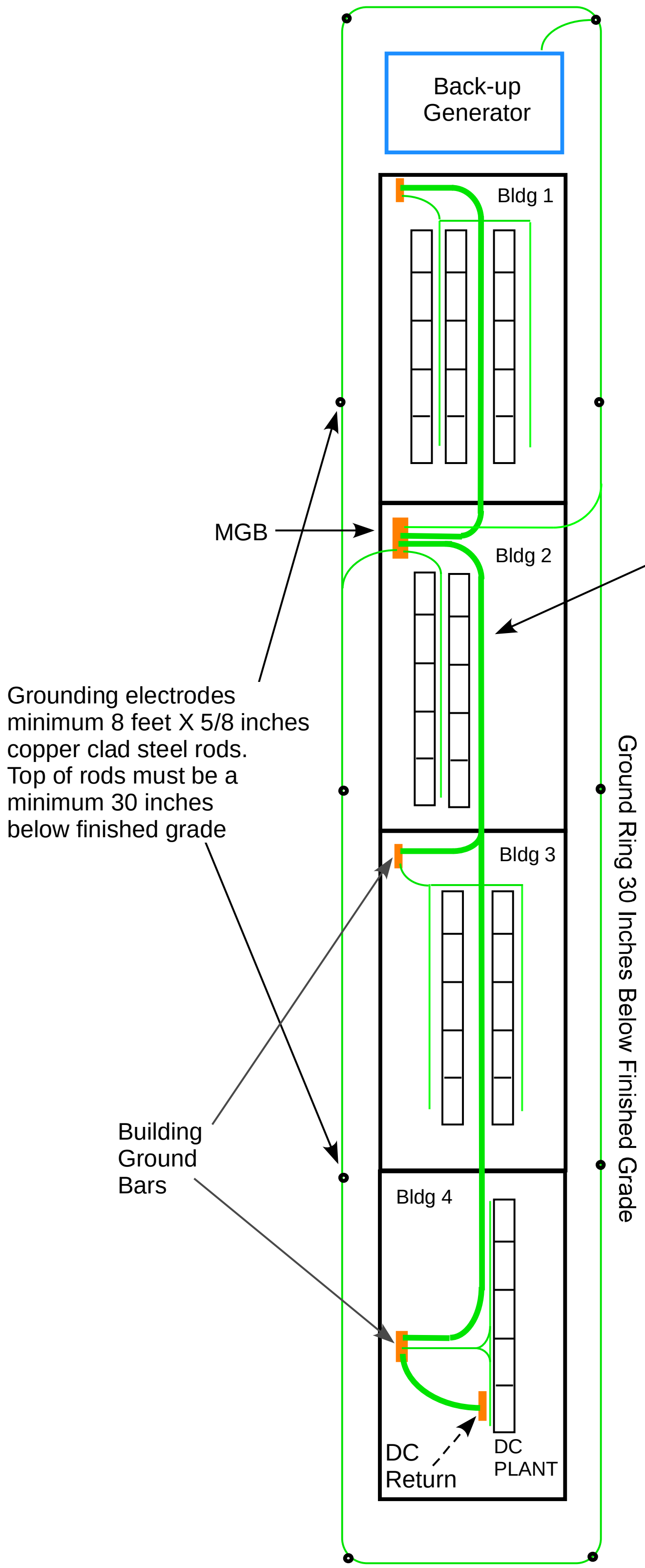


Figure 10-6 Fiber Regen Grounding example

10.3 Outdoor Type Electronics Cabinets/Housings Located Above ground or in the Underground

10.3.1 Above ground outdoor type electronic equipment cabinets

Above ground outdoor type electronic equipment cabinets shall be properly grounded for safety and equipment protection. A made ground electrode must be engineered and installed in accordance with Chapters 3 and 4, and Section 10.1.

Install a made ground electrode to establish a cabinet ground system. The ideal ground field measures ≤ 5 Ω resistance to earth (less ideal is the 25 Ω specified in the NEC®). The installer must measure resistance to earth after installation with a 3-point, fall of potential, tester. Typically, 4 ground rods should be installed for most cabinets (if ≤ 5 Ω are achieved with fewer rods, no more are needed). Exothermically weld (or use an approved listed irreversible compression crimp) ground rods to a 2 AWG solid tinned copper conductor, typically in a ring. The ⅝ in dia. x 8 foot (or 10 foot) ground rods should be spaced 10-20 feet (due to right of way limits, it may not be possible to achieve 10 foot spacing; in these cases, space the rods as far apart as possible). The ring must be placed at a minimum of 2 inches (preferably 18-48 inches) outside of any concrete pad on which the cabinet(s) sit, and at least 30 inches deep. Oftentimes, more than one electronics cabinet may be placed at the same site. The same ground field should be used for both cabinets. Two 2 AWG solid tinned copper conductors must be routed from the ground electrode field into the first cabinet at a site and connected at the SPGP. The two 2 AWG solid tinned conductors must be exothermically welded or crimped with an approved tool and die designed for solid connections to a two-hole copper connector and attached to the cabinet ground bar. All contact surfaces must be cleaned to a bright metal finish and a conductive non-oxidizing agent applied. (Figure 10-7 provides an example of DLC cabinet grounding but note that it represents the dimensions of only one type of cabinet.)

Note: Not all anti-corrosion compounds are conductive. Only products that are listed as conductive are acceptable to use where an anti-oxidant compound is required.

In cold areas, consideration may need to be given to 10-foot ground rods instead of 8 foot rods. The 10-foot rod will ensure penetration below the frostline.
If a cabinet or repeater case is placed within ¼ mile of an electrical substation or high voltage AC lines, contact the Lumen Electrical Protection Engineer assigned to the region for special considerations concerning ground potential rise (GPR), high voltage protection, and grounding electrode systems.

If the cabinet has a DC power plant, the battery return bar (the positive bar) shall be ground referenced to the cabinet ground bar with a 2 AWG stranded insulated copper conductor. All equipment units within the cabinet shall be grounded either through direct contact with the grounded cabinet or with a 6 AWG stranded copper conductor.

Cable sheaths, equipment units and battery plant framework shall be grounded as required with a minimum 6 AWG stranded copper conductor to the cabinet ground bar.

The ACEG bar within the AC distribution panel should be grounded to the cabinet ground bar as shown in Figure 10-10. Cabinet metal may also be used to meet this bonding requirement as long as a resistance of less than 100 milli-Ohms can be shown between the ACEG and the cabinet ground bar.

Any metallic objects (fences, metal posts, CATV boxes, phone cable closures, etc.) that have ground potential and are located within 6 feet (it is desirable to bond anything within 10 feet) of the cabinet shall be bonded to the driven ground system per NESC® Article 384C.

All conductor to conductor connections must be done with copper crimp connectors (C or H taps). All connections to any metalwork must be done with 2-hole copper crimp connections. All contact surfaces must be cleaned so that metal to metal contact is made. All connections must be treated with a conductive non-oxidizing compound to prevent corrosion.

Small RTs, DSLAMs and ONUs (Optical Network Units) serving 96 or fewer customers are sometimes used. Sometimes they are powered like a traditional RT, with local power, and a power pedestal. In those cases, a ring ground (as described in the preceding paragraphs) and less than 25-ohm resistance to earth are strongly preferred. In the case of line-powered over twisted pair remote-powered ONUs/RTs follow the manufacturer's grounding guidelines (in the case of some small ONUs/RTs, this may mean only two rods are required as the minimum), or drive a minimum of 3 rods (preferably 4) in a straight line in the cable right-of-way, separated by at least 10 feet and connected together (see Figure 7-23 for an example of this 3-rod configuration). Square and triangle configurations of the rods are also acceptable if they will fit in the right-of-way and allow proper spacing of the rods. If the power company's MGN is nearby, bond to it. Note that in some locations where the project is funded through RUS funding, it may be necessary, per RUS standard units, to install an MGE that meets a minimum 25 ohms.

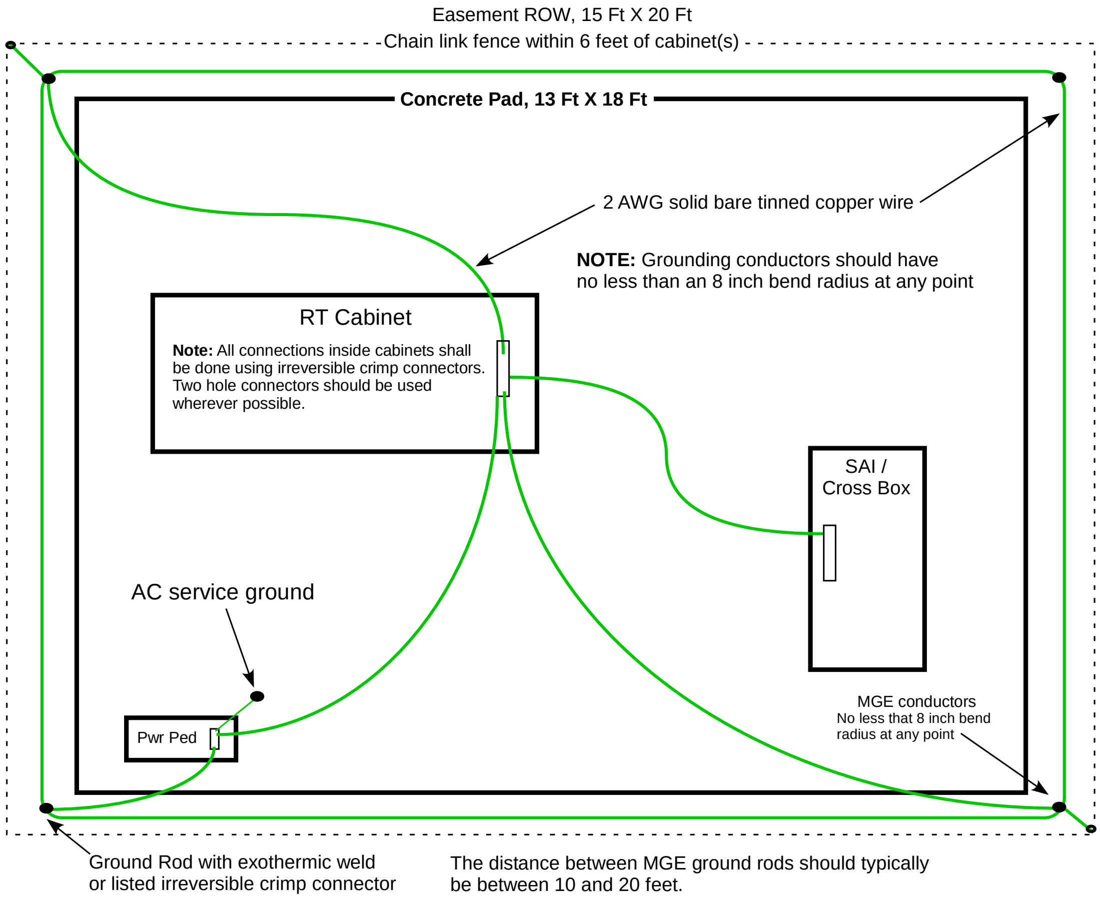


Figure 10-7: Typical RT Site Where Most Structures are Bonded to a Common Bar (Cabinet MGB)

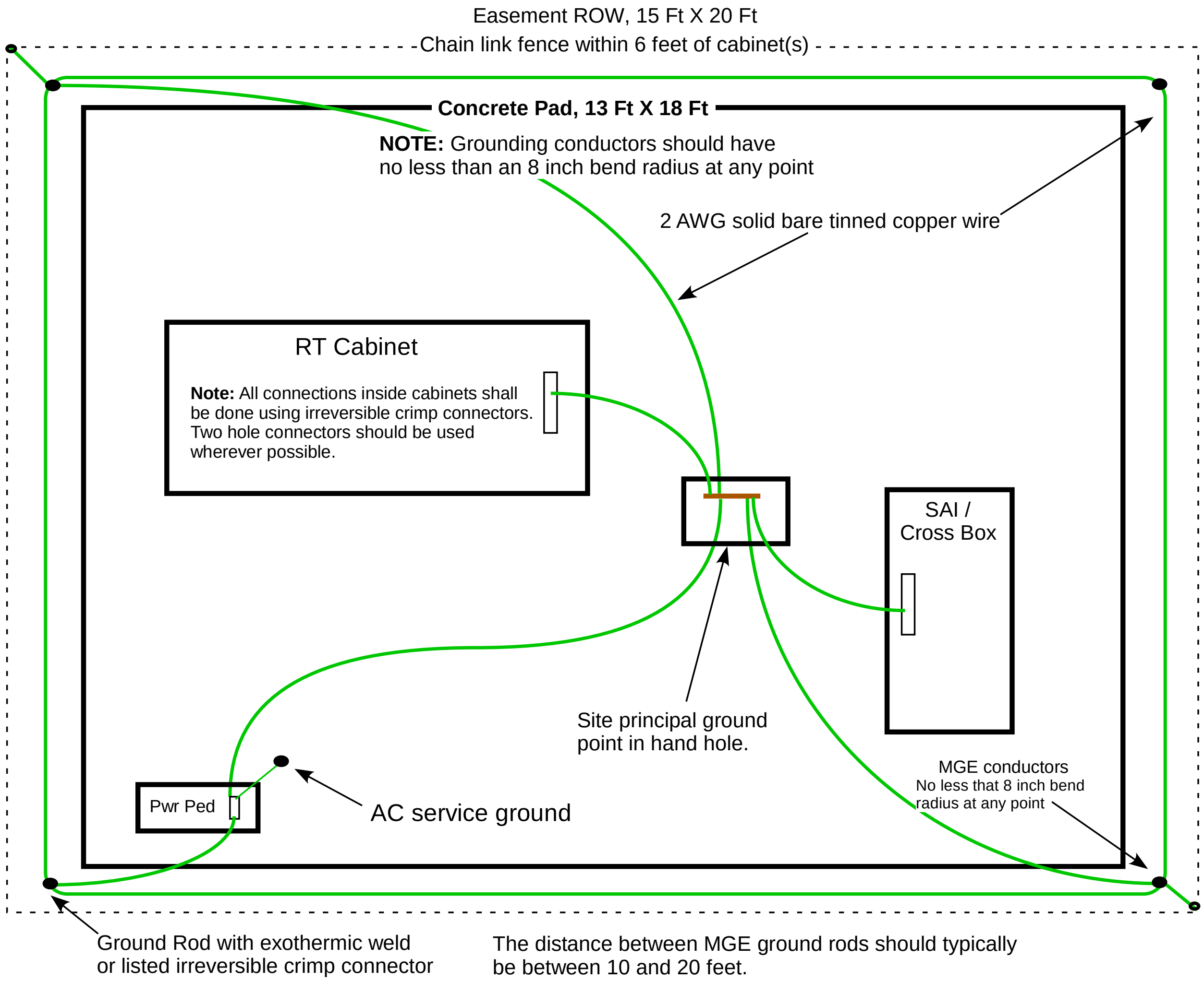


Figure 10-8: Typical RT Site Where Most Structures are Bonded to a Common Bar (SPGP in Hand Hole)

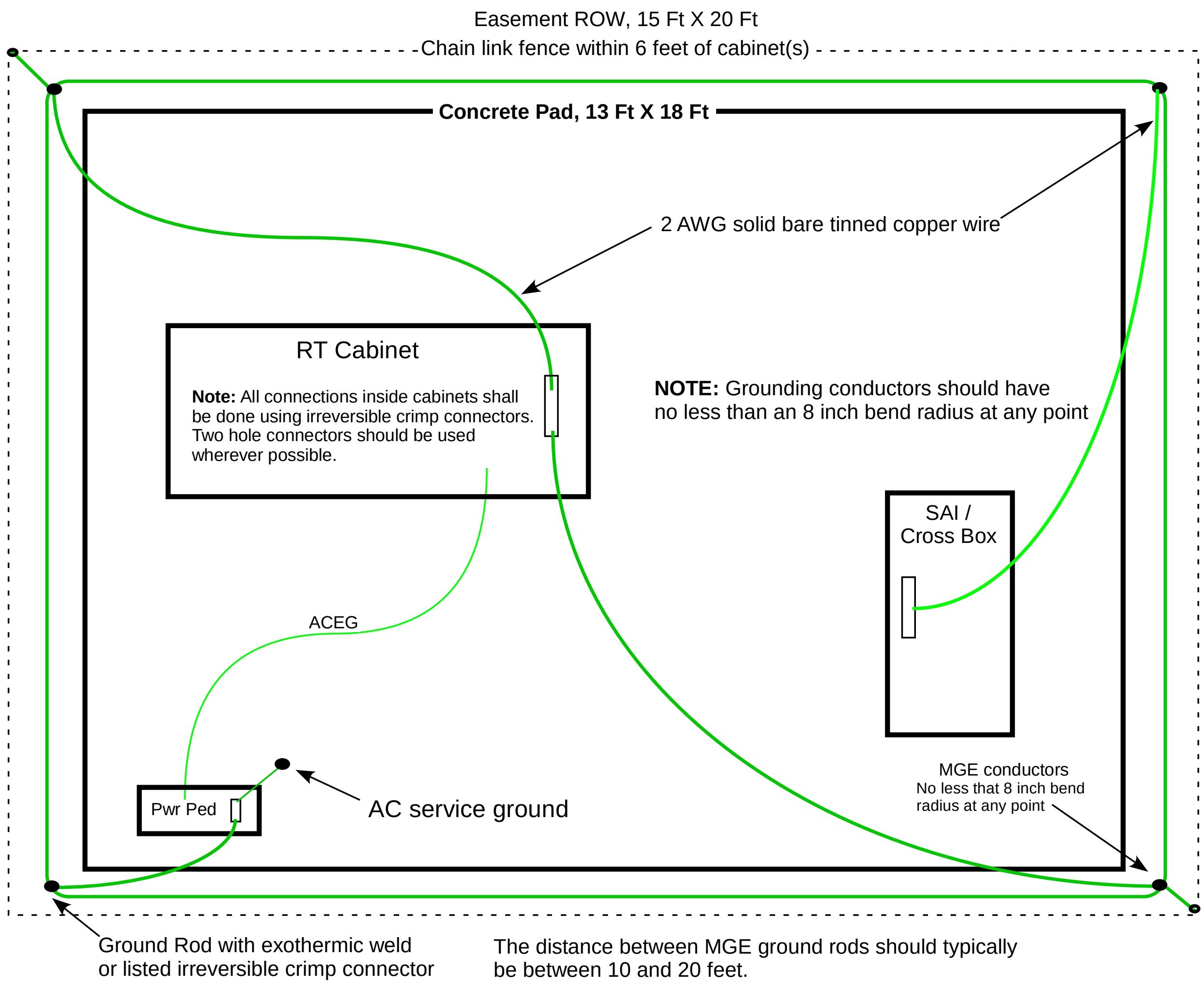


Figure 10-9: RT Site Structures Grounded to Ring Separately

Above-ground doublers and repeaters should be bonded to an accessible MGN. If no MGN is accessible, a made ground electrode system, that meets a 25 ohm minimum must be installed.

For all RTs, ONUs, doubler and repeater cases ensure that the cable sheaths and protectors are grounded per manufacturer specifications.

If there are multiple ground rings established at a given site, they should be bonded together (reference Figures 7-1 and 7-2).

At RT sites with multiple enclosures, it is highly recommended that they be bonded to the RT grounding system. If an enclosure is close enough to the RT cabinet that open doors from both cabinets are 6 feet or less apart, the enclosures shall be bonded to the grounding system. (See Figures 10-7 to 10-9)

Many RT cabinets with in Lumen have one end of the cable shield of the cable(s) placed between the collocated RT cabinet and the SAI/ first splice enclosure isolated and are only grounded in the splice chamber of the RT. The shields of these cables are isolated at the SAI/ splice enclosure in the following manner. No bonding hardware may be installed and the metallic shield must be tape isolated. In some older cabinets, the isolation may occur in the RT splice chamber rather than in the SAI (isolation in the SAI is preferred in all new RTs). In these cases, it is often useful to tie the SAI grounds directly to the ring, as depicted in Figure 10-9. Also, in these cases, the shields of the cables going towards the RT should not contain any bonding hardware (such as bullet bonds), and it is recommended that the shield be insulate on that side with tape to prevent arcing. The cables should have a label affixed to denote whether and where the shield is isolated. Finally, in these cases, to prevent violation of the SAI isolation, and to improve testability of ground electrode fields, bare ground wires entering/leaving enclosures should be protected (typically with plastic conduit for a foot or two) from contact with other metal objects.

10.3.2 Outdoor Type Electronic Equipment Apparatus Cases Placed Underground

When repeater/ doubler cases are placed in manholes, the apparatus case(s) and any associated protectors should be bonded to the grounding ribbons or conductors.

10.4 Grounding of the AC Neutral

Per the NEC®, the power pedestal and electronic equipment enclosures are treated as a common structure for purposes of MGN to ACEG bonding. Figure 10-10 shows this configuration.

Note: The only exception might be an extreme distance separating the power ped and the served equipment enclosures.

The power utility or the electrician contracted to install AC service to the site, will usually drive their own ground rod(s) near the AC service entrance per local and national codes and practices. The grounding electrode conductor shall be sized per NEC® table 250.66.

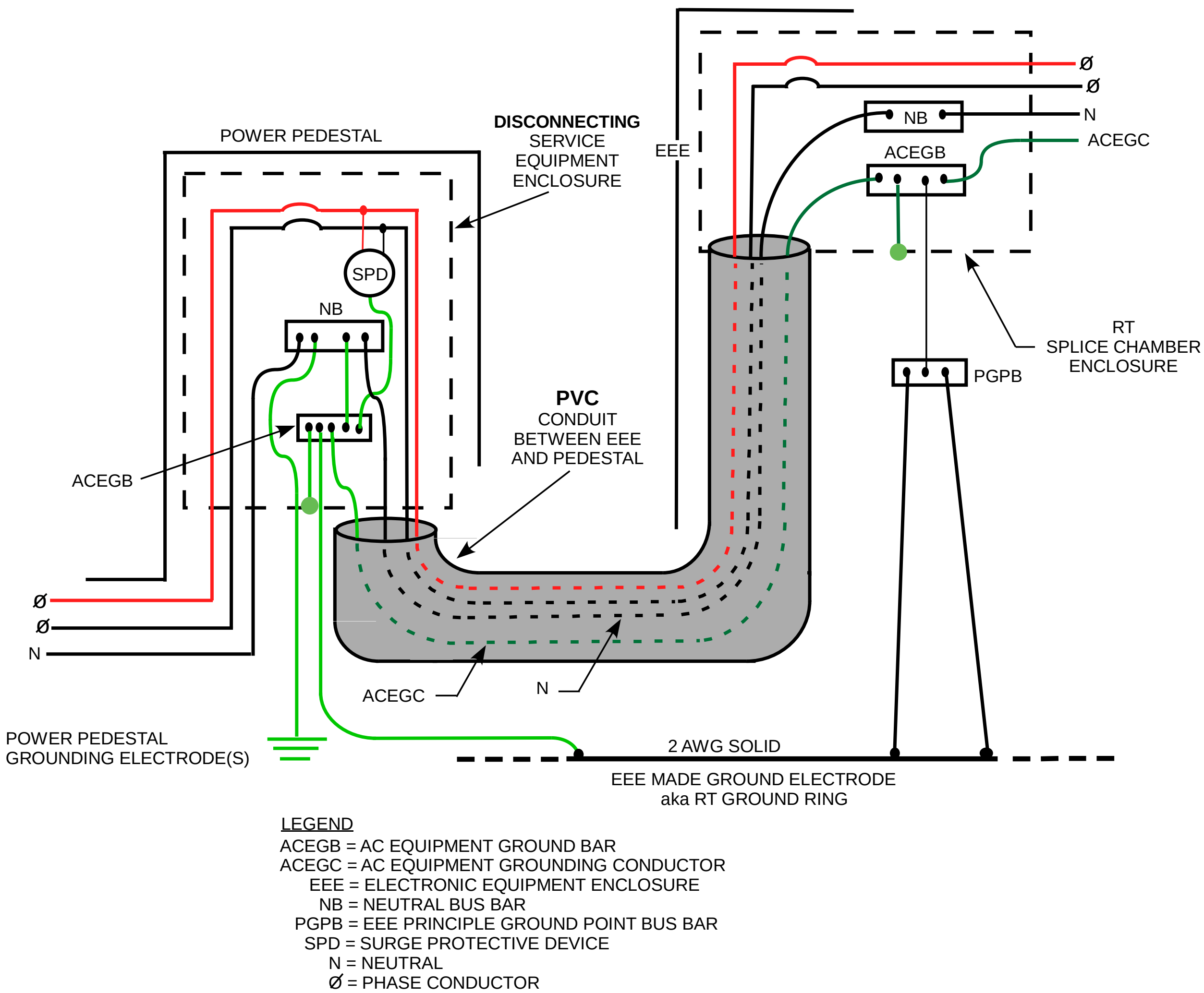


Figure 10-10: Power Pedestal and RT Treated as one Structure

Figures 10-7 through 10-9) show a ground rod driven at the power pedestal. This is an NEC® Code requirement.

Note: In some cases, a second ground rod may be added (bonded together and separated by at least 6 feet) in order to meet the requirements of NEC® Article 250.53A2 without performing an earth resistance test to check for less than 25 Ω.

10.4.1 Portable Generator Grounding

When portable generators are connected to the power pedestal, they must be wired as shown in section 7.19 of Lumen/ CenturyLink Tech Pub 77385, an excerpt of which is shown here.

UL® 2201 requires small portables less than 15 kW to have the engine frame and the neutral bonded at the genset, making them "separately-derived". However, they usually serve sites having a "hard-wired" neutral (non-separately-derived). This situation can be made safer by limiting genset distance from the site receptacle to 15 feet, and by ensuring that the receptacle is less than 10 feet from the HSP MGN-ACEG bond. This is mostly not an issue because the majority of smaller gensets are not presently listed to UL® 2201.

10.5 Commercial Customer Premises Electronic Equipment Installation Grounding

Customer Premises grounding for Lumen is covered in detail in Tech Pub 77368, Chapter 6 and Section 7.8. If Lumen is collocating their backhaul equipment in a wireless carrier's cabinet, see Tech Pub 77419 for guidelines and requirements. See section 7.23 of this document for guidance on wireless backhaul cabinet/enclosure grounding.

10.5.1 Special Protection Requirements for Customer Premises Locations On or Near Electrical Supply Locations

Special electrical high voltage protection (sometimes requiring specialized isolation equipment) is required for communications facilities located on or near electric power generating stations or electric substations, or transmission lines. Guidelines are outlined in Lumen/ CenturyLink Tech Pub 77321. Contact a Lumen Electrical Protection Engineer for further assistance.

10.5.2 Customer Premises Computer Room

Sometimes the space the customer gives Lumen to place telecommunications equipment is in a computer room. There are two basic types of computer room grounding schemes: single-point, SRG, "isolated"; and multi-point ground systems. Multi-point ground systems are similar to an integrated ground plane described in Chapters 3 and 5, and Section 10.5 of this document; so those rules apply. For computer rooms with a single-point SRG grounding system, the customer may require that Lumen equipment be grounded in a specific manner. Guidelines in Chapter 11 should be followed in these cases.

E-911 PSAP locations where the local governmental agency owns the 911 equipment, but it is maintained by Lumen, are not covered by this document or by Tech Pub 77368. For these types of sites, see Tech Pub 77339 or ATIS-0600321.

10.5.3 Customer Premises Isolated Ground Planes

If Lumen equipment is installed within 6 feet of a PBX or other equipment where the manufacturer requires an isolated ground plane, Lumen equipment may need to be FOG bonded. Whether the Customer performs this FOG bonding, or Lumen does, is open to negotiation. Depending on the recommendations of the equipment manufacturer, an isolated ground plane may be required. When equipment is DC-powered, the guidelines of Chapters 8 and 9 should be followed in setting up an isolated ground plane if the manufacturer requires it. For AC-powered equipment , follow the manufacturer grounding recommendations.

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11. Computer Room Ground Environment

11.1 Purpose

This section recommends a multi-point grounding method for computer installations. It is not intended to replace or modify the grounding requirements of the NEC® and/or other applicable codes. These codes provide for safety grounding, but do not provide the low noise ground system required by interconnected sensitive electronic equipment. The protection afforded by the multi-point grounding system described herein should be equal to or exceed present requirements of equipment suppliers. This section establishes a standard that:

- Will allow sensitive electronic systems to be compatibly installed into a common ground plane and be served by a common power supply.
- Must be used as a specification for a grounding system.

11.2 Scope

In this section, only raised floor installations of computer equipment are considered in detail.

11.3 Grounding Concepts

There are two fundamental grounding concepts in use, the single point ground system and multi-point ground system.

In the single point ground system, components are bonded together at a ground window to create a common signal reference ground plane.

Note: For additional information on single point grounding, see chapter 9.

Although a single point ground system is recommended for a Stored Program Control Switching system environment, in a general purpose computer room environment it is difficult to prevent foreign ground contacts. For this reason, the single point ground system is not recommended by the IEEE Recommended Practice for Powering and Grounding Sensitive Electronic Equipment® (Emerald Book®).

In a multi-point ground system, as in the single point ground system, all components are effectively bonded together to create a common signal reference ground plane (Fig. 11-1). Any connections to this ground plane are required to have all conductive paths entering, or within 6 feet of the ground plane, bonded to the signal reference ground plane. For this chapter, signal reference ground plane is referred to as the Signal Reference Grid (SRG).

11.4 Ground Point For Co-Located Computer Rooms

If the CO Ground is not located in the computer room space, an extension of the CO Ground should be provided. This ground should consist of a copper ground bar, installed within the computer space, insulated from its support, and bonded to the CO Ground bar by a 750 kcmil insulated copper ground conductor. Two hole, crimp type lugs must be used for all connections.

11.5 Signal Reference Grid (SRG)

The SRG system provides a ground reference for the raised floor computer equipment. This ground will provide a low impedance path to high frequency disturbances and a capacitive coupling with the data cable shield to reduce high frequency noise.

The SRG must be connected to the CO ground bar with a minimum 2 AWG, copper wire using two hole compression lugs at the CO ground bar. The method of connection to the SRG must be dependent on the type of SRG installed.

As a minimum, the SRG must consist of a bolted stringer raised floor support structure. The bolted stringer to the pedestal head connection of this structure must be installed and maintained with a resistance of less than 0.5 milliohms.

The integrity of the bolted stringer SRG is dependent on maintaining a low resistance stringer to pedestal head connection. Since proper maintenance of this connection cannot be guaranteed, it is recommended that a supplemental SRG be installed with the bolted stringer raised floor. This supplemental SRG can take the form of a continuous sheet metal element installed prior to the installation of the raised floor support pedestals (for new construction only) or a grid of bare copper wires installed under the raised floor as described below for non-bolted stringer applications.

In existing facilities where a non-bolted stringer floor is installed, a supplemental SRG must be installed. This supplemental SRG must be composed of multiple runs of bare, stranded 2 AWG copper wire routed along each row of the raised floor pedestals in both directions under the raised floor, thus forming a grid. Bond each wire run at the intersecting point of each perpendicular wire run and the raised floor support pedestal (Fig. 11-3) by a mechanical connector that must also tie the grid to the pedestal.

Prior to installation of the SRG connector, ensure that the surfaces of all raised floor pedestals are properly prepared. Remove all grease, dirt, surface coatings (i.e. paint), and rough projections. Torque and/or compress all SRG fittings to manufacturer's specifications.

If the floor support pedestal leveling adjustment is at the top of the pedestal, then a 6 AWG flat braid strap must be installed between the pedestal leg and one of the four adjacent stringers. Connection to the stringer must be on the bottom using a two-hole, crimp lug and two (2) #10 self-tapping screws. The type of pedestal leg (round or square) will determine the method for that end of the connection as follows:

- Connection to round pedestals must be made by clamping the 6 AWG flat braid to the leg with a screw type, stainless steel hose clamp (Fig. 11-2A).
- Connection to a square pedestal must be made with a two hole, crimp lug and two (2) #10 self-tapping screws (Fig. 11-2B).

11.6 Cabinet Grounding System

Individual system cabinets (i.e. processor cabinets, expansion cabinets, peripherals, communications cabinets, power distribution units, transformers, and floor mounted air handling equipment) must be grounded to the raised floor grid.

Note: Some manufacturers' specifications do not require this connection. This equipment may be excluded from the grounding requirement after careful review and consideration by a Lumen Facility Environmental Manager.

The connection between the cabinet and the SRG must be made with a 6 AWG, flat braided copper strap and should be no longer than two feet. The braided SRG ground strap must be attached with a 2-hole, crimp type lug to a flat surface near the bottom of the cabinet frame (Fig. 11-4), in a reasonably accessible location. This area must be prepared to a bare, bright finish for connection of the ground strap by drilling and tapping two ¼-20 holes and attaching the lug with two ¼-20 x ¾ inch bolts. An alternate method would be to drill two $^{5}/_{16}$-inch holes and attach the lug with two ¼-20 x ¾ inch bolts, two ¼-20 nuts and two internal tooth lock washers (ITLW) ,#10 self-tapping screws may also be utilized if required. The internal equipment mounting bracket, which may be more readily available, can also be used to connect the ground lug.

Connection to the SRG must be provided by one of the following methods:

- Attaching a 2-hole, crimp type lug to the bottom of the raised floor stringer, utilizing two ¼ inch self-tapping screws.
- Connection to a square raised floor support pedestal may be accomplished by one of two methods:
  - Drill two ¼ inch holes through the pedestal (Fig. 11-4), attach a 2-hole, crimp type lug with two ¼-20 x 1½ inch long bolts, two ¼ inch ITLW, and two ¼-20 nuts. The bolts are sufficient in length to attach a lug on each side of the pedestal for grounding two computer cabinets at the same location.
  - Using a fabricated stainless-steel bar (Fig. 11-5 & 11-6) drilled to accommodate the above mentioned 2-hole lug and a ¼ x 1½ inch U -bolt (depending on the width of the pedestal). Attach the U-bolt and bar to the pedestal using two ¼ inch ITLW and ¼-20 nuts. Attach the 2-hole lug to the bar using two ¼-20 x ¾ inch round head bolts, two ¼-20 nuts, and two ¼ inch ITLW. Two lugs may be attached at this point for two cabinet ground connections.
- Attaching to a round pedestal may be accomplished by the method above or by clamping the flat braid with a screw-type, stainless steel hose clamp.

Note: Torque all connections to 80 in-lbs. ¼-20 Teflon lock nuts may be substituted for the ITLW and ¼-20 nut. A conductive compound that inhibits oxidation must be applied to all metallic contact surfaces.

Note: Not all anti-corrosion compounds are conductive. Only products that are listed as conductive are acceptable to use where an anti-oxidant compound is required.

Remove all drill tailings with a hepa-vacuum.

Desktop CRT terminals, small printers, and other peripheral units of less than cabinet size need not be connected to the framework grounding conductor if grounded through the ACEG green-wire of the AC system.

Tables, desks, filing cabinets, and similar nonelectrical objects in proximity to the computer will not usually require grounding. If Electrostatic Discharge (ESD) proves to be an operational problem, grounding to the SRG is permissible.

11.7 Other SRG Connections

In general, all metal equipment (mechanical, electrical, etc.) crossing the grid of the raised floor must be properly bonded to the SRG at the point of crossing or penetration. Metal equipment within 6 feet of the raised floor must be bonded at the point of closest proximity. Equipment separated from the SRG by a wall may be excluded.

Single or multiple electrical conduits or mechanical piping must be attached to a metal channel with appropriate channel pipe straps. A 6 AWG flat braided strap with compression connectors must attach the channel to the nearest raised floor pedestal as described in paragraph 11.6.

A suitable pipe clamp and a 6 AWG flat braid with compression connectors at both ends attached to the nearest raised floor pedestal will be an acceptable alternate bonding method for individual electrical conduits or mechanical piping.

11.8 ACEG "Green-Wire Ground"

Each computer cabinet and peripheral cabinet shall be connected to an AC source by an electrical cord equipped with an equipment ground green-wire conductor (referred to as an ACEG). The supplier's specifications may include additional grounding requirements (i.e. Isolated Ground receptacles).The use of Isolated Ground (IG) receptacles is not recommended by Lumen. However, they may be installed if it is found that their use will solve a specific noise problem or if the organization that is responsible for the maintenance of the computer equipment requires them. IG receptacles do not provide a ground path to the receptacle box through the ACEG green-wire ground pin of the receptacle and must be installed with an additional ground wire connecting the receptacle box to the source ground bus per the NEC®. If IG outlets are used, they should be connected to the "source ground bus" wire with a pigtail so that if one receptacle is removed it does not interrupt the "isolated" ground system.

11.9 Raised Floor Surface

Laminated floor tiles should be used in computer rooms. Carpeted floor tiles should not be utilized due to the possibility of Electrostatic Discharge (ESD).

To provide an adequate static electricity drain path and maintain personal safety, the resistance from the top of the floor tile to the SRG should be greater than 0.5 megohms but less than 20,000 megohms.

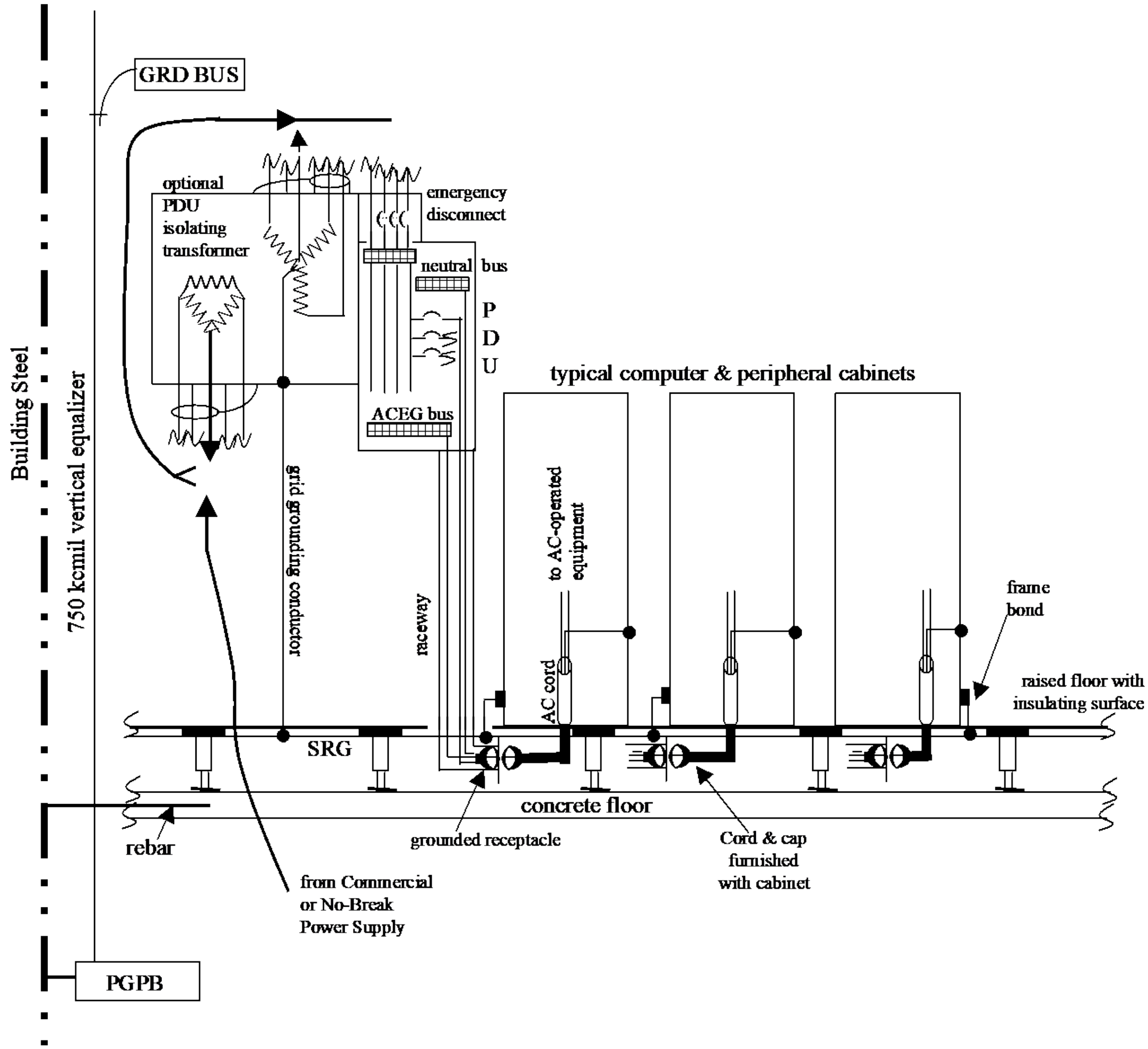


Figure 11-1: Typical Computer Room Grounding Arrangement

11-2 A Round Pedestal

11-2 B Square Pedestal

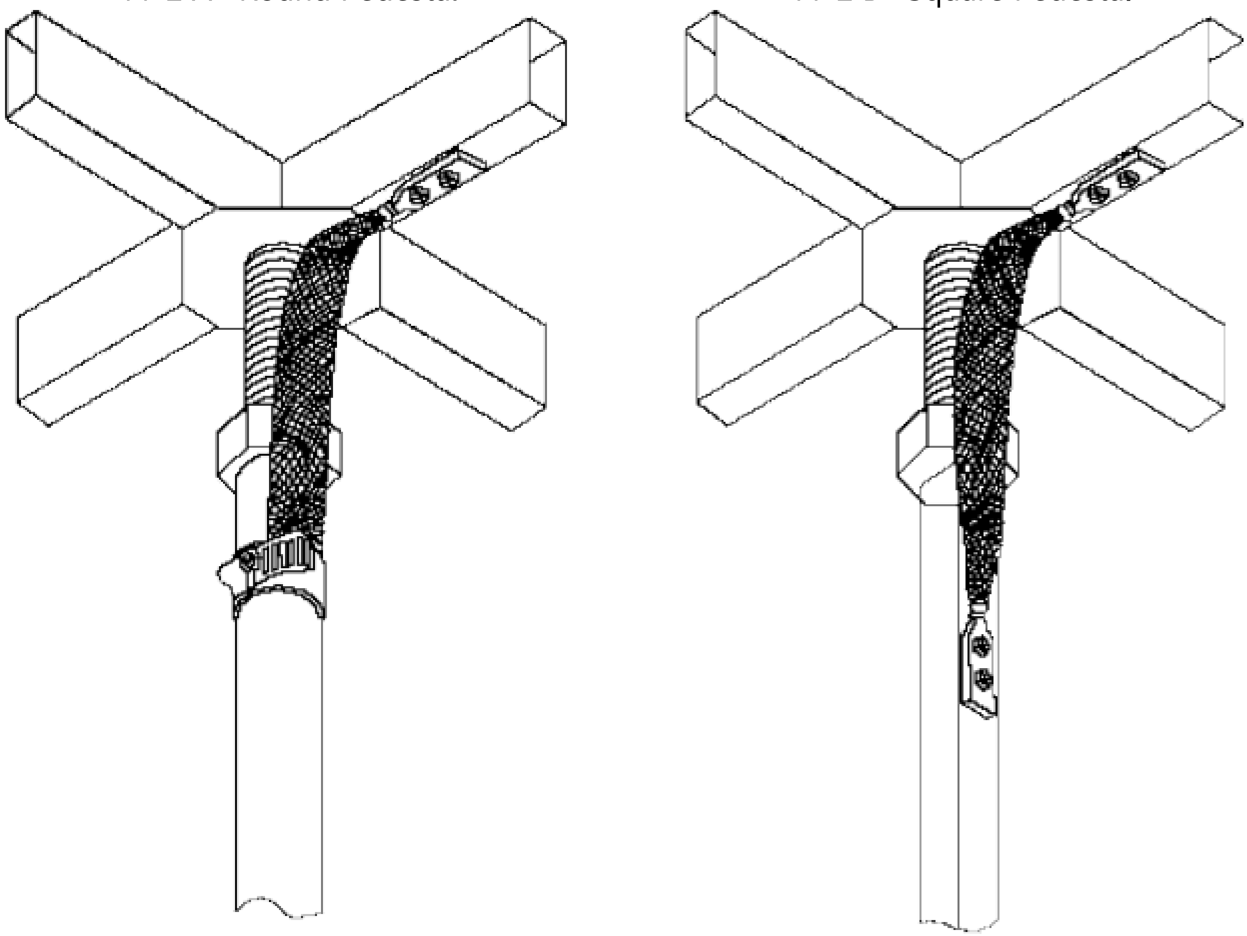


Figure 11-2: Bolted Stringer Raised Floor to Pedestal Connection

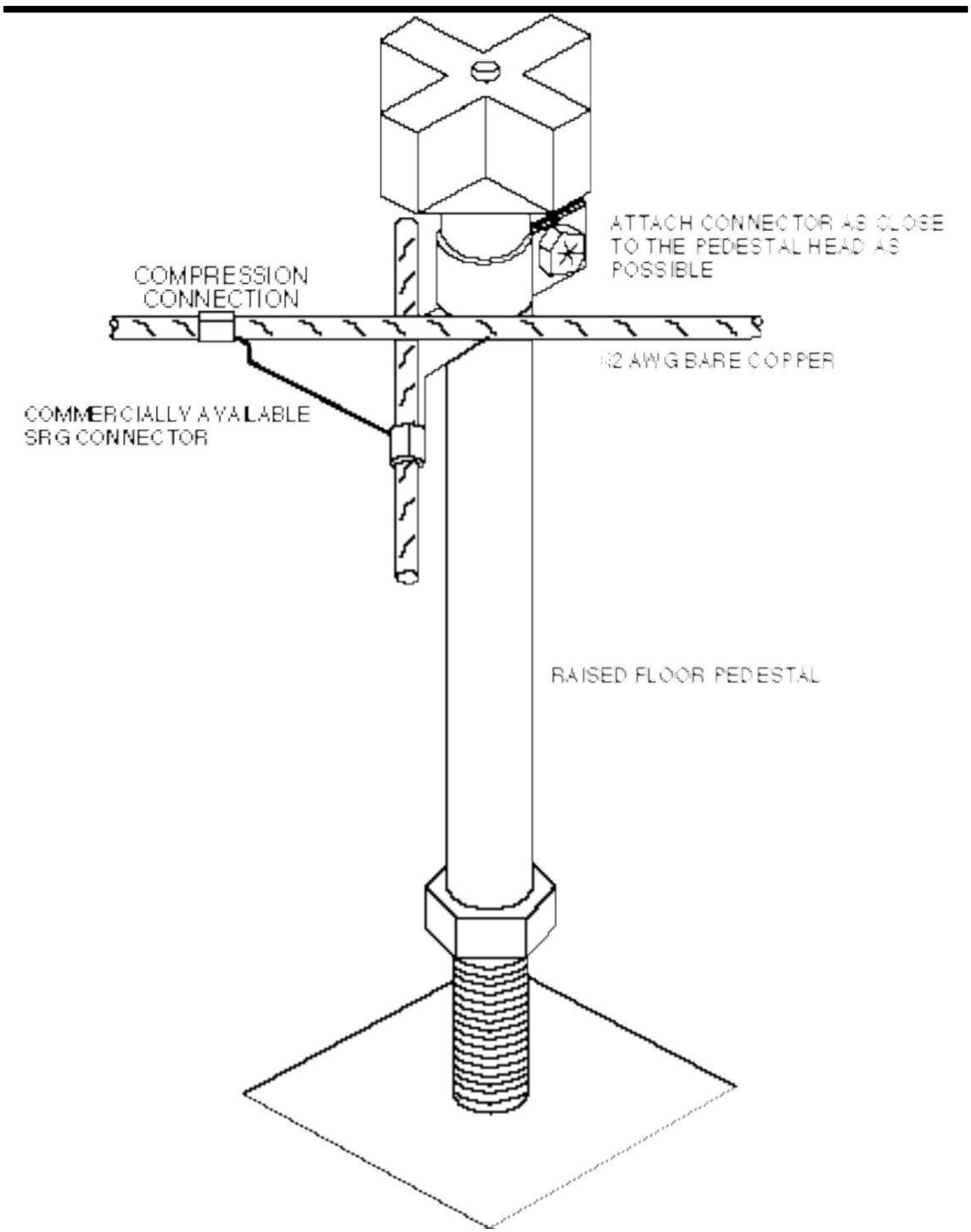


Figure 11-3: Supplemental Signal Reference Grid

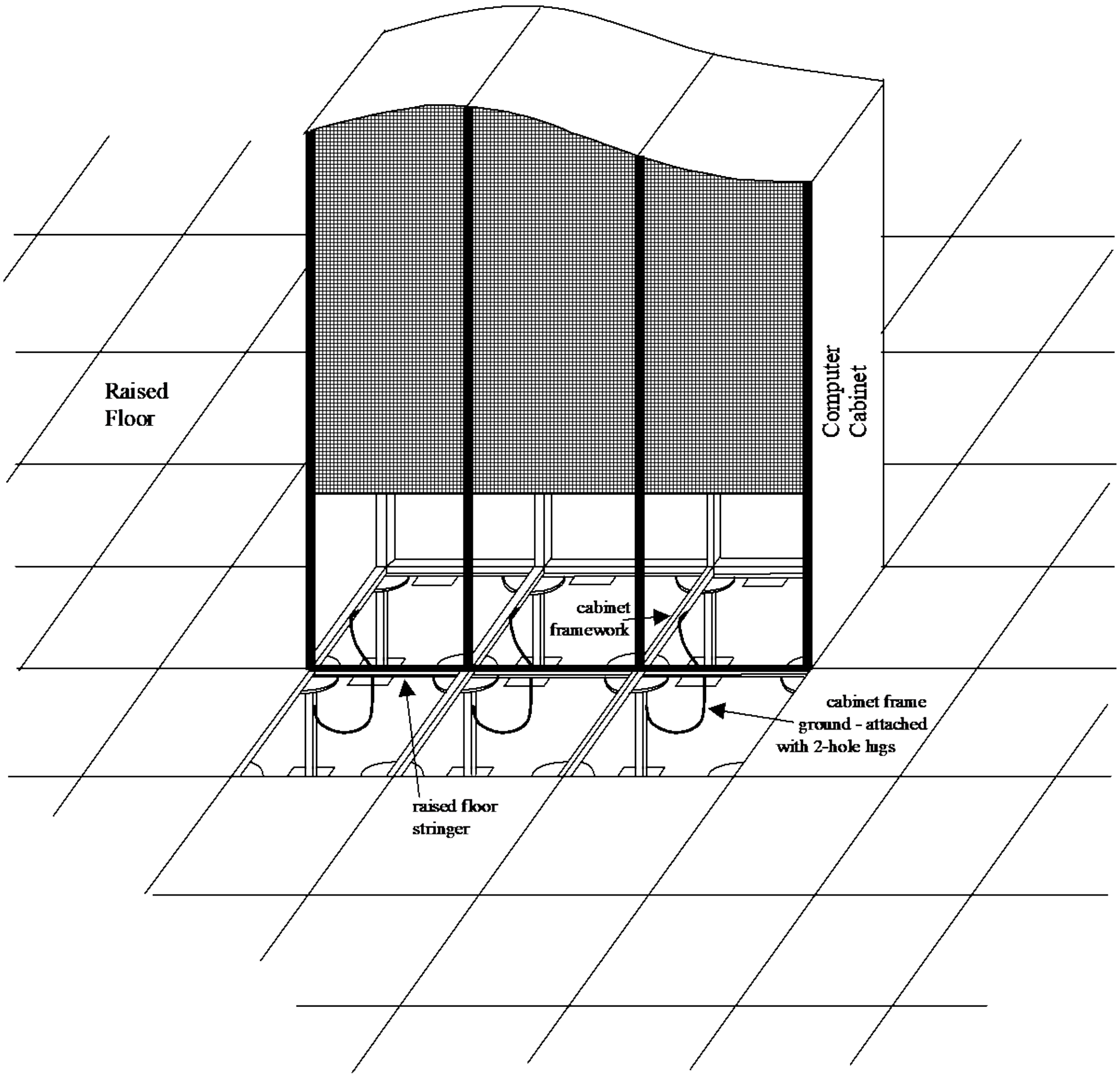


Figure 11-4: Typical Cabinet Grounding Arrangement

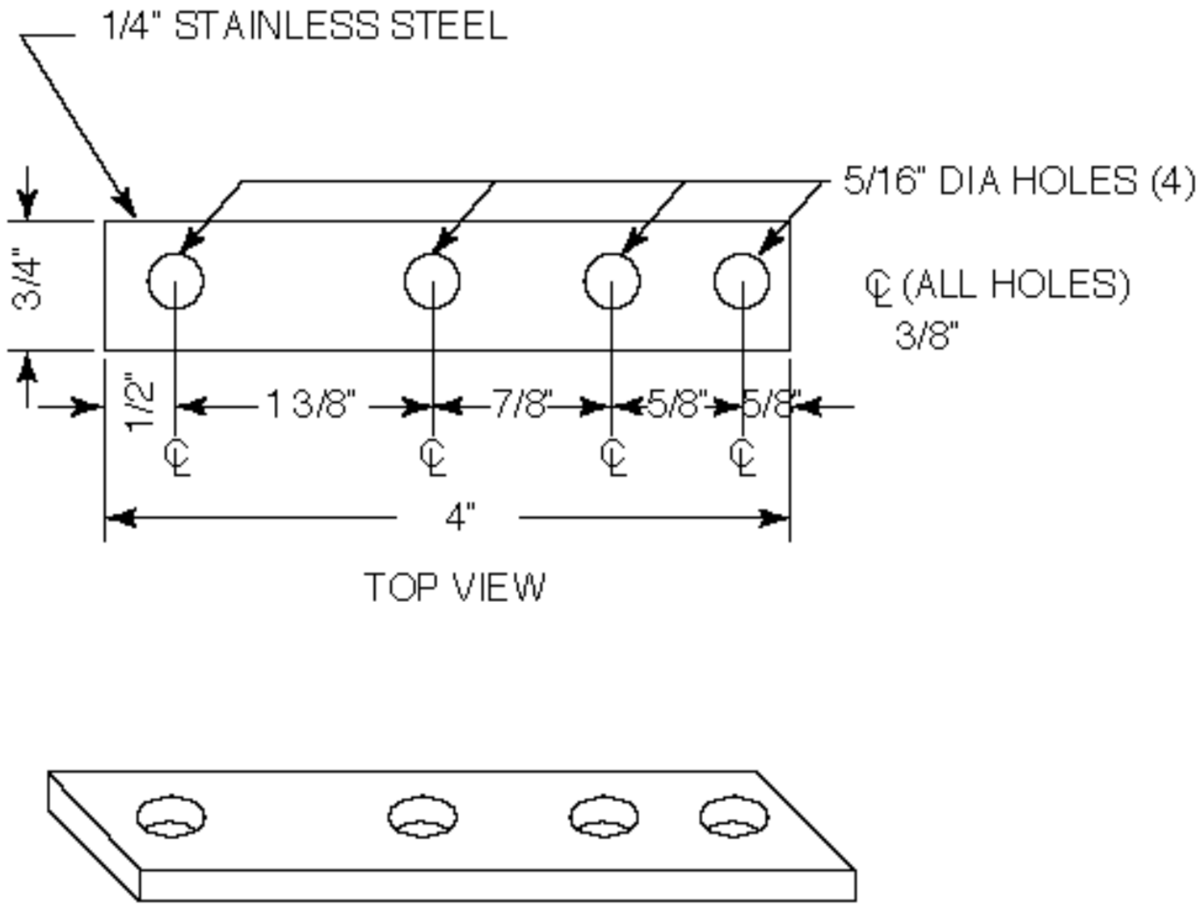
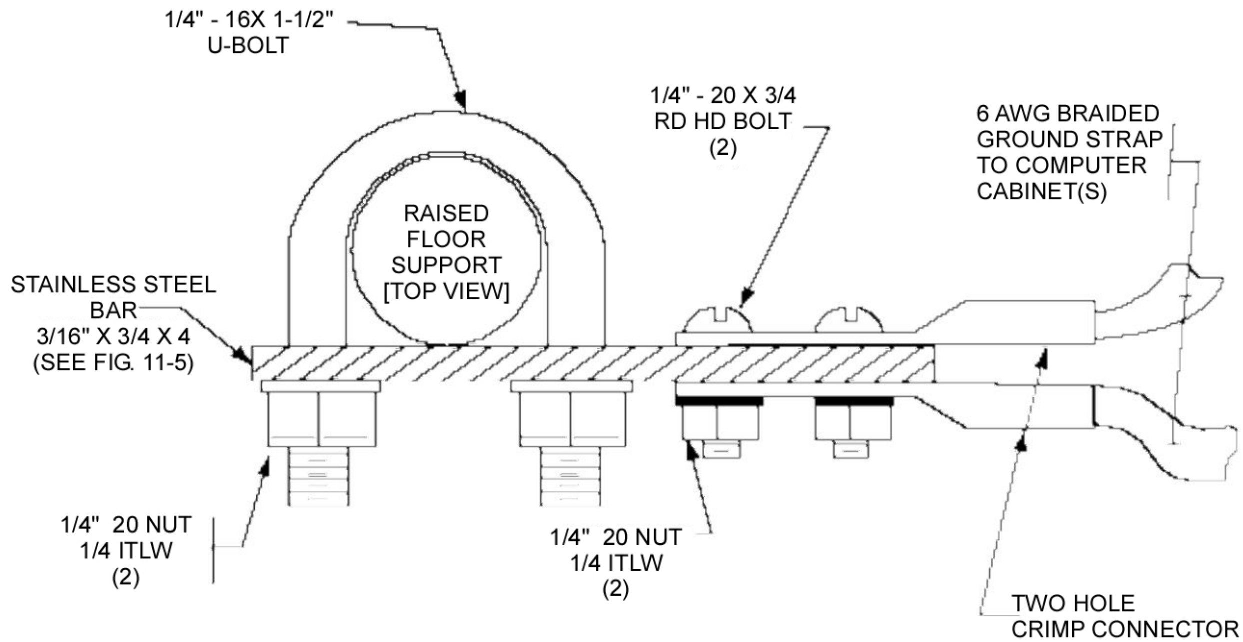


Figure 11-5: Computer Cabinet Grounding Bar



Notes:

1. A conductive non -oxidizing agent must be used on all metallic connections.
2. This configuration can also be used for square pedestals

Figure 11-6: Attaching Braided Strap to a Round Raised Floor Support Pedestal

CONTENTS

Chapter and Section **Page**

12. Definitions

12.1 Acronyms

A	Amperes (a measure of electrical current); or Absorbers
AC	Alternating Current; or Armored Cable
ACEG or AC EG	Alternating Current Equipment Ground (green-wire ground)
Ah	Ampere-hour (battery rating)
ANSI	American National Standards Institute
AWG	American Wire Gauge
10Base-T	10 Mbps ethernet Transmission
100Base-T	100 Mbps ethernet Transmission
Batt(s)	Battery (-ies)
BCT	Bonding Conductor for Telecommunications
BCW	Bare Copper Wire
BDB	Battery Distribution Board/Bay (Primary Power Plant distribution)
BDFB/BDCBB	Battery Distribution Fuse / Circuit Breaker Board/Bay
BET	Building Entrance Terminal (equivalent of a NID for a larger business)
BFR	Bona Fide Request (special request process for Collocators)
BICSI	Building Industry Consulting Services International
BR	Bellcore Requirements; or Battery Return
BRI	Business Resources Incorporated (old terminology for the Real Estate Services department within U S WEST)
BSP	Bell System Practice
BX	Armored Cable
Cat5	Category 5 twisted-pair ethernet cabling
Cat6	Category 6 twisted-pair ethernet cabling
CBN	Common Bonding Network (new term for integrated ground plane)
CDF	Combined Distribution Frame
CDO	Community Dial Office (small CO)

CEC	Controlled Environmental Cabinet (half-buried vault)
CEF	Cable Entrance Facility
CEGB	Cable Entrance Ground Bar/Bus
CEV	Controlled Environmental Vault
CLEC	Competitive Local Exchange Carrier (Collocator)
CLGB	Collocator's Local Ground Bar
CMGB	Collocator's Main Ground Bus
CO	Central Office
coax	coaxial cable
COE	Central Office Equipment
COGB	Central Office Ground Bus/Bar
COGF	Central Office Ground Field
config	configuration
CORM	Clamp-On Resistance Meter
CPE	Customer Premises Equipment
D-4	Digital Carrier System, 4^{th} generation
DA	Distribution Area (interface between F1 and F2 cable)
DC	Direct Current
DC-C	DC return Commonly bonded to the frame ground at the equipment (shared return)
DC-I	DC return Isolated from the frame ground (DCEG)
DCG	DC System Ground reference conductor
DCEG	DC Equipment Ground conductor
DISC*S	Digital Intelligent Subscriber Carrier System
DLC	Digital Loop Carrier
DLO	A flexible type of RHW power and grounding cable
DMM	Digital multimeter

DMS®	Digital Multiplex System (switching system made by Nortel)
DOD	U.S. Department of Defense
DS-1	Digital Signal Level 1 (1.544 Mbps data rate)
DS-3	Digital Signal Level 3 (44.736 Mbps data rate, with 28 DS-1s)
DSLAM	Digital Subscriber Line Access Multiplexer
DSX	Digital (system) Cross-Connect
E-911	Emergency 911
EEE	Electronic Equipment Enclosure
EIA	Electronic Industries Alliance
EMI	Electro-Magnetic Interference
EMT	Electrical Metallic Tubing
ENT	Electrical Non-metallic Tubing (flexible corrugated conduit)
ESD	Electrostatic Discharge
ESS	Electronic Switching System (see also SPCSS)
F1	Feeder copper cable (from electronics at CO/RT to SAI)
F2	Distribution copper cable (from SAI to homes/businesses)
FGB	DMS switch Frame Ground collection Bar; or Floor Ground Bar
FGE	Frame Ground Equalizer (equivalent to the DMS FGB)
FMC	Flexible Metal Conduit
FOG	Foreign Object Ground
FRWK	Framework
GB	Ground Bar/Bus
GE	Ground Equalizer
GEC	Grounding Electrode Conductor
genset	portable generator (engine-alternator)
GigE	Gigabit ethernet
GND or GRD	Ground
GPDF	Global Power Distribution Frame (for 5 ESS™ switches)
GPR	Ground Potential Rise

GPS	Global Positioning System (used to provide sync/timing)
GR	Generic Requirements
GWB	Ground Window Bar/Bus
HDSL	Hi-bit rate Digital Subscriber Line (carries DS-1)
HSP	House Service Panel (Commercial AC Service Entrance)
HVAC	Heating, Ventilation, and Air-Conditioning
I	symbol representing current, in Amperes; or Isolated
IBN	Isolated Bonding Network (new term for isolated ground plane)
ICB	Integrated Collector Bar (DMS foreign object ground collector bar)
ICDF	Inter-Connection Distributing Frame (Collocator cross-connect bay[s] — see also SPOT)
ICEP	Inductive Coordination and Electrical Protection
IDF	Intermediate Distributing Frame
IEC	International Electro-Technical Commission
IEEE	Institute of Electrical and Electronics Engineers
IG	Isolated Ground (receptacles for some computer rooms)
IGB	Intermediate Ground Bar (a bar sometimes used in non-IGZ areas in PANI offices as a collection point for frame grounds
IGP/IGZ	Isolated Ground Plane/Zone
IL	Information Letter
info	information
IOF	Inter-Office Facilities
ITLW	Internal Tooth Lock Washers
ITU	International Telecommunications Union
J-box	electrical Junction box
kcmil	the new designation for MCM (1 circular mil is equal to the cross-sectional area of a circle 1/1000th of an inch in diameter)
kW	kilo-Watts
LNS	Local Network Services of Lumen
LPDC	Local Power Distribution Cabinet (for 5 ESS™ switches)

LPS	Lightning Protection System
LRE/G	Logic Reference Equalizer/Ground (DMS Collector bar)
MAP	Managed Access Point (computer room for Class 4/5 switches)
max	maximum
Mbps	Megabits per second
MC	Metal-Clad cable
MCM	Thousand Circular Mils (old designation for kcmil)
MDF	Main Distribution Frame
MET	Main Earthing Terminal
(T)MGB	Main Ground Bus (in the Ground Window); or the RUS “standard” (PANI) Master Ground Bar (OPGP equivalent); or the (Telecommunications) Master Ground Bar
MGE	Made Ground Electrode (typically a driven rod ring/field)
MGN	Multi-Grounded Neutral
MH-0	Man-Hole 0 (the first Manhole outside the CO)
MI	Mineral-Insulated metal-clad cable
mi	mile
MIL	Military (Specification)
min	minimum
MOV	Metal-Oxide Varistor (one type of a surge protection component)
MPD	Main Power Distribution bay (Ericsson switch distribution bay)
NEBS	Network Equipment — Building System (a family of Telcordia documents governing physical safety, hazard, and electromagnetic compatibility of equipment)
NEC®	National Electrical Code®
NECA	National Electrical Contractors Association
NESC®	National Electrical Safety Code®
NFPA®	National Fire Protection Association®

NID	Network Interface Device (the terminal mounted on the side of a residence or small business that is the interface between the telephone company-owned equipment and the inside wiring owned by the subscriber – also known as a SNI)
NNS	National Network Services (Lumen long-haul network)
NRTL	National Recognized Testing Laboratory
OEM	Outside Equipment Manufacturer
OFC	Optical Fiber Cable
Ω	Omega (Ohms symbol, unit for Resistance/Impedance/ Reactance)
ONU	Optical Network Unit
OPGP or OPGPB	Office Principal Ground Point Bus (see also SPGP)
OSHA	Occupational Safety and Health Act
OSP	Outside Plant
PANI	Producers, Absorbers, Non-Isolated, and Isolated (a combined OPGP/COGB/MGB)
PBD	Power Board (Power Plant Distribution Bay — see also BDB)
PBX	Private Branch Exchange (small Customer Premises switch)
PD, PDC, PDF, etc.	Power Distributing Center, Cabinets, or Frames (secondary power distribution points for a switch — these are all given different names depending on the switch manufacturer and vintage)
PDSC	Power Distribution Service Cabinet (feeding AC to rectifiers)
PDU	Power Distribution Unit (AC distribution cabinet used in data centers)
PE	Protective Earth (international term)
P.E.	Professional Engineer
(S)PGP or SPGPB	(Site) Principal Ground Point Bus for non-CO applications
PIC(S)	Plug-In Cards / Circuit Packs; or Plastic Insulated Cable
Prem	customer Premises
PSAP	Public Service Access Point (911 call center)
PUC	Public Utility Commission
PVC	Polyvinyl Chloride (conduit/pipe)

R	Resistance
RBOC	Regional Bell Operating Company
RE	Remote Electronics
REA	Rural Electrification Association
Rect(s)	Rectifier(s)
RFI	Radio Frequency Interference
RGS	Ring Ground Systems
RHW-LS	Rubberized, High-temperature, Water-resistant, Low-Smoke – a type of approved cable (referring to the insulation type) for use in DC power and grounding circuits, typically with an insulation rating of 75°C – the insulation is often soft and rubber-like (but can be hard it is is cross-linked thermoset); when ordered for telecom power, it often comes with a cotton braid covering
RMC	Rigid Metal Conduit
ROW	Right of Way
RR	Relay Rack
RSM	Remote Switch Modules
RSU	Remote Switch Units
RT	Remote Terminal
RTN (or RET)	battery Return
RUS	Rural Utilities Service (a division of the USDA)
SAI	Serving Area Interface (Cross-Connect) cabinet
SLC	Subscriber Loop Carrier
SME	Subject Matter Expert
SNI	Subscriber Network Interface (see the definition for NID)
SPCB	Single-Point Connection Bus (new term for the MGB)
SPCSS	Stored Program Control Switch System (see also ESS)
SPCW	Single-Point Connection Window (new term for Ground Window)

SPD	Surge Protective Device (formerly known as a TVSS)
spec	Specification
SPG	Single Point Ground (isolated ground window bus)
SPOT	Single Point of Termination (old terminology for Collocator circuit cross-connect bay[s] — see also ICDF)
SRG	Signal Reference Grid
sync	Synchronization (timing)
T-1	T-carrier, signal level 1 (1.544 Mbps 4-wire copper data service)
TBB	Telecommunications Bonding Backbone (vertical riser)
TEBC	Telecommunications Equipment Bonding Conductor
TEF	Telecom Entrance Facility
telco	telecommunications company
telecom	telecommunications
TIA	Telecommunications Industry Association
TFFN	Thermo-plastic, Flexible, Fixture wire, with Nylon jacket (used for 16-20 AWG DC power and grounding often, instead of RHW, etc.)
TGB	Telecommunications Grounding Bar (generic term that can refer to any of the sub-bars for grounding in a building, such as the MDFGB, the CEGB, COGBs, FGBs, etc.)
THHN and THWN	Thermo-plastic, High-temperature, (Water-resistant), Nylon-jacket types of approved manufactured cable (the insulation actually) for use in AC circuits, with an insulation rating of 75 or 90 degrees C.
TIP	Telephone Inside Plant (cables)
TR	Technical Requirements
TVSS	Transient Voltage Surge Suppression (now known as an SPD)
UBC	Unit Bonding Conductor
UE™	Universal Enclosure (half-buried vault)
UL®	Underwriters Laboratory
USDA	United States Department of Agriculture

V	Volts
VA	Volt-Amperes (apparent Power)
VGR	Vertical Ground Riser
W	Watts (useable Power)
WiMAX	Worldwide interoperability for Microwave Access
X	Reactance (inductive or capacitive resistance to AC current flow)
XC	Cross-Connect (cabinet, for a DA)
XHHW	thermo-set, X- (cross) linked, High-temperature, Water-resistant — a type of approved manufactured cable (the insulation actually) for use in DC power and grounding circuits, with an insulation rating of 75 or 90 degrees C —the insulation is a "hard rubber-like" coating that includes a fibrous plastic liner (i.e., it does not need fiber wrapping at points of impingement with metal cable racking, etc.)
yr	year
Z	Impedance (measured in Ohms)

12.2 Glossary

ACEG(C) or AC EG

AC Equipment Ground Conductor is sometimes referred to as the green-wire ground.

Arrester

An arrester is a protection device used on power lines to limit the line-to-ground surge voltage caused by lightning.

Bonding

Bonding is the permanent joining of metallic parts to form an electrically conductive path to ensure electrical continuity and the capacity to safely conduct imposed current.

Cable

A conductor with or without insulation, or a combination of conductors with insulation in a protective sheath. For individual conductors, this term is often used interchangeably with "wire".

Cable Entrance Facility (CEF)

A cable entrance facility is a dedicated space in the central office where cables enter from the outside plant network. Electrical protection measures here protect the CO from the outside plant environment. This is often a below-ground "vault".

Carbon Blocks

Carbon blocks are voltage limiting protection device containing machined blocks of carbon which provide a spark gap that discharges when the spark initialization voltage is reached. The spark initialization voltage is determined by the physical separation between the carbon blocks. (More modern SPD devices use electronic components, like MOVs, or gas tube air gaps.)

Central Office Ground (CO GRD)

Central Office Ground is a system of conductors designed to provide a low impedance connection to the building principal ground point. The system consists primarily of a vertical equalizer, CO GRD buses, and horizontal conductors. The system provides ground reference for frames and power supplies.

Central Office Ground Bus (CO GRD BUS or COGB)

A COGB is a bus bar that references the principal ground point through the vertical equalizer. Usually, one or more of these buses is provided on each floor to permit the grounding of frames and power supplies as required. Larger buildings may have more than one of these buses.

Conductor

A conductor is a material, usually in the form of a wire, cable, or bus bar, suitable for carrying an electric current.

Conduit

Conduit is a tubular raceway for holding wires or cables, which is designed expressly for, and used solely for, this purpose. Conduit differs from pipe and metallic tubing in that it is not normally used to conduct liquids or gasses.

Duct

A duct is a single enclosed raceway for conductors or cable.

Earth Resistivity

Earth resistivity is the DC resistance of the soil on a per unit basis. The commonly used unit of measure is the meter-ohm, which refers to the resistance measured between opposite faces of a cubic meter of soil. It is the reciprocal of earth conductivity, which is expressed in an ohmic reading.

Effective Ground

Effective Ground refers to a planned and intentional connection to earth of sufficiently low impedance and having sufficient current-carrying capacity to prevent voltage buildups that may result in undue hazards to personnel and/or equipment.

Gas Tube Protector

A gas tube protector is a voltage limiting protection device containing gas tube protector units. The gas tube consists of a spark gap or gaps that discharge in a gas atmosphere within a sealed envelope.

Ground

Ground refers to a conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.

Example: The earth is considered a "ground" itself. It is the principal ground point, and all other planned or unplanned grounding connections lead to the principal ground point, the earth.

Grounded

Grounded refers to a connection to earth or to some conducting body that serves in place of earth. A ground grid or office electrode system are examples of the conducting bodies that serve as a connection to earth.

Grounded Conductor

A grounded conductor refers to an intentionally-grounded system or circuit conductor.

Example: The conductor usually referred to as the "grounded conductor" is the one identified as "the neutral" in AC circuits and "return" in DC circuits.

Grounding Conductor

A grounding conductor is used to connect equipment or the grounded circuit of a wiring system to grounding electrode(s). Some examples of grounding conductors are:

- The vertical equalizers (also called vertical risers) in multistory buildings.
- The grounding conductors used to interconnect frames in a Stored Program Controlled Switching System (SPCSS).
- The Alternating Current Equipment Ground (ACEG), also called "the green-wire", used to provide fault current return path on grounded frames in AC power systems.
- The equipment bonding jumper used to connect the grounded conductor (the neutral) to the ground bus in AC entrance switch gear.
- The grounding conductor that interconnects frames in transmission equipment.
- The grounding conductor used to interconnect the shield for telephone cables.

Grounding Electrode Conductor

The grounding electrode conductor used to connect the grounding electrode to the equipment grounding conductor and/or to the grounded conductor of the circuit at the service equipment or at the source of a separately derived system. The following are examples of grounding electrode conductors:

- A conductor that references the return bus of a DC plant to a ground source bus.
- In a building's AC entrance switchgear, the conductor that connects the insulated neutral bus with the OPGP / PANI- MGB or the water pipe.
- In separately derived AC power sources such as transformers, the conductor that interconnects the frame of the transformer to the nearest ground reference.

Ground Impedance

Ground impedance is the impedance of the contact between the soil and a grounding electrode. Ground impedance is not a measure of the current carrying ability of the electrode. This value should be as low as economically feasible.

Ground Mat

A ground mat (sometimes called a ground grid or array) is an extensive system of bare conductors buried below the surface of the earth. The ground mat is intended to provide a low impedance connection to earth and equalize potentials within the area.

Ground Potential Rise (GPR)

Ground potential rise is a voltage difference between grounding electrodes caused by conduction of earth return currents. A ground potential rise occurs most often when power fault current is conducted to ground. However, when lightning currents are conducted to ground at a protector, cable pairs may be subject to GPR.

Ground Window or Single-Point Connection Window (SPCW)

A ground window is a dimensional transition zone which is the interface between the building's integrated ground plane and a given isolated ground plane.

Heat Coil

A heat coil is a current limiting protection device that grounds a conductor when overheated by current due to power contact or induction. It is used as protection against current caused by voltages insufficient to cause operation of the carbon block, gas tube or solid-state voltage limiting protection device.

House Service Panel (HSP)

The house service panel is the main AC panel(s) where commercial AC enters the building and is then distributed.

Horizontal Equalizer

A relatively low impedance conductor that interconnects buses on the same floor of a building that require the same potential reference. When a number of buses are interconnected, they are sometimes connected in a ring configuration that allows all buses to share the same path.

Incidental Ground

Incidental ground is an unplanned grounding connection.

Example: Incidental grounds usually occur during the mechanical assembly and installation of frames, raceways, piping, ducts, superstructure, and other conductive objects. When the frames are bolted to adjacent frames, a superstructure, and/or the superstructure to ceiling inserts in contact with building steel, they can form incidental ground connections.

Note: Incidental ground connections from building steel to isolated ground planes are not permitted. Incidental grounds should not be depended upon to produce a reliable electrical connection. Painted and oxidized surfaces and loose mechanical connections tend to insulate adjacent conducting surfaces.

Induction (Electric)

Electrical induction refers to voltage controlled currents induced in a telephone line by capacitive coupling from the electric field of a nearby power line.

Induction (Magnetic)

Magnetic induction refers to currents induced in a telephone line by inductive coupling from the magnetic field of a nearby power line.

Insulating Joint

An insulating joint is a splice in a cable sheath made so that continuity of the sheath, shield, metallic strength member and metallic moisture barriers are deliberately interrupted (by a capacitor that will allow AC currents to flow) to prevent the flow of electrolytic currents (DC) that may cause corrosion.

Integrated Ground Plane or Common Bonding Network (CBN)

An integrated ground plane is a set of interconnected frames that is intentionally grounded by making more than one connection to a ground reference. Examples of integrated ground planes are radio, transmission ("toll") equipment frames and the main distributing frame.

Isolated Ground Plane or Isolated Bonding Network (IBN)

An isolated ground plane is a set of interconnected frames intentionally grounded by making only one connection to a given ground reference. This plane, taken as a conductive unit with all its metallic surfaces and grounding wires bonded together, is insulated from contact with other grounded metalwork in the building. During external fault occurrences in AC or DC power systems and when lightning flows in the building, none of these currents can flow in the isolated ground plane because of the single-point connection. Each SPCSS grounded in this way is defined as an Isolated Ground Plane.

(Main) Aisle Feeder/Equalizer

750 kcmil horizontal equalizers extend ground potential into the different areas of a given floor. Smaller conductors (1/0 AWG through 350 kcmil) may branch off into a main aisle to further extend this ground potential. These conductors in main aisles are typically referred to as main aisle feeders or main aisle equalizers.

Main Ground Bus (MGB) or Single-Point Connection Bus (SPCB)

A single-point connection bus is a busbar (or busbars) located within the ground window that provides the electrical interface for connections between the building's integrated ground plane and the isolated ground plane.

Master Ground Bar (MGB)

A Master Ground Bar is the RUS PANI concept equivalent of a Telcordia isolated-integrated ground plane system OPGP.

Multi-Grounded Neutral (MGN)

The MGN should not be confused with the ACEG. The power utility does not run an ACEG in its transmission and distribution systems. Instead, they periodically ground the neutral conductor. For this reason, the neutral conductor (among the phase conductors delivered to us) is considered “multi-grounded”.

Office Ground Electrode

An office ground electrode refers to the ground electrode whose extension into the building is used as the Office Principal Ground Point Bus (OPGPB) for connection to equipment grounding systems serving communication and computer installations.

Office Principal Ground Point Bus (OPGPB) — Also applies to SPGP(B)

An Office Principal Ground Point Bus is located near, but external to, the AC entrance switch gear. It is bonded to the neutral bus and to the frame of AC entrance switchgear. All main grounding conductors and electrodes connect to the OPGPB. In the past, the principal ground point often was the metallic cold water pipe into the building. Use of insulating couplings and nonmetallic water pipes in water systems now make water pipes, at worst, unreliable as grounding electrodes and, at best, supplemental grounding electrodes. A suitable grounding electrode is now required as a substitute for the water pipe. Suitable grounding electrodes, not in order of preference, are:

- Ground rings or grids
- Ground rods or ground rod arrays
- Well casings or backfilled wells or rods
- Supplemental ground fields (as defined in Section 3.2.8)
- Structural steel ground grids
- Any combination of the above

Optical Fiber Cable

A fiber optic communications cable contains optical fibers as the primary transmission medium. The cable may or may not contain metallic components. Strength members may also be non-metallic.

Peripheral Bus

In this document, peripheral bus refers to an interior conductor ring surrounding a radio equipment area (see Figures 3-7 and 7-1).

Pipe

A pipe is usually a circular tube designed to carry liquids or gasses. It is sometimes incorrectly used interchangeably with conduit or duct.

Protector

A protector is a device consisting of one or more carbon block, gas tube or solid-state protector units and a mounting assembly for limiting abnormal voltages on communications circuits.

Raceway

A raceway is a channel or enclosure designed expressly for holding wires, cables, or busbars, with additional functions as permitted in the NEC® (see NEC 250® and the definitions in Section 100).

Radial Grounding or Star-IBN

A system is radially grounded when two or more sets of frames of the same system are grounded by using a separate grounding conductor from a common grounding point (see Figure 8-2).

Reference Point 0

Reference Point 0 is the point at which all grounds within a Central Office building are referenced to earth.

Separately Derived Power Supply

A separately derived power supply has electrical isolation between its input and output current carrying members (see NEC® Articles 250.30 and 100; as well as Telcordia GR-295).

Serial Grounding or Chain-IBN

A system is serially grounded when a set of isolated ground frames in the system is connected in series from its associated ground window (see Figure 8-2).

Service

The "service" refers to the conductors and equipment for delivering electric energy from the serving utility to the wiring system of the premises served.

Service Entrance (see House Service Panel)

Single Point Ground (For Frames)

A single-point ground is a method used to ground a set of equipment frames for a given electronic entity that can have only one ground connection from the given set of frames to a planned ground reference. Because this set of frames does not have multi-connections (either planned or incidental) to other ground references, it is classified as an isolated ground plane. This grounding is mostly used for switches (and in a modified form for computer rooms).

Single Point Ground (For Power Supplies)

Single-point ground refers to power supplies when one current-carrying member of a separately derived power source is connected to a ground reference at only one point, it is single-point grounded. (In contrast to this, grounded conductors having more than one connection to a ground reference along their length are classified as a multi-grounded system.) Examples include:

- The DC source feeding isolated ground loads has a single ground connection from the insulated -48 volt power plant return bus to the ground window of the system.
- The entrance AC power to a building is grounded by a single connection from its neutral to the main grounding electrode.
- An example of a multi-grounded system (also known as common DC return) is:
  - A -48 volt source that feeds some integrated ground plane older digital loop carrier (DLC) and IOF carrier systems (such as SLC-96, DISC*S, D-4, some older T-carrier, etc.). These loads are grounded at the power source, at the BDFBs and at the loads (where the return conductor is also bonded to the frame ground).

Sleeve

A sleeve is a metallic or plastic hollow body typically placed through a wall, floor, or ceiling to provide a path for cabling through that wall or floor/ceiling. In this usage, a sleeve (especially a cylindrical type) is sometimes called a conduit. However, a sleeve is typically larger in diameter and shorter in length than a conduit.

A sleeve can also refer to the grounded insulating "shield" around telephone cables designed to protect them from noise or lightning.

Stringer

Above each individual aisle/lineup is a grounding conductor (typically #2 AWG). This individual aisle ground conductor is typically referred to as an (aisle) stringer because it is "strung" along the outside of the cable rack and above the lineup. The individual equipment frames/bays/relay racks tie into the stringer with #6 AWG pigtails.

Surge Protective Device (SPD) (Transient Voltage Surge Suppression)

Surge Protective Device refers to a family of devices that prevent voltage surges (including those caused by lightning) from passing to sensitive electrical and electronic equipment. In telecommunications, SPD’s are typically installed at exposed ends of copper pairs (including at the MDF and the home), and on the AC Service Entrance, among other places. SPD’s may use carbon filaments, gas tubes, MOVs or other solid state devices, or any combination of the above.

NOTE: SPD’s are rated for either AC or DC voltages. When installed at a Lumen facility, the SPD’s used shall be the correct voltage type and rating.

Ufer Ground

A Ufer ground is a concrete-encased metal electrode, at least partially in contact with the earth. It is named after Herb Ufer who proved that metal (including rebar) inside of concrete in contact (especially fully or partially buried) with the earth makes an excellent ground electrode.

Vertical Equalizer (or) Riser

The vertical riser is the main vertical grounding conductor used to obtain ground reference between the GRD BUS on each floor and the OPGPB in a building. The conductor must be continuous or exothermic welded, extending through the height of the building. This conductor is bonded to the OPGPB. On each floor, the CO GRD BUS connects to the vertical equalizer to form an effective earth reference.

Wire

A wire is a slender rod or filament of conductive metal (or grouping of several of these). It may or may not have insulation. The term is often used interchangeably with "cable" or "conductor".

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Chapter and Section **Page**

13. References

13.1 Industry Standards Documents and Codes

ATIS 0600313	*Electrical Protection for Telecommunications Central Offices and Similar Type Facilities*
ATIS 0600316	*Electrical Protection of Telecommunications Outside Plant*
ATIS 0600318	*Electrical Protection Applied to Telecommunications Network Plant at Entrances to Customer Structures or Buildings*
ATIS-0600321	*Electrical Protection for Network Operator-Type Equipment Positions*
ATIS 0600333	*Grounding and Bonding of Telecommunications Equipment*
ATIS 0600334	*Electrical Protection of Communications Towers and Associated Structures*
IEC EN-50310	*Application of Equipotential bonding and Earthing in Buildings with Information Technology Equipment*
IEEE/ANSI C2	*National Electrical Safety Code*
IEEE/ANSI 81	*IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System*
IEEE 142	*Recommended Practice for Grounding of Industrial and Commercial Power Systems (Green Book)*
IEEE/ANSI 487	*IEEE Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Power Stations*
IEEE 1100	*Recommended Practice for Powering and Grounding Electronic Equipment (Emerald Book)*
IEEE 1657	*Recommended Practice for Personnel Qualification for Installation and Maintenance of Stationary Batteries*
ITU-T K.27	*Bonding Configuration and Earthing Inside a Telecommunication Building*
NECA/BICSI-607	*Standard for Telecommunications Bonding and Grounding Planning and Installation Methods for Commercial Buildings*
NFPA 70HB®	*National Electrical Code (NEC®) Handbook*
NFPA 76®	*Standard for the Fire Protection of Telecommunications Facilities*
NFPA/ANSI 780®	*Standard for the Installation of Lightning Protection Systems*

TIA/EIA-222	*Structural Standards for Steel Antenna Towers and Antenna Supporting Structures*
TIA/ANSI J-607-B	*Generic Telecommunications Bonding and Grounding (Earthing) for Customer Premises*
UL 44	*Thermoset-Insulated Wires and Cables*
UL 83	*Thermoplastic-Insulated Wires and Cables*
UL 96	*Standard for Lightning Protection Components*
UL 467	*Grounding and Bonding Equipment*
UL 486A-B	*Wire Connectors*
UL 486C	*Splicing Wire Connectors*
UL 486E	*Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors*
UL 497	*Standard for Protectors for Paired-Conductor Communications Circuits*
UL 497A	*Standard for Secondary Protectors for Communications Circuits*
UL 497B	*Standard for Protectors for Data Communications and Fire-Alarm Circuits*
UL 497C	*Standard for Protectors for Coaxial Communications Circuits*
UL 2200	*Stationary Engine Generator Assemblies*
UL 2201	*Portable Engine Generator Assemblies*

13.2 Ericsson (formerly Telcordia and Bellcore) and Bell System Documents

BR 802-001-195	*General Ground Requirements for ESS and Power*
BR 802-010-100	*Use of a Clamp-On Resistance Meter*
BR 876-310-100	*Electrical Protection of Communications Facilities Serving Power Stations*
BSP 802-001-196	*Protective Grounding Systems — General Grounding Requirements for Data Processing Computer Systems*
BSP 802-001-197	*Protective Grounding Systems — General Equipment Requirements for Microwave Radio and Auxiliary Station*
BSP 802-001-198	*Protective Grounding Systems — General Equipment Grounding Requirements for AC Service Distribution Systems*

GR-63-CORE	*Network Equipment — Building System (NEBS) Requirements: Physical Protection*
GR-295-CORE	*Mesh and Isolated Bonding Networks: Definition And Application To Telephone Central Offices*
GR-487-CORE	*Electronic Equipment Requirements*
GR-1089-CORE	*Electromagnetic Compatibility and Electrical Safety — Generic Criteria for Network Telecommunications Equipment*
GR-1275-CORE	*Central Office / Network Environment Equipment Installation/Removal* GR-1502-CORE *Central Office / Network Environment Detail Engineering*
IL-87/07-059	*Grounding Requirements for Rooftop-Mounted Antenna Towers*

13.3 Government Specifications

MIL-HDBK-419A	*Grounding, Bonding, and Shielding for Electronic Equipments and Facilities*
MIL-F-29046	*Flooring, Raised, General Specification For*
REA 1751F-802	*Electrical Protection Grounding Fundamentals*
RUS 1753E-001	*General Specification for Digital Stored Program Controlled Central Office Equipment*
RUS 1751F-801	*Electrical Protection Fundamentals*
RUS 1751F-810	*Electrical Protection of Digital and Lightwave Telecommunications Equipment*

13.4 Lumen/ CenturyLink Technical Publications

PUB 77321	*Protection of CenturyLink Facilities Serving Electrical Supply Locations*
PUB 77339	*Enhanced 911 (E-911) Public Service Access Point (PSAP) Environmental Specifications and Equipment Installation Guidelines*
PUB 77350	*Telecommunications Equipment Engineering, Installation and Removal Guidelines*
PUB 77351	*Engineering Standards General Equipment Requirements*
PUB 77368	*Customer Premises and Carrier Hotels Electronic Equipment Environmental Specifications and Installation Guide*

PUB 77385	*Power Equipment and Engineering Standards*
PUB 77419	*Specifications for the Placement of CenturyLink Equipment in Customer-Owned Outdoor Cabinets*

13.5 Ordering Information

All documents are subject to change and their citation in this document reflects the most current information available at the time of printing. Readers are advised to check status and availability of all documents.

American National Standards Institute (ANSI) documents from:

American National Standards Institute
Attn: Customer Service
11 West 42nd Street
New York, NY 10036
Phone: (212) 642-4900
Fax: (212) 302-1286
www.ansi.org

Alliance for Telecommunications Industry Solutions (ATIS) documents from:

Alliance for Telecommunications Industry Solutions
1200 G St. NW, Ste. 500
Washington, DC 20005
Phone: (202) 628-6380
Fax: (202) 393-5453
www.atis.org

Lumen/ CenturyLink Technical Publications from:

www.Lumen.com/techpub

IEC documents from:

International Electrotechnical Commission
3, rue de Varembé
P.O. Box 131
CH – 1211 Geneva 20
Switzerland
Phone: +41 22 919 02 11
Fax: +41 22 919 03 00
www.iec.ch

IEEE documents from:

IEEE Customer Service Center
445 Hoes Lane
Piscataway NJ, 08855-1331
Phone: (800) 678-4333
Fax: (732) 981-9667
www.ieee.org

ITU documents from:

International Telecommunications Union (ITU)
Place des Nations
1211 Geneva 20
Switzerland
Phone: +41 22 730 6141
Fax: +41 22 730 5194
www.itu.int

MIL SPECs from:

www.assistdocs.com

NECA documents from:

National Electrical Contractors Association
3 Bethesda Metro Center, Ste. 1100
Bethesda, MD 20814
Phone: (301) 657-3110
Fax: (301) 215-4500
www.necanet.org

NFPA documents from:

NFPA Customer Sales
1 Batterymarch Park
Quincy, MA 02269-9101
Phone: (800) 344-3555
Fax: (617) 770-0700
www.nfpa.org

Telcordia documents from:

Ericsson Inc.
Customer Service Center (IDO)
One Ericsson Drive
Piscataway, NJ 08854-4156
Phone: (844) 251- 0201 (USA and Canada)
(913) 241- 6682 (All others)
https://telecom-info.telcordia.com/site-cgi/ido/docs2.pl?ID=251466554&page=doc_center

TIA/EIA documents from:

Telecommunications Industry Association
2500 Wilson Blvd., Ste. 300
Arlington, VA 22201
Fax: (703) 907-7727
Phone: (703) 907-7700
www.tiaonline.org

USDA RUS documents from:

United States Department of Agriculture Rural Development
1400 Independence Ave. SW
Washington, DC 20250-0107
Phone: (202) 720-8674
www.rurdev.usda.gov/RDU_Bulletins_Telecommunications.html

UL documents from:

Underwriters Laboratories
Phone: (888) 853-3503
www.ul.com

13.6 Trademarks

CEC	Trademark of Oldcastle Precast / Utility Vault
D-4	Trademark of Lucent Technologies
DISC*S	Trademark of Tellabs
DMS	Trademark of Genband (formerly of Nortel)
ESS	Trademark of Lucent Technologies
SLC	Trademark of Lucent Technologies
UE	Trademark of Emerson Network Systems