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Grounding - Central Office and Remote Equipment Environment

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NOTICE

This publication presents U S WEST 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 a Central Office buildings or Remote Equipment Enclosures.

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CONTENTS

Chapter and Section **Page**

CONTENTS (Continued)

CONTENTS (Continued)

Chapter and Section **Page**

CONTENTS (Continued)

Chapter and Section **Page**

CONTENTS (Continued)

Chapter and Section **Page**

CONTENTS (Continued)

Chapter and Section **Page**

CONTENTS (Continued)

Chapter and Section **Page**

CONTENTS (Continued)

CONTENTS (Continued)

Figures (Continued) **Page**

CONTENTS (Continued)

Figures (Continued) **Page**

CONTENTS (Continued)

Figures (Continued) **Page**

CONTENTS

Chapter and Section **Page**

1. Introduction

1.1 General

This publication presents QWEST'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 (RSUs / RSMs), or other telecommunications equipment that is installed within a building, normally referred to as a Central Office building. The publication also covers grounding requirements and principles for remote equipment enclosures, such as Controlled Environmental Vaults (CEVs), huts, Remote Terminal (RT) cabinets, and Customer Premises equipment installations.

CONTENTS

Chapter and Section **Page**

2. General Requirements

2.1 Reason for Grounding

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 / or ground system shall be grounded so that shock potentials are not transmitted to personnel. The grounding and bonding of metallic frames and raceways will minimize potential differences between these structures when lightning or fault currents flow.

2.1.2 Equipment and Distribution Circuit Protection

If the grounding and bonding system is of sufficiently low impedance, overcurrent devices (i.e., fuses and circuit breakers) may disconnect faulted circuits to prevent electrical fires and limit damage to equipment or circuit conductors.

2.1.3 Electrostatic Discharges (ESD)

The effects of ESD are minimized by maintaining a bonded environment of low impedance paths between grounded points throughout the ground plane or system. Many metallic parts of the ground plane are capable of storing electrostatic charges, and care must taken during the installation and maintenance of ESD sensitive devices to ensure that static electricity is discharged to well-grounded frames.

2.1.4 Reliability

The grounding system should resist deterioration and require minimal maintenance.

2.1.5 Equipment Operation

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

2.1.6 Noise Reduction

The grounding system should minimize electrical interference by maintaining low impedance bonding paths between ground points throughout the communication system and prevent or minimize the injection of noise currents and RF energy into isolated ground planes.

CONTENTS

Chapter and Section **Page**

Figures

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, and moisture. The following factors that can affect the impedance to earth of a grounding electrode include:

- Temperature affects the resistivity, which decreases at higher temperatures and drastically increases when the moisture in the earth freezes (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 rods or other 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 or other objects can affect the zone of influence required for proper electrode soil bonding. Where possible, placement of grounding electrodes shall 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.

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

Before installing an earth electrode system at a CO, CdO, or Radio site, a soil resistivity measurement shall be made to determine the earth resistivity of the surrounding site and to determine what type of ground electrode system should be used. After installing the ground electrode, the system should be tested prior to connecting the system to other ground electrodes. The impedance of the ground electrode system measured with an earth megger (proper use of a meg-ohmeter for measuring earth resistivity and impedance to earth is described in IEEE Std 81), should be 5 ohms or less. (Although a “megger” is the most reliable method of measuring the impedance to earth, use of clamp-on resistance meters [CORMs] for taking these measurements has been gaining in popularity. Proper usage procedures for a CORM are outlined in Bellcore BR 802-010-100; but even when followed there is a high potential for misapplication when trying to measure impedance to earth. For this reason their use for measuring the impedance to earth of a ground electrode system is generally discouraged. If an existing ground electrode system cannot be disconnected to measure impedance to earth with a megger, a properly used CORM might prove useful. CORMs are especially useful for measuring continuity or isolation [see Sections 3.4, 6.3, and 8.23.4].) If a 5 ohm impedance cannot be obtained, contact the local U S WEST Electrical Protection Engineer for assistance. For Outside Plant (OSP) locations such as CEVs, huts, Remote Terminal (RT) cabinets, etc., exceptions can be made. For these sites, this requirement to measure soil resistivity and obtain 5 ohm impedance may not always be realistically done. Although soil resistivity tests and 5 ohm impedance are desired, these types of locations shall only be held to the requirements of Chapter 10 of this document, and resistivity of the ground electrode system (in conjunction with the electric utility’s multi-grounded neutral [MGN]) shall not exceed the 25 ohms referenced in NEC Article 250-56.

Office ground electrodes employed in U S WEST telephone installations are (1) the power utility’s multigrounded neutral, (2) public water system pipes, (3) private well casings, or (4) made grounding electrodes such as ground rings, ground grids, or ground rod arrays.

3.2 Acceptable Methods

The acceptable methods for establishing a Central Office Ground Electrode are listed below, in order of preference.

3.2.1 Ground Ring

Driven rods, which individually represent rather modest contact with earth, are used in multiple and bonded together with wire to create a common electrode. They are arranged in a pattern around the site perimeter to equalize potential in earth in the area of the site. The primary conductor of a ground ring system circles the entire structure and is extended into the site by at least two conductors, connected at opposite sides of the ring and terminated at the OPGPB or interior ring 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). If there is no existing OPGPB, then one should be established. The exterior ring shall be connected to the top of the stainless steel ground rods, spaced not less than 10 feet or more than 15 feet apart around the ring, by means of a suitable exothermic weld connection or approved compression connection. For size of driven rods, see paragraph 3.3. All buried connections of No. 2 splices shall also be exothermic weld or an approved compression connection designed for solid wire.

- • The minimum length of ground rod(s) used in a driven ground, ring ground, or a supplementary 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 shall be installed at least 18 inches 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). Ufer ground systems that are located above the frost line, and susceptible to freezing, are not acceptable.
- • 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 2-1/2 feet (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 250-52c3).

- • The exterior ring shall be connected to the top of the ground rods by means of a suitable exothermic weld connection or an approved compression connection designed for solid wire. All buried wire connections shall also be exothermic welded or approved compression connections

3.2.2 Deep Driven Rod

A 5/8 inch stainless steel rod shall be driven down to a minimum of 40 feet and a reading of 5 ohms or less must be obtained (the 5 ohms pertains to CO type sites — see Chapter 10 for requirements for OSP types of sites). After obtaining this reading, then 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 OPGPB with a minimum of two No. 2 AWG solid copper conductors (or if stranded conductors are used, they must be of the insulated type and run in PVC conduit from the composite box back into the building). All connections to the rod must be treated with a copper-coat or other corrosion prevention product. Make sure that all connections are pointed downward, with a minimum 12 inch bending radius.

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 fifteen feet apart, 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. For Central Offices, locations with 2500 lines or less require a grid with a minimum of 6 rods. Locations which exceed 2500 lines require a grid with a minimum of 12 rods. As with the ground ring, the rods are spaced between 10 feet and 15 feet apart. The array is installed 18 inches below grade, all connections are made with exothermal welds, and two conductors from opposing corners are extended into the Central Office and connected to the OPGPB. If no OPGPB exists, one shall be established.

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, 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 18 inches below grade.

3.2.5 Well Casings

Well casings, which generally penetrate earth to a considerable depth, constitute an excellent electrode with massive current dissipating ability. It may be economical to install well casing and pipe as a supplementary ground system rather than 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 at existing buildings will cause considerable expense. While the National Electric Code (Article 250-81) requires that the buried portion of the system be not less than 10 feet (3.05m), for U S WEST 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 supplementary ground field will be more economical than a well supplied for grounding purpose only, unless special cost considerations are a factor.

3.2.6 Deep Well Ground

A single 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 two and one half feet below grade level. The down 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:

$$Z = \frac{R\,[\ln(96L / d)\ -\ 1]}{(191.5)\,L}$$

WHERE:

ln = Natural logarithm (base “e” [exp]) of the quantity in parentheses.

Z = ESTIMATED GROUND RESISTANCE AT A FREQUENCY MUCH LOWER THAN LIGHTNING. Due to soil ionization around the casing at lightning frequency, this value may be reduced by a factor of two during actual lightning current flow. For calculation purposes, design all well grounding systems so that Z is less than or equal to 2 ohms.

L = LENGTH OF WELL CASING IN FEET. A minimum of 20 feet must be used for any single well casing regardless of R value. The maximum casing length is limited to 250 feet.

d = DIAMETER OF WELL CASING IN INCHES. A 2 inch minimum is required.

R = AVERAGE SOIL RESISTIVITY IN METER-OHMS AT THE WELL SITE AND CASING PENETRATION DEPTH. The following range of resistivity values may be used as a guide for preliminary calculations. For the final design, use values obtained from a MEGGER FOUR-TERMINAL ground resistivity test.

SOIL COMPOSITION	METER-OHMS
Sea water (reference)	1 - 2
Clay with no sand or gravel	3 - 160
Clay mixed with sand & gravel	10 - 1,350
Chalk, shale, or sandstone	60 - 800
Sand and gravel mixture	300 - 5,000
Quartzite, granite rock	500 - 10,000

3.2.7 Backfilled Wells

In rocky areas, it may be nearly impossible to find naturally occurring soils nearby that are good enough to obtain a decent 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 piping (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 grade concrete. Then the system is initially “watered”.

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

3.2.8 Supplementary Grounding Electrodes

Many below-ground structures are available for use as supplementary grounding electrodes (supplementary means that at least one of the methods described in Sections 3.2.1 to 3.2.7 must be used as a primary grounding electrode). Some are described on the following pages:

Public Water Systems - Public water pipes, though always buried below frost lines, can no longer be considered reliable due to increased use of insulating couplings and nonmetallic water pipes. However, if metallic water pipes are available, they provide an excellent surface contact with a large surface area of permanently moist earth and may be used as a supplementary electrode to good effect.

Central Office Buildings with Basements - Figure 3-2 illustrates the following recommended methods of establishing a supplementary ground field for buildings having basements:

- • Electrical continuity through columns via structural steel, or welded or wire strapped reinforcing bars.
- • Reliable continuity through column steel.
- • Since there are a large variety of construction methods, a supplementary ground field must be designed to fit the unique requirements of the building by the grounding system designer.

\- Figure 3-2, Plan "A" - Plan "A" consists of ground rods at every column footing.

\- Figure 3-2, Plan "B" - "B" illustrates a typical configuration recommended for use in buildings that do not have continuity through vertical columns. The ground field conductors are run in proximity to (within 2 feet) the column footing but are not bonded thereto. Minimum requirement for ground rods, at columns on the peripheral conductor ring only, is shown. Additional rods near interior columns may be employed at the discretion of the designer. The ground field conductors, bonded either to steel columns or run near footings of reinforced concrete columns, provide a low impedance path for currents that may seek earth through the columns. These bare conductors effectively disperse the current over a wide area to driven rods on the periphery of the building where permanently moist earth is most probable. Contact of the bare wire with earth adds to the contact surface afforded by rods, to reduce the effect of earth resistivity. The wire, which bonds the driven rods into a widely dispersed common electrode, also acts as an equalizer that minimizes difference of potential in the earth under the building. The ground field shall be connected to the building OPGPB with at least two conductors originating from opposite sides of the field. These connections afford paths to the ground electrode for currents imposed on the equipment grounding system within the building and provides earth potential reference to the communication and electrical power systems therein. Generally, Plan "A" will provide an adequate ground electrode, but Plan "B", or any plan within the minimum / maximum parameters of Plans "A" and "B" may be employed at the discretion of the ground system designer.

Buildings without Basements — 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.

Existing Building Additions — 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.

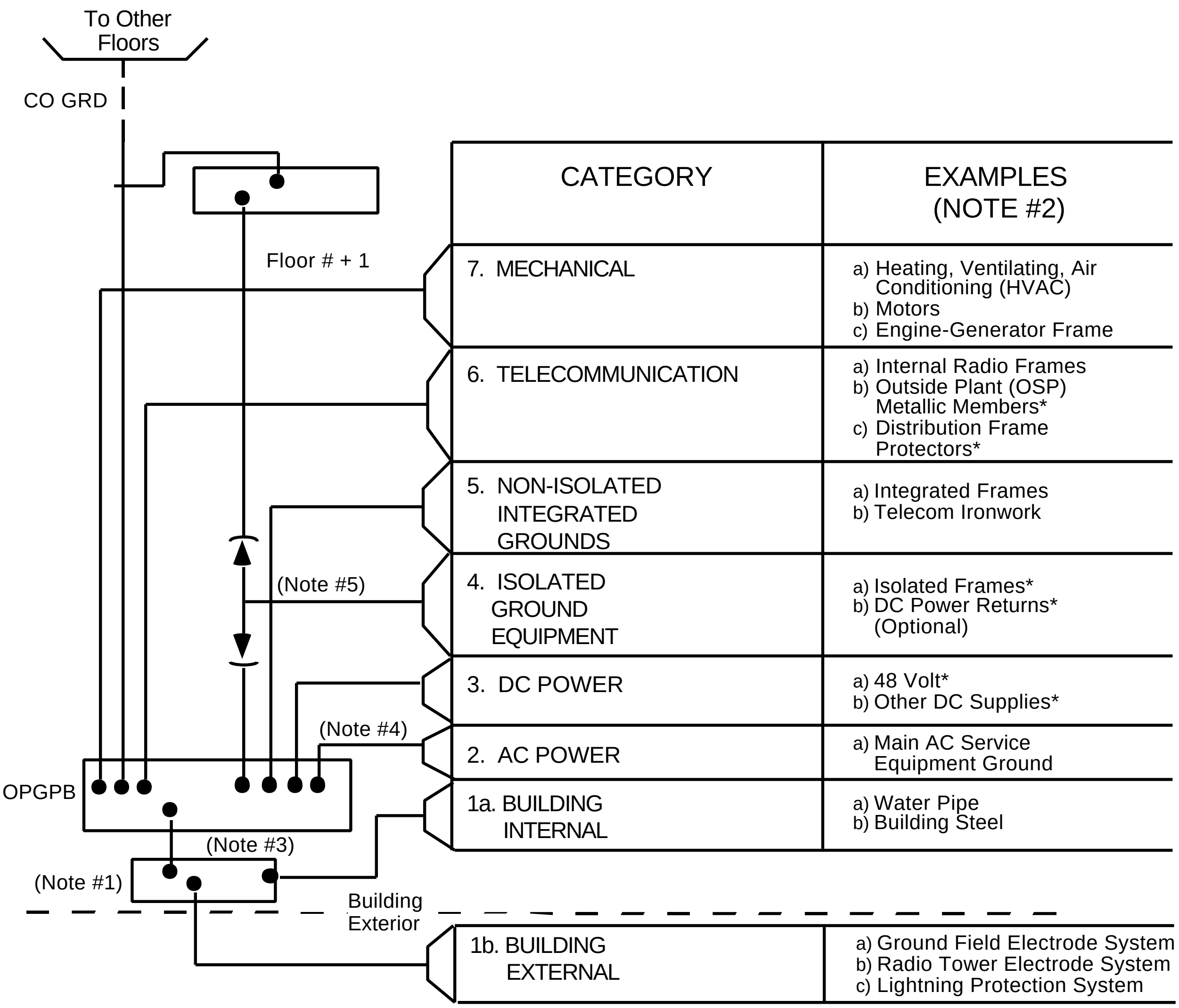
- • When a common communication installation is housed in two closely adjacent buildings (i.e., separated by an alleyway) having individual grounds, the principal ground points shall be bonded together using a 750 kcmil conductor.
- • Structural steel ground grids are provided in some types of building construction. They shall be bonded to the OPGPB with a No. 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 ground electrode resistance is excessive, it may be possible to reduce it by adding additional ground rods, a counterpoise system radiating from the ground electrode system or by connecting the casing of a drilled well to the electrode system. Contact the U S WEST Electrical Protection Engineer for assistance.

3.3 Materials

3.3.1 Ground Rods

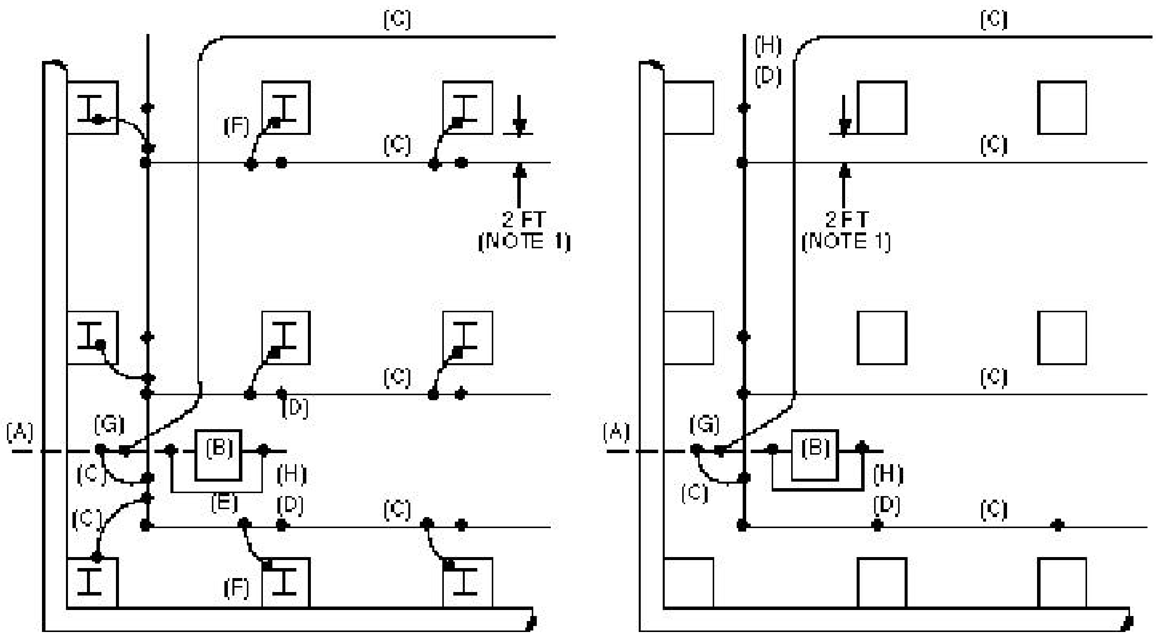
Solid stainless steel rods shall be used in COs, CDOs, fiber backbone huts, and Radio sites. They shall be at least 5/8 inch (15.87mm) in diameter. The stainless steel rods shall be of American National Standard Institute (ANSI) grade 32 or 34 alloy, which are resistant to corrosion. Copper is significantly 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. Because stainless steel rods are very costly, they make economic sense at our extremely 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 in these applications. For OSP applications, copper-clad steel rods shall be permissible. Although not quite as good as stainless steel rods for the reasons mentioned above, they are still very good, long-lasting rod material. Bare or galvanized steel rods, or steel covered with stainless steel tubing, or hollow core pipes of any type shall not be used as driven ground rods. Nonferrous rods or their equivalent shall be listed and shall not be less than 1/2 inch (12.7mm) in diameter.



Notes:

1. The bar shown may be part of the floor #n bar.
2. Items marked with an asterisk may have ground bars associated with them.
3. Located on same floor.
4. Category 2, AC power conductor is determined by the NEC.
5. Category 4, conductor to CO GRD bar or OPGPB.
6. 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).

Figure 3-1: Grounding System - General



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

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

LEGEND

(A) Water Pipe
(B) Water Meter
(C) No. 2 AWG Bare Tinned Copper Wire
(D) 5/8” Stainless Steel Rod; 8 ft. long
(E) Denotes an Exothermic Weld of a No. 2 to a No. 2 AWG Wire
(F) Denotes an Exothermic Weld of a No. 2 AWG Wire to Column Steel
(G) Denotes an Exothermic Weld of a No. 2 AWG to Water Pipe or the OPGP
(H) Denotes an Exothermic Weld of a No. 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 3-2: Various Methods of Establishing Supplementary Ground Fields in Buildings with Basements

3.3.2 Exterior Ground Wire

Ground electrode systems employing driven rods or wire counterpoise are constructed by use of a No. 2 AWG solid tinned copper (untinned copper is allowed in certain OSP applications) conductor buried in the earth. As the wire is subject to corrosion, tinned copper wire is used exclusively at COs, CDOs, fiber huts, and Radio sites because it corrodes at a slower rate than any other economically acceptable wire.

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 are used. Types of wire for buried applications are:

- • **Required — Minimum No. 2 AWG Bare Solid Tinned Copper Conductor**
  - For general applications, this wire provides adequate conductivity, maximum longevity, minimum galvanic effect, and adequate strength. Wire shall be soft (annealed) or semi-hard drawn commercial grade.
- • **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 (see the relevant paragraph later in this section) and high cost make it somewhat impractical as a requirement for the hundreds of thousands of OSP applications (e.g., CEVs, RT cabinets, etc.) Although bare solid tinned copper is preferred, bare solid untinned copper shall be allowed in OSP applications.
- • **Prohibited — Insulated Conductors for general Bonding of Driven Ground Systems**
  - 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.

- **<u>Prohibited</u> — 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 probability of the individual small diameter strands simultaneously 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. Stranded tinned copper conductors shall be permitted as part of roof lightning protection systems as main or bonding conductors.
- **<u>Prohibited</u> — Aluminum Grounding Wire** of all types shall not be used.

Tinned solid copper wire is generally not 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 U S WEST , and may be made available to our contractors.

Pigtail leads shall not be employed to connect individual rods to the No. 2 wire. An exothermic weld or an approved compression connection approved for the application shall be employed to connect the primary ground conductor to the top of the ground rod.

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. <u>Do not</u> pound the ground rod after the compression connection has been applied.

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). Aluminum conductors shall not be used in the equipment grounding system.

Types of wire for interior applications are:

- • <u>**Preferred**</u> **— Stranded RHW (or XHHW) type Insulated Copper Wire, where the Insulation is Colored Green**
  - (In accordance with the NEC, wires other than "grounding" conductors shall not be colored green. For example, the "grounded" -48 VDC battery return conductor[s] shall have insulation colored gray or black. The "green" wire requirement for DC grounding conductors is applicable as of January 1, 1999, and only applies to No. 6 AWG and larger conductors. Although it is recommended for smaller wires, including chassis grounds, it is not required.) This wire shall be connected with crimp connectors. The insulation affords protection of the wire from paint and corrosion, ensures a bare bright surface for bond connections, 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.
- • <u>**Alternate**</u> **— Stranded Bare Copper Wire**
  - This wire shall be connected with crimp connectors. It is easy to install and is commercially available. Special care must be employed to avoid separation of the strands at bends. Separation does not reduce the wire's protective property but is often objectionable in appearance. Stranded wire requires more frequent support than solid wire. Bare stranded wire supported from walls shall not be painted when walls are painted.
- • <u>**Alternate**</u> **— Solid tinned or untinned bare copper wire**
  - This wire can only be connected with an appropriate crimping tool and die designed for the size wire and connector; therefore, exothermic welds or pressure type connectors are required for bonds. 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.

- • **<u>Prohibited</u> — 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 points of channel discontinuity. 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 existing systems of this type be replaced.
- • **<u>Prohibited</u> — Aluminum Wire** of all types is prohibited.

3.3.4 Connectors

<u>Thermal Welding</u> — Thermal welded connections are required for all connections buried in earth, between copper conductors, or for termination of copper conductors to steel or iron objects. Such connections are superior to other methods. Their use is also recommended for above ground terminations on the exterior of the building, and within the building, where practical. Thermal welding includes both exothermic welds and brazing. After a thermal weld is made, it is advisable (although not required) to apply a Butile primer or some other form of acceptable protection to seal the weld, and prevent the start of corrosion at the weld point.

<u>Exothermic Weld</u> — The exothermic type welding process utilizes graphite molds to form welds. A crucible in the top of the mold holds a metallic powder which, when ignited, produces molten copper that flows by gravity into the form surrounding the joining point. The hot copper melts the material of the items being welded, forming a molecular bond. Each configuration of weld requires a unique graphite mold; and, because of limitations imposed by the gravitational flow requirement and heat generated by the process, there is some restriction of application. Newer type molds are designed with a cover and filter system (which eliminates smoke and sparks) for use in telecommunication facilities.

<u>Brazing</u> — Brazing may be used in place of exothermic welds where expedient, except in vertical risers. 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 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 within a telecommunication equipment area.

Crimp (Compression Type Bolted Tongue Connectors) — Crimp type connectors are required to maintain low resistance conductivity between wire and connectors. Crimp type bolted connectors shall preferably be used for terminating stranded wire ground conductors to frames, cabinets, and other units requiring a bolted ground connection. Crimp lugs used for solid copper wire must employ the proper lug, crimping tool and die designed for solid wire connections. 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 3-8).

- • Two hole bolted tongue connectors are required. One / single hole connectors are not acceptable. Contact area of metal to which the connectors are bolted shall be prepared to a bare bright finish and coated with an anti-oxidant compound before joining.

Clamp Type Pipe Connectors — Ground clamps may be utilized for termination of ground conductors at water pipes (if applicable) and conduits. 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 3-7 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 (see Figure 3-8 SK-C).

Solder Type Connectors — In conformance with NEC Article 250-8, connections which depend solely on solder shall not be used for ground connections.

3.4 Connections

All connections of the No. 2 AWG wire to ground rods, building steel, or to other No. 2 branch or bond runs shall be exothermic weld or an approved compression connection designed for the application to ensure a permanent low impedance connection. All connections, buried or exposed to elements need to be protected with a corrosive preventive product.

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 CORM (see Bellcore BR 802-010-100 for methods).

3.5 Office Principal Ground Point Bus (OPGPB)

- Establish an Office Principal Ground Point Bus on a standard bus bar located near the AC Service Entrance Switchgear.
- • Bond the OPGPB to the Office Ground Electrode and to any supplementary electrodes which exist in the Central Office, 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 the NEC section 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 spelled out in Section 3.8.

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 busbars serving as the building principal ground point when the connector is a bolted tongue or other device that may be inadvertently disconnected. A tag identifying the use of the conductor and / or its far end terminations 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 vertical equalizer is required in a multifloor building to bond the floor CO GRD buses together and to provide earth potential reference to the CO GRD system. The vertical equalizer functions as a current path for ground current interchange between discharge ground circuits on various floors during periods of load unbalance, as a low impedance path to battery for fault current and, through its low impedance connection to the earth potential electrode, effectively extends an approximation of earth potential to each of the CO GRD buses connected thereto. When this arrangement is provided, any floor CO GRD bus may be considered as an appearance of the grounding electrode, and any equipment requiring connection to a grounding electrode for proper operation and/or protection shall be connected to the CO GRD bus on the same floor as the equipment.

Figure 3-3 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 shall 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 12 inches is required. Splicing of the vertical equalizer by any means other than exothermic weld or compression type connections are prohibited.

The vertical equalizer shall 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. 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.

3.8 Design Parameters of Horizontal Equalizer System

A Central Office Ground (CO GRD) bus is required on every equipment floor of buildings utilizing the CO GRD system. The bus shall 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 shall be such that:

- • The maximum conductive run length between a bus and the furthest grounded equipment unit shall not exceed 200 feet and shall 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 3-4).
    - — Figure 3-4 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 bar is too small to accomodate all the connections required by equipment growth. Generally, bonding stringers 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" shall be connected to the original COGB 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, for maximum equalization.

- • The bond between the vertical equalizer and the CO GRD bus, which provides a conductive path for interchange of current between floors, shall be as short as practicable, so as to minimize impedance in the path. Preferably, the length shall be less than 20 feet.

- • All runs of CO GRD equalizer conductors shall 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 shall 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 the possibility of doing this).

- • As indicated in Figures 3-4 and 3-5, the general direction of horizontal equalizers that terminate at discharge ground buses of Battery Distributing Fuse Boards (BDFB) or on horizontal ground equalizers of Toll system discharge circuit conductors shall normally be diagonal to the walls of the building, and that at least one 750 kcmil horizontal equalizer shall be extended into each quarter section of the building. These conductors shall bond BDFB ground 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 that BDFB equalizers may also serve as horizontal equalizers, and that more than one BDFB can use the same equalizer. This is illustrated in Figure 3-5.
- • Frames, cabinets, and other metallic objects in an equipment area must be equipment grounded to the CO GRD system (referred to as framework ground [FRWK GRD]). These units may be connected directly to the CO GRD bus, CO GRD horizontal equalizers, or to equipment frame ground buses that are utilized as combined discharge-equipment ground paths. The minimum size of a bond for framework ground to a single bay or cabinet or other individual unit requiring FRWK GRD shall be a No. 6 AWG stranded conductor. Where a group of bays or miscellaneous units are to be grounded, extend a No. 2 AWG conductor from the CO GRD bus or from a horizontal equalizer, with multiple No. 6 bonds extended therefrom. Figure 3-6 shows typical equipment connected to horizontal equalizers and CO GRD buses.
- • It is important that a reasonably direct equalization path be established between discharge ground points for the reason that large current flow may be expected in equalizers whenever two or more power plant discharge circuits feeding BDFB or other toll equipment equalizers terminate on the same floor and the load is heavy on one or more and at the same time light on others. Wherever horizontal CO GRD equalizers run within reasonable proximity to other such runs, or in proximity to 750 kcmil discharge ground equalizer conductors of toll type systems, they shall be bonded together so as to form a direct conductive path, supplementing the circuitous path afforded by connection of CO GRD equalizers to the CO GRD bus. Such bonds are illustrated in the lower right quadrant of Figure 3-5. This is indicated by the BDFB and the “duct bay” equalizer run closely together. They should be bonded together. No precise formula for application of such bonding can be provided. As a rule of thumb, it may be said that conductors in proximity are generally eligible for bonding if:
  - • Points of proximity occur further than 35 conductor feet from the CO GRD bus.
  - • Total conductor run length via the CO GRD bus between points of proximity is greater than 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 3-5 for an example).

- — Examination of a job grounding schematic drawing after horizontal equalizers and main aisle ground equalizers are located thereon may reveal other conditions where supplementary bonds will reduce the length of ground current paths between discharge ground conductor termination's significantly.

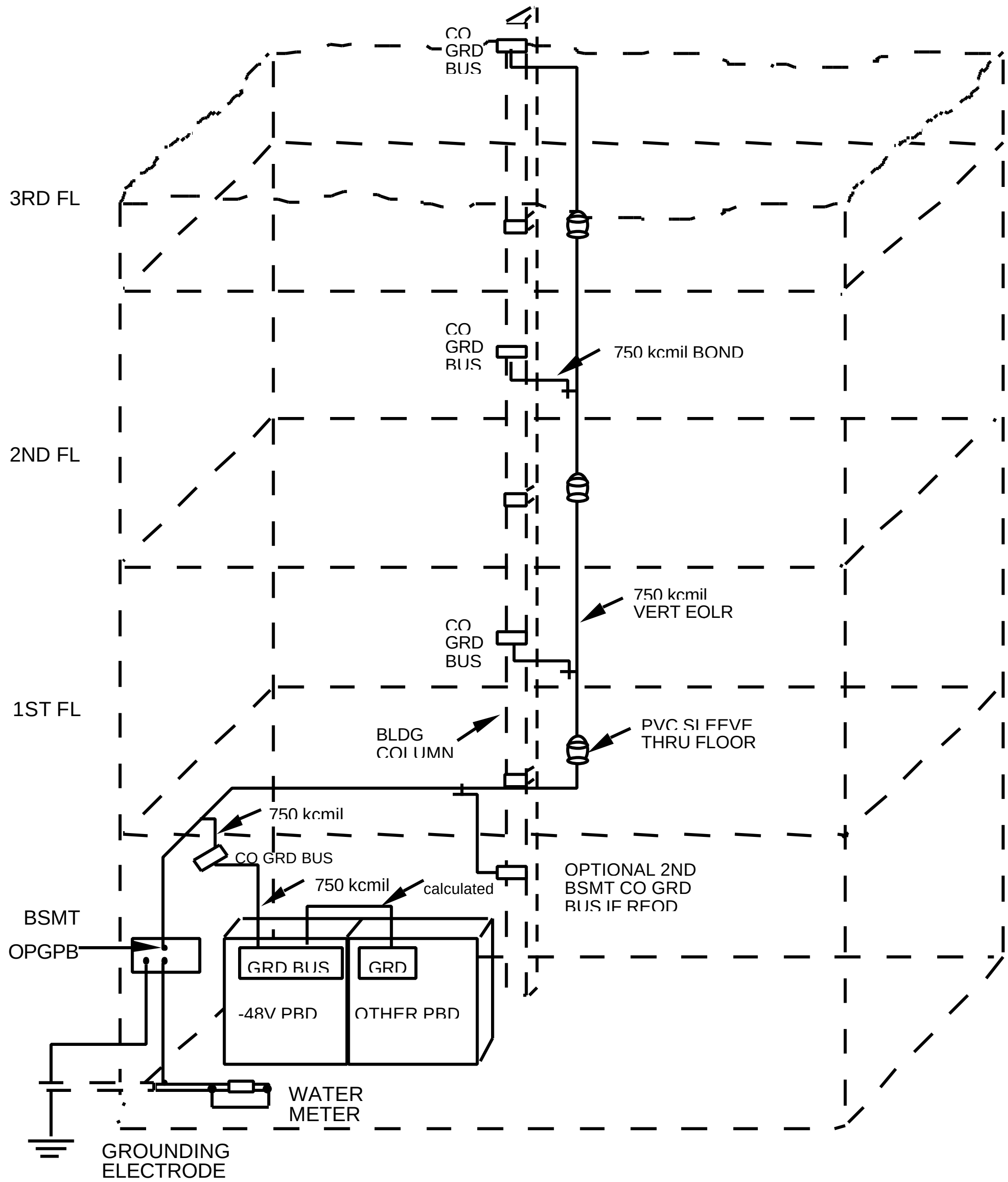
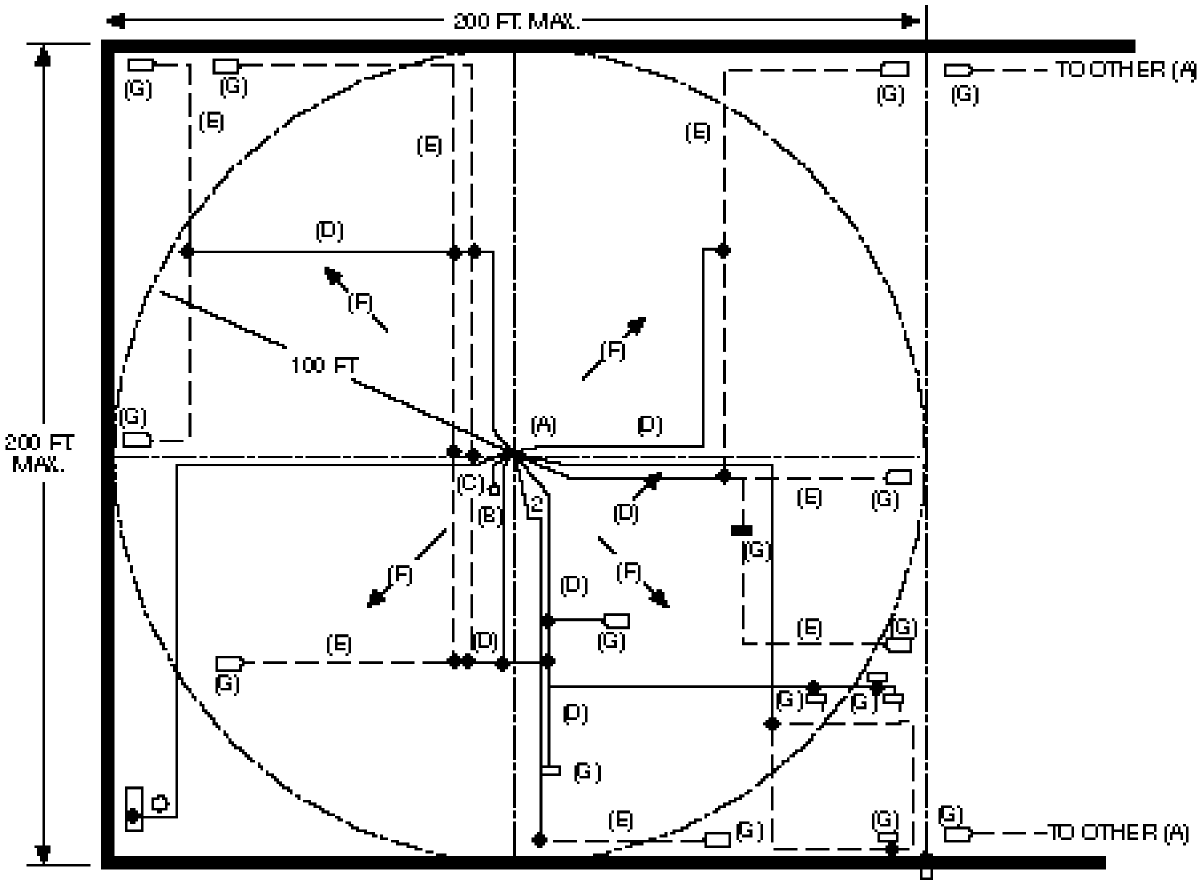


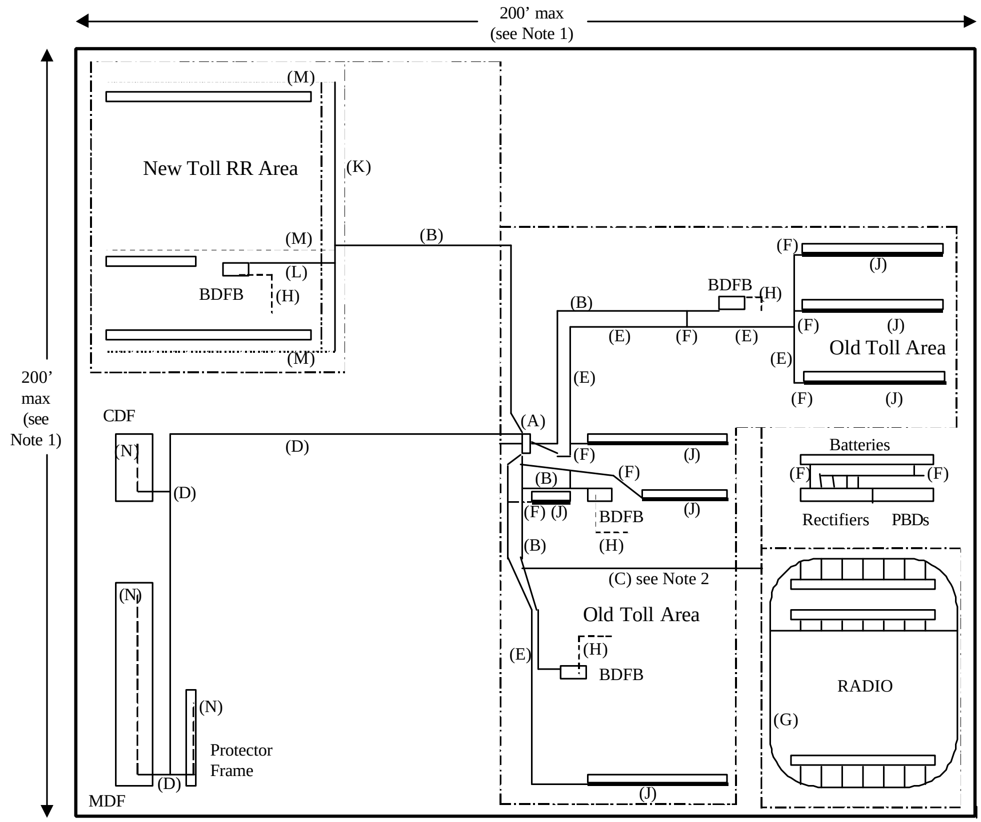
Figure 3-3: Typical Routing of a Vertical Equalizer and Placement of CO GRD Buses in a Multifloor Building with a Basement



LEGEND

(A) CO GRD Bus (COGB)
(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 3-4: Representation of the Maximum Area to be Served by a Single CO GRD Bus



LEGEND

(A) Floor CO GRD Bus (COGB)
(B) 750 kcmil CO GRD Equalizer
(C) 350 kcmil CO GRD Equalizer
(D) #1/0 AWG CO GRD Equalizer to Frames
(E) #2 AWG CO GRD Equalizer
(F) #6 AWG FRWK GRD Bond
(G) #2 AWG Radio Ring Ground
(H) Discharge Ground (Return) Conductor
(J) Duct Bay e/w 1" Pipe
(K) 750 kcmil Combination Discharge/FRWK GRD Main Aisle Equalizer
(L) 750 kcmil BDFB Ground Bond
(M) 350 kcmil RR GRD Bond
(N) Distribution or Protector Frame GRD Bus

NOTES

(1) Max. run length to the furthest point of ground conductance shall not exceed 200' from the COGB. The area served by a COGB shall not exceed that bounded by a square superimposed on a 200 foot diameter circle circumscribed about the COGB. The Vertical Riser and Horizontal Equalizers shall 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 (i.e. the equalizer for toll Relay Racks may be tapped to extend CO GRD to frameworks or cabinets or distributing frames in the vicinity). Equalizers other than 750 kcmil should be increased to equate the conductance to that of the normal conductor sizes for both applications (i.e., normally, a 1/0 AWG is required for a PBD ground, but it is increased to 350 kcmil when also used for power equipment FRWK GRD).

Figure 3-5: Typical CO GRD Horizontal Equalizer System on a Toll Equipment Floor

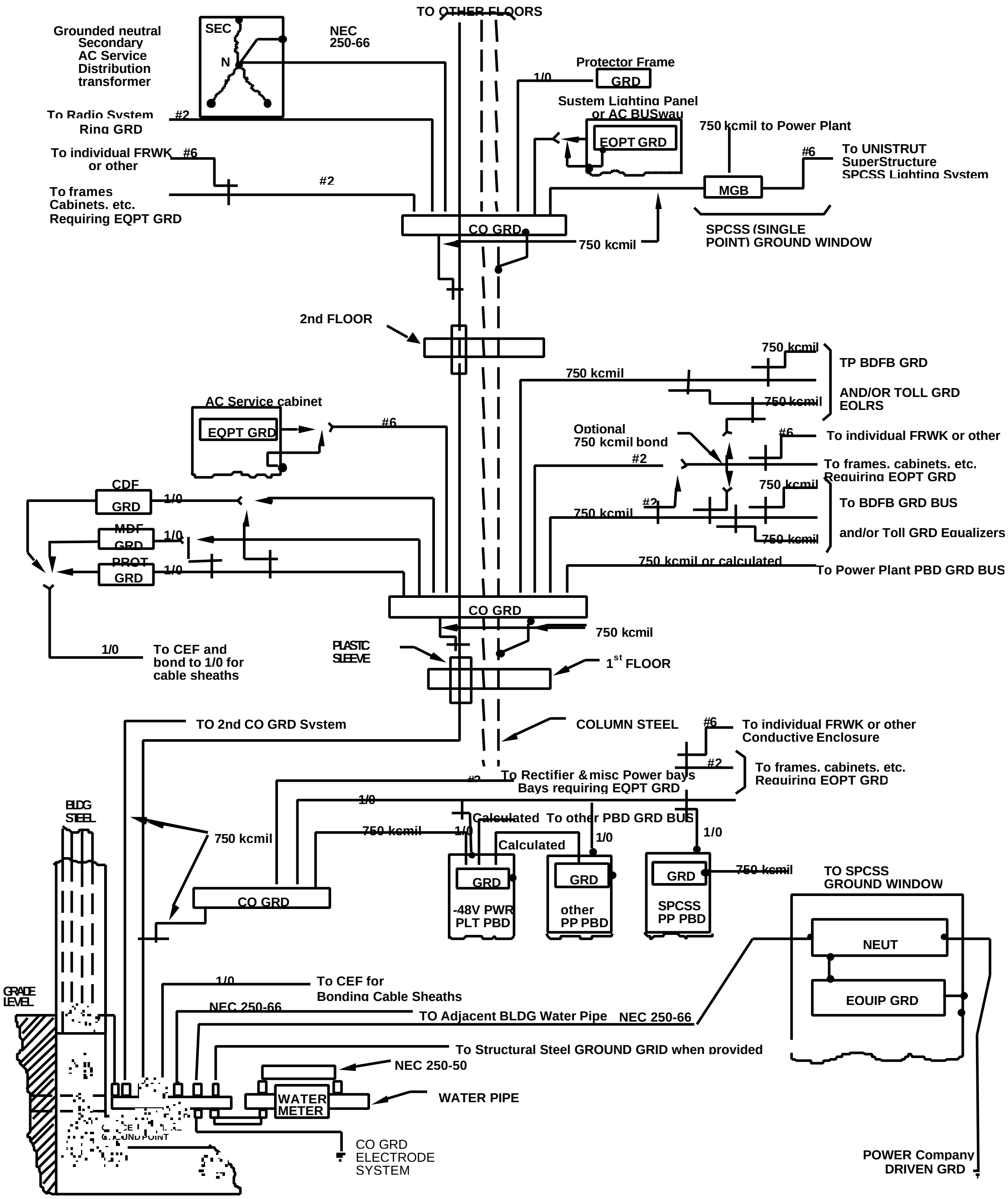


Figure 3-6: Typical Equipment Connected to a CO GRD System

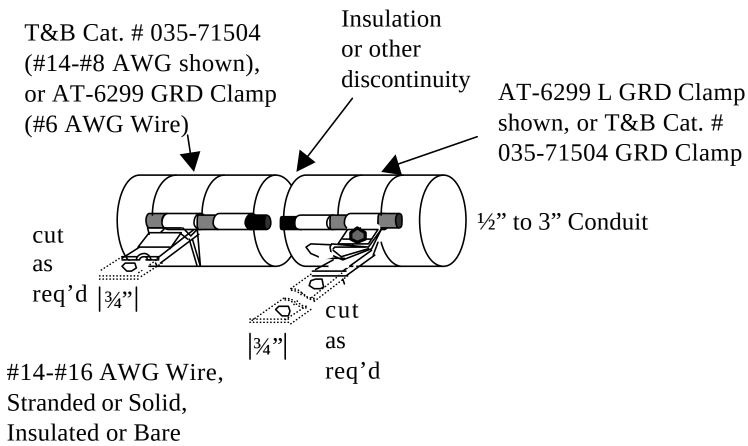
3.9 CO GRD System Raceway Application

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, 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 pipe (see National Electrical Code {NEC} Article 347 "RIGID NONMETALLIC CONDUIT"). The equipment grounding conductors should always be run and supported so that as much of the runs as practicable may be visually inspected.

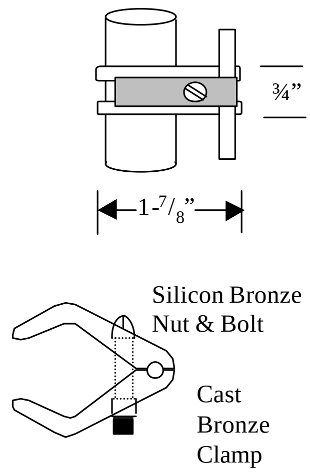
The only exception to the use of nonmetallic raceways shall be for installations where local electrical codes specifically prohibit the use of raceways of insulating material. Short runs of metallic raceway, principally rigid conduit, may then be used. These sleeves, guards, or short supporting runs must be short-circuited at each end by means of a No. 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 8.13.4 for further information on what types of “girdling” is allowable.)

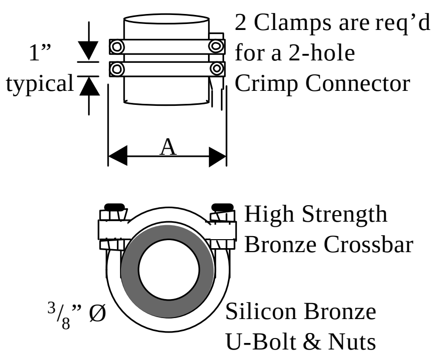
In some cases, AC raceways (including conduit) may seem like a convenient support structure for DC grounding wires. However, NEC Article 300-11 prohibits this practice. Per U S WEST Technical Publication 77350 (Installation), DC grounding conductors can be secured to cable racks, hangers, or other suitable framework, but not on AC conduit or raceways. Refer to that publication (and specific section) for more detail.



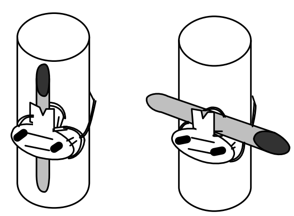
SK-A Conduit Bonding Clamps



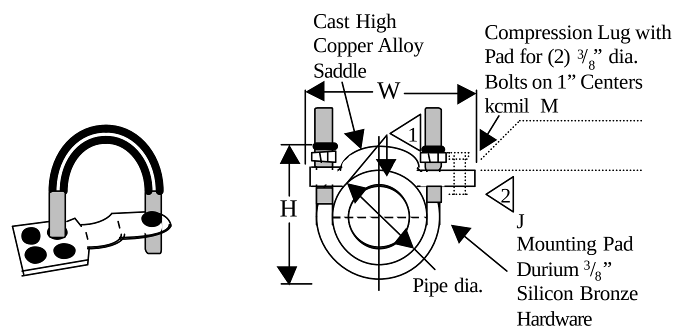
SK-B



SK-C Ground Pipe Connector for 2-Hole Compression Lug



SK-D



SK-E

Figure 3-7: Pipe and Conduit Ground Clamps

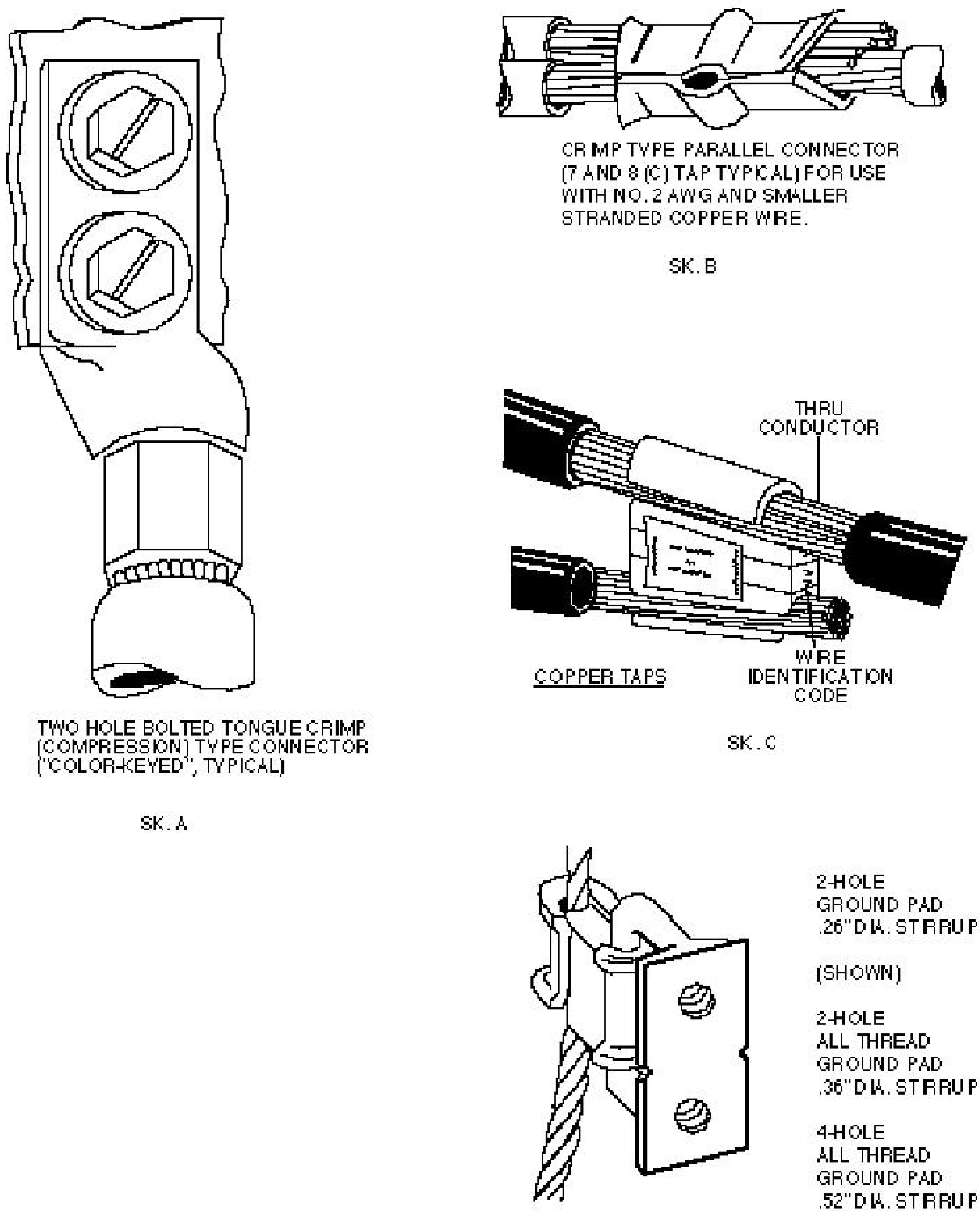


Figure 3-8: Crimp (Compression) and Pressure-Type Connectors

3.10 Grounding and AC Feeds for Separate Buildings

In some cases, multiple buildings may be found on a U S WEST 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 unique lightning attachment points. Grounding guidelines for radio site buildings, towers, and antennas are found in Chapter 7 of this standard. The following guidelines are not as stringent as those for radio towers, but they do borrow heavily from those guidelines and Figures.

Per NEC Article 250-32, separate buildings supplied from a common AC service must have each building tied to at least one acceptable grounding electrode field (as described previously in this chapter). If the grounding electrode field is a “ring” (or the grounding electrode field is within 100 feet of the supplementary building), and the “separate” and / or “new” building is within 10 feet of the original building, the new building ground system should be tied to the ground electrode field of the main / existing building in accordance with the aforementioned NEC Article. When the grounding electrode field of the existing building is not nearby, it is permissible to establish a new ground electrode field. When the new and / or supplemental structure is within 10 feet of the original building, the ground electrode fields must be tied together (see Figure 7-1 for an example of how this is done).

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

The AC feeder from the main building to the separate building must comply with the grounding requirements of NEC Articles 225-30 through 225-34, and 250-32. (Although exceptions in the Code allow for this AC feed to not have a disconnect at the “new” building, U S WEST requires it.) 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 is fed from the same AC service as the primary building, and the supplementary building is not completely under the “lightning” zone of protection (as defined for different geometries by NFPA 780), the potential is there for the AC feed to conduct lightning back into the primary building. In these cases (most of them), installation of Transient Voltage Surge Suppression (TVSS), as well as the routing of the AC feed through the building becomes important.

For a shared AC power distribution system (reference Figure 7-23 — although it references Wireless equipment, treat the Wireless equipment as if it were a separate building) TVSS devices 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 TVSS should be provided. Even with TVSS 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 additional TVSS at the point the AC service leaves the primary building (and bond this TVSS to the ground electrode field of the primary building).

Cable routing through the office is also a concern. If lightning does enter the building on the AC feed going to the supplementary structure, we do not want it to have convenient points to jump off into sensitive equipment. If possible, The AC feed (and any grounding 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 that more of the AC is run outside the building rather than inside. Figures 7-16 and 7-22 are poor examples of this. 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 7-23). 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 ESS 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 further information). If the AC service is being obtained from a sub-panel (as illustrated in Figure 7-23), 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 10 feet of the primary structure, and does not fall completely under its zone of protection. 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 for grounding).

The existing grounding electrode system for the U S WEST 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 “best” 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 7-20 represents the ideal situation (everything important to grounding is near each other). When this situation isn’t 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 TVSS “5-pin” protectors. These 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 7-17 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 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 or Vault (see Figures 7-20 and 7-21). This external protection pedestal 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 Figure 10-7 or Figure 7-21.

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 7-19 and 7-20).

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 331 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.

CONTENTS

Chapter and Section **Page**

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.

4.1 AC Neutral Conductor

The neutral conductor is usually grounded at the service transformer by the serving utility and must always be grounded at the electric service disconnect. The neutral is not, under any circumstances, connected to a grounded object on the load side of the main service disconnect. Neutrals are insulated current carrying conductors and connection to a grounded object would create a load current path through the grounded objects in parallel with the neutral conductor. A neutral conductor must never be used as a source of ground reference for the same reason. 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). In order to maintain the single point concept, neutral busbars 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 the neutral and grounded metal does not occur at any point 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 distribution systems that receive power through a transformer; or from a DC powered motor-alternator set, inverter, or by means other than direct connection to a secondary system, are commonly found in COs. These systems normally employ a neutral conductor and require ground reference. Since the neutral of the secondary system is prohibited from connection to grounded objects on the load side of the main disconnect, it cannot be extended to provide ground reference to separately derived systems. Therefore, a separate grounding electrode conductor must be extended from the neutral of each such separately derived system to a source of ground reference. In offices equipped with a CO GRD system, a floor CO GRD bus is an optimal point for obtaining ground reference. In other offices, a connection of the grounding electrode conductor to the OPGPB known to have low impedance to earth is acceptable. (The grounding electrode conductor shall be sized in accordance with NEC Table 250-66.)

Engine-alternator and inverter-derived AC supplies provided for service in case of AC power failure are normally controlled through automatic or manual switching so that the standby supply is never adjoined to the commercial supply. In wire connected services the neutral conductor of the standby supply must be permanently connected to the neutral of the commercial secondary service. The grounding electrode conductor of the secondary service system, therefore, suffices as a single point ground reference for both the standby and commercial systems, and such separately derived systems do not require a separate grounding electrode conductor. One exception applies:

- When an engine-alternator is located in a separate building (or other enclosure) which has its own ground electrode, the standby system neutral shall also be connected 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.)

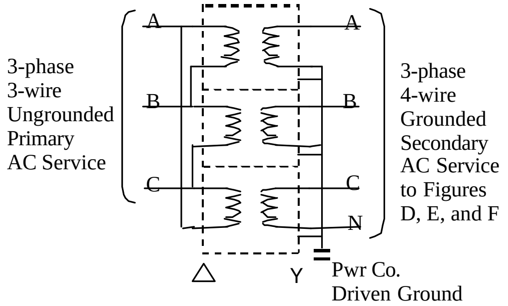
4.3 NEC Code Requirements

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. And refer to Article 702 for general Engine-alternator (Optional Standby Systems) provisions. Where local Codes differ from the National Electric Code, installations shall conform to the local code requirement.

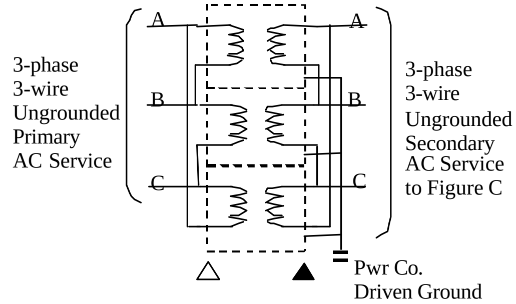
The NEC requires that the path to the ground from circuits (feeder and/or branch), equipment, and conductor enclosures shall:

- 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.

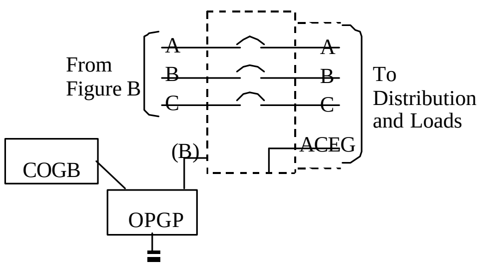
To ensure that the requirements of continuity and low impedance and to provide additional insurance against noise generated in AC systems, all circuits shall include the "green-wire" sized per table 250-122 of the NEC, even when metallic conduit or other raceway is used.



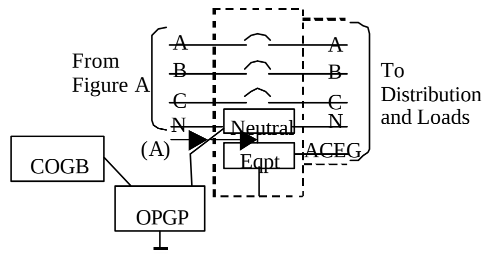
A. Typical Delta-WYE Service Transformer Arrangement



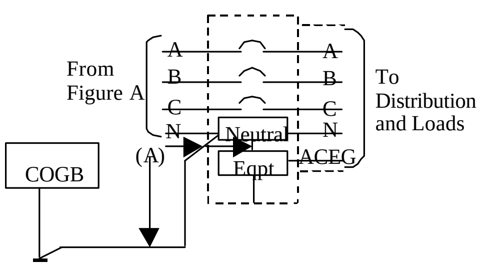
B. Typical Delta-Delta Service Transformer Arrangement



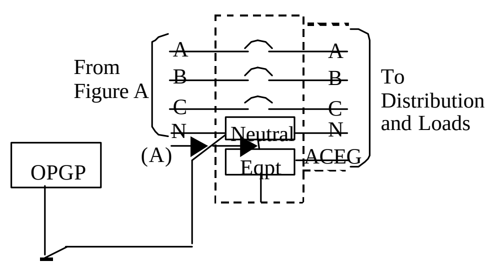
C. Service Disconnect Equipment Ungrounded AC Service Water Pipe or Driven Ground Electrode



D. Service Disconnect Equipment Grounded AC Service Water Pipe or Driven Ground Electrode



E. Service Disconnect Equipment Grounded AC Service Service Grounded at Electrode other than Water Pipe



F. Service Disconnect Equipment Grounded AC Service Service Grounded at Electrode other than Ring or other Driven Ground System

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, D, E, and F show typical service grounding arrangements when the service grounding is or is not the building principal ground point
4. 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

Figure 4-1: Typical AC Service Grounding Electrode Arrangements

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 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 4-1.
- 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 U S WEST specifications. The conductor size shall be in accordance with NEC Article 250-66 (a) or (b).
- 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.

4.5 AC Equipment Ground Conductor

An AC Equipment Ground (ACEG) conductor provided in the same raceway with phase conductors 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 U S WEST 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. The ACEG conductor is not a current carrying conductor. In a three-phase grounded circuit, as defined in NEC Article 310, if the neutral conductor carries only the unbalanced current from other conductors in the same circuit it is not counted as well. (If there are harmonic currents present in the neutral conductor, then the neutral shall be considered to be a current-carrying conductor and must be counted. The neutral must be appropriately sized if harmonics are likely, in accordance with the requirements of the NEC. And for sites with lots of switch-mode power supply loads, such as computers, flourescent 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 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 the 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 ACEG conductors is not permitted. Each raceway shall contain an ACEG sized per the aforementioned table to the protection device.

The AC equipment ground conductor in raceways or conduit shall be NEC standard green insulated, bare stranded or solid wire. AC wire for distribution 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 4-2), 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 ACEG conductors shall be in accordance with requirements of the branch circuit overcurrent device ampacity or setting. The main ACEG conductor shall be connected 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.

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 U S WEST 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, by extending a No. 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 4-3). 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 components grounded by different systems.

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

4.6 U S WEST 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 U S WEST 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 cordset, 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 shall be prepared to a bare, bright finish (see NEC Article 250-12).
- Current carrying metallic surfaces shall be coated with corrosion preventive compound before joining.
- Raceway fittings shall be made up tight to provide a permanent low impedance path for fault currents.

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

Every ground conductor terminated at a busbar serving as the building principal ground point and at CO GRD busbars of the CO GRD system, when terminated with a bolted tongue connector or other device that could be inadvertently disconnected (this basically includes all connections other than those that are exothermically welded or brazed) shall be equipped with a "DO NOT DISCONNECT" tag.

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 spot).

Installation of metallic raceways shall be in conformance with requirements outlined in the National Electrical Code, Section 352; 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

4.8 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 busbar or ground stud electrically bonded to the cabinet or directly to the cabinet interior with terminal lugs. The cabinet must be electrically connected 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 No. 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.

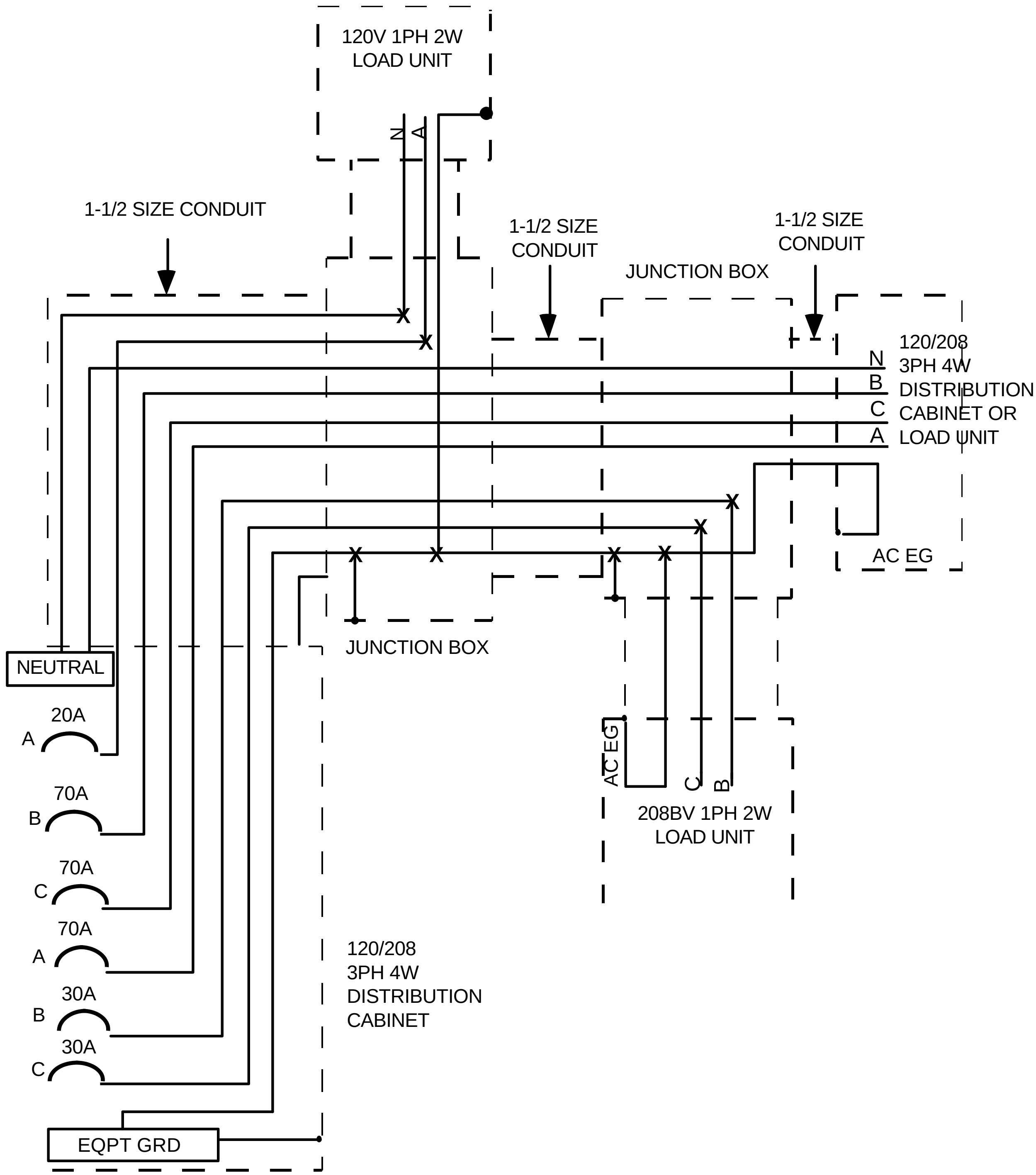
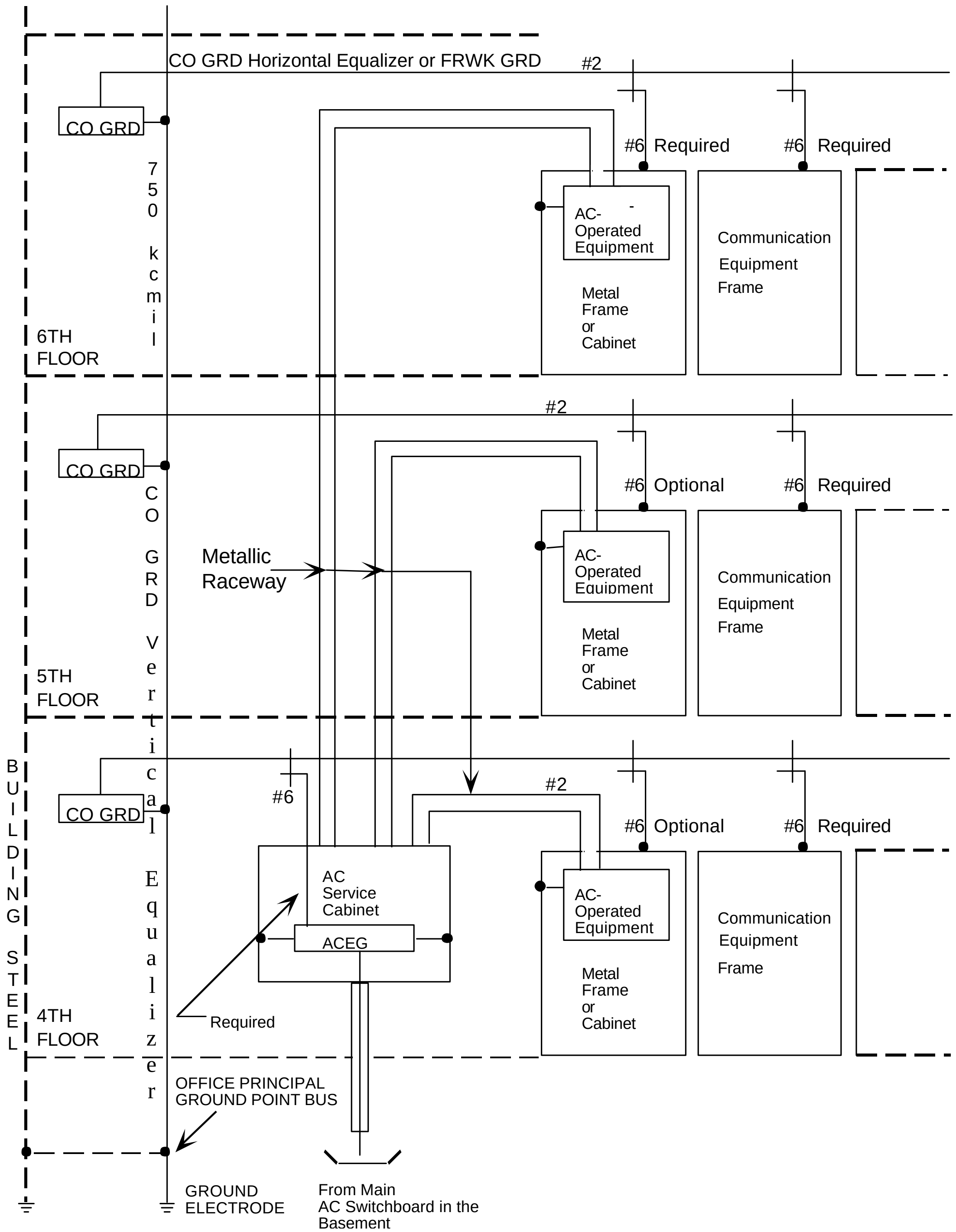


Figure 4-2: Single ACEG Conductor Serving Multiple AC Circuits in a Common Conduit Run



Note: although not shown, each feed is run with an ACEG

Figure 4-3: Requirement for Grounding Frames Mounting AC Operated Equipment Units

4.9 Grounding for AC Standby Plants

The primary control cabinet for the standby set shall be bonded to the metallic (steel) sub-base or chassis. These bonds should be made with bare, stranded, or ribbon conductors, designed and installed to withstand the vibration generated by the standby set. Figure 4-5 shows a general grounding scheme for a standby engine room. A #2 stranded insulated conductor shall be run from the COGB (or alternatively to the OPGPB if it is closer) to the standby engine room. Ground the standby engine with a #2 AWG, and all other components with a #6 AWG stranded insulated conductors. If the fuel tank is located outside, then the metallic fuel lines must be bonded with a #2, since they constitute a ground source (if flexible piping is used on the fuel lines where they enter the building, due to earthquake zone requirements or other reasons, there must be a bond around the flexible section using a minimum #6 AWG). The following must be bonded to the #2 using a No. 6, 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 with an outside ground source

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 the tank corrosion protection system. Metallic or metallic braided fuel lines shall be bonded to the CO ground system on entry into the building.

Standby engines located outside of the main building enclosure shall also be grounded to the driven ground system; in addition if these standby engines are housed in metal building enclosures the metal building shall be grounded to the driven ground system. (See Figure 4-6.)

When the engine exhaust stack is higher than the building roof, it can serve as a lightning rod. In these cases, it is preferable to attach a # 2 AWG from the external stack, run it outside of the building, and connect it to the external ground electrode field (this keeps any lightning which hits the stack from entering the building). Also, attempt to bond the thimble (through which the exhaust stack exits the building) to this # 2 conductor. When this can’t be done, ensure to bond the stack per Figure 4-5.

When the standby AC neutral is switched by a transfer device, the standby AC system is classified as a separately derived AC source. Service grounding for such systems shall conform to the provision of the NEC governing separately derived systems, including Articles 250-20, 250-26, and 250-30. When local codes differ from the NEC, follow the requirement acceptable to the authority having jurisdiction.

Standby sets whose nominal line-to-line voltage is greater than 480 volts shall be treated as a separately derived system, and shall have their neutral solidly grounded. A direct and continuous connection shall be made from the neutral to the nearest CO ground bus by means of a grounding conductor which meets the NEC size requirements of 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, the following provision should apply. For standby sets of 480 volts 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 equipment ground conductor 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 switch to the main AC entrance panel neutral bus, if such a bus is not provided for in the transfer panel. In addition, the neutral and the phase lead(s) of the set should be the same size.

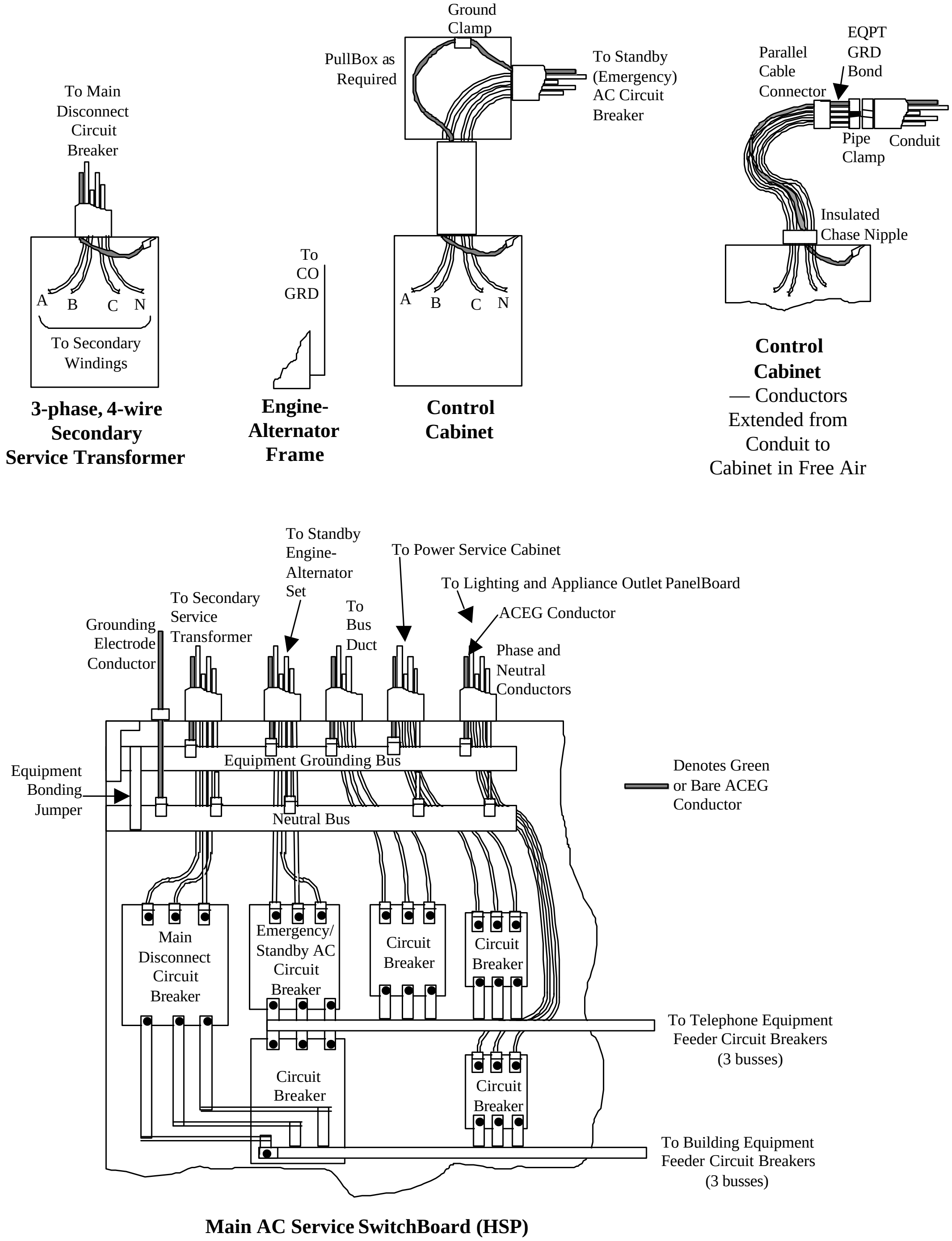
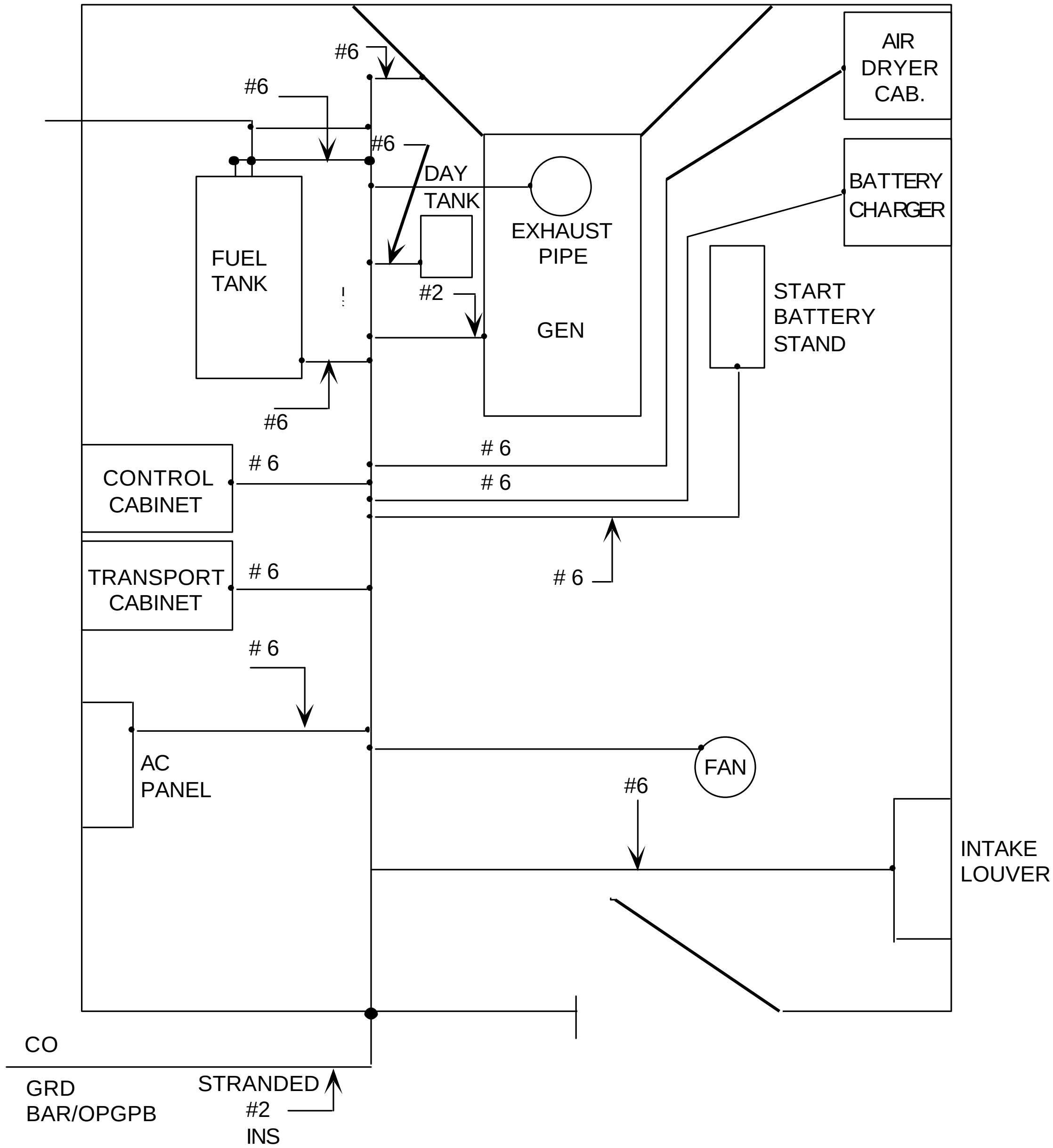


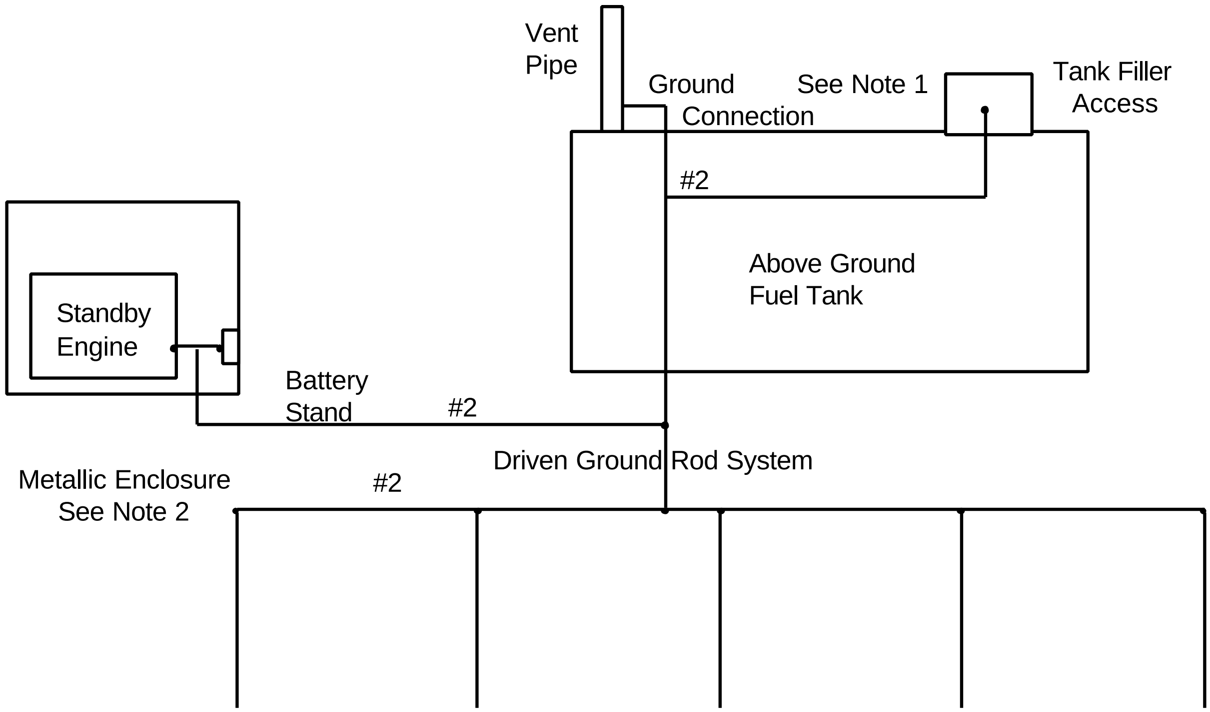
Figure 4-4: Typical Arrangement of ACEG Conductors at the Service Entrance and Standby Equipment



Notes:

1. All connections to the No. 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 shall point towards the ground source if possible (i.e., towards the source of the #2 coming from the COGB or OPGPB

Figure 4-5: Typical Standby Engine Room Grounding Scheme



Notes:

1. Some fuel tanks are equipped with a ground tab at the vent pipe for ground lead connection. If the ground tab is not available use a pipe clamp. (See Figure 3-7, 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.

Figure 4-6: Typical Above-Ground Fuel Tank / Steel Containment Tank and Outside Standby Engine Grounding Scheme

4.10 Ground Fault Protection

Where ground-fault detection is required, grounding the neutral at two 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.

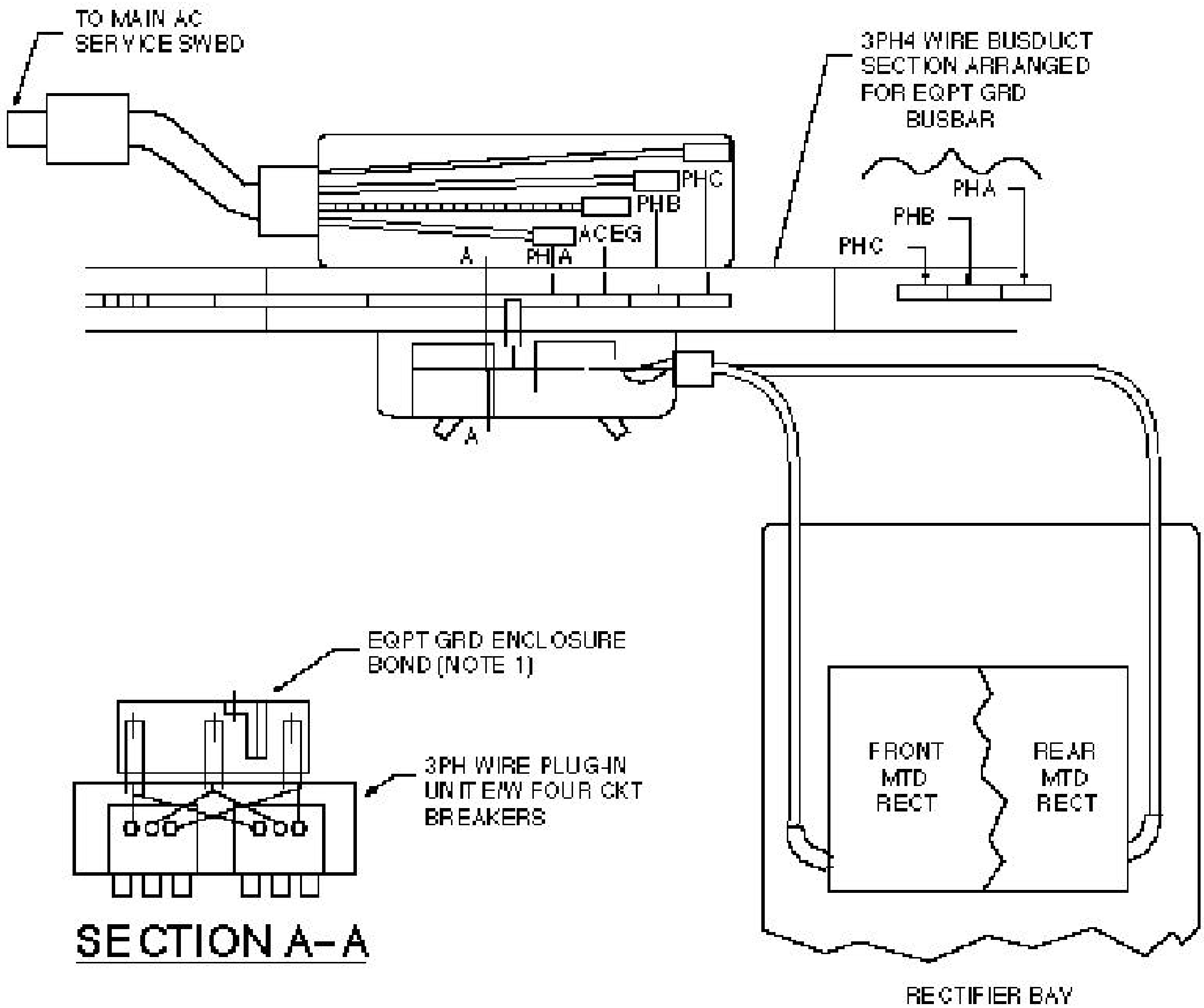
4.11 Busduct System

Busduct components used to supply floor mounted DC rectifiers in Central Office power plant installations are manufactured by outside suppliers to U S WEST 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 (CO GRD or grounding electrode) on the same or adjacent floor to that on which the AC Service cabinet is located. The ACEG conductor provided with the feeder circuit is considered adequate for providing connected AC operated equipment only when the ACEG conductor obtains ground reference (CO GRD or OPGPB) on the same or adjacent floor to that on which the AC Service cabinet is located. Otherwise, the cabinet shall be framework grounded to the floor CO GRD system, using a No. 6 AWG wire (see Figure 4-3). ACEG conductors shall terminate in the interior of the cabinet enclosure on an equipment ground busbar electrically connected 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 insure that the neutral does not have electrical continuity through mounting apparatus, terminal mounting bolts, or otherwise to the cabinet enclosure. Figure 4-8 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 unit enclosures.



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

Figure 4-7: Typical Busduct System Equipment Grounding Arrangement For a 3-Phase, 3-Wire System

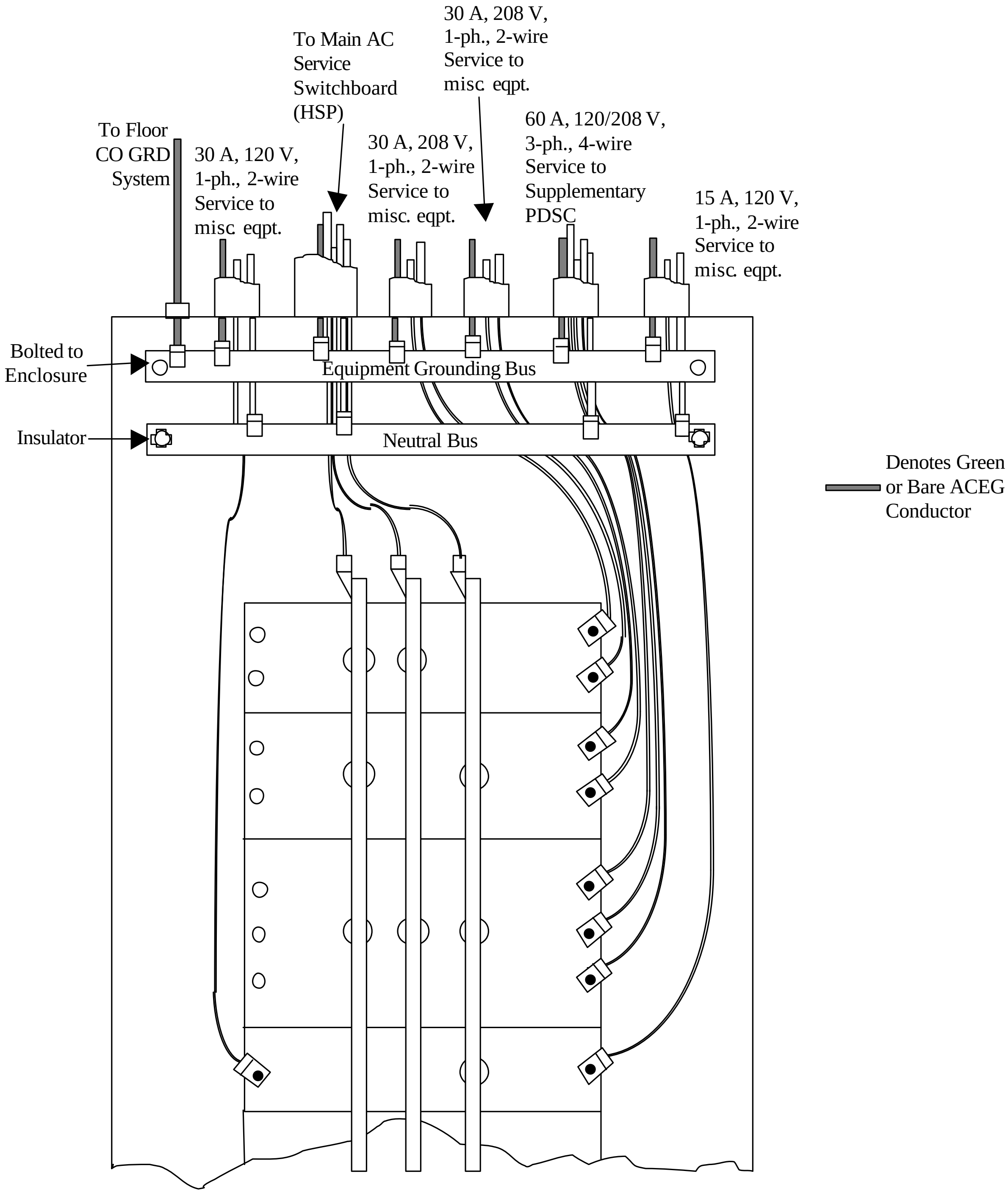


Figure 4-8: Typical Power Distribution Cabinet Equipment Grounding Arrangement

4.13 AC Equipment Ground Busbars

Certain equipment bays and cabinets provided for distribution of AC service are equipped with equipment ground busbars 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 such 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 (1) raceways, and (2) a network of green insulated conductors. The conductors are extended through the raceways that carry the phase conductors and connected to noncurrent carrying framework of the apparatus associated with the system. The purpose is (1) to enhance the raceway conductivity so as to ensure a low impedance path for fault current from a point of fault to overcurrent protective devices, which in turn ensures fast operation, (2) the bond across inadvertent discontinuities in raceway conductance, and (3) to short out noise producing high impedance joints in raceways.

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 recommended 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.

Note: General Electric type DH busway (MD) has been used in the No. 1 ESS and other analog electronic systems lighting distribution circuits, in place of panel boards. There is no practical way to extend an ACEG conductor within the busway. The busway enclosure metal must, therefore, be depended on to provide continuity from the ACEG conductor furnished with busway feeders to plug-in circuit breaker units mounted thereon. It is expected that some DH busway installations will be replaced with the standard distribution system for SPCSS installations that utilizes "Wiremold" raceway. When replacement occurs, ACEG conductors shall be added.

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 shall 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 required. Armored cable, conduit or other raceway metal utilized as enclosures for branch circuit conductors serving the receptacle must be electrically connected (conduit locknuts or equivalent) to the box or frame.

When branch circuit conductors are not run in electrically continuous metallic raceway, an ACEG conductor must be provided from the panelboard to the receptacle. The ACEG conductor shall terminate on the metal outlet box or other enclosure mounting the receptacle, not on the EG (green) terminal screw of the receptacle. Ground continuity is provided to the U ground slot via the receptacle mounting members (see NEC 250-148 and 250-36). 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.

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 shall 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 cordage may be used to power equipment within a bay or cabinet but shall not be used for permanent powering of equipment extending out of enclosure.

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. Generally, two circuits are used to serve the receptacles located in frame lines comprising an equipment block (group of contiguous frame lines). In each block, the two circuits are alternated so that each serves receptacles in alternated frame lines.

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-ampere 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 on the end guard.

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 ampere 120V 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 circuit conduit metal, the duct enclosure 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 other 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 National Electric Code Article 333 for conductor sizes, quantity, and color normally available. Armored cable containing No. 14 to 1/0 AWG wire contains a bare bonding strap to decrease sheath resistance. This strip 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. U S WEST 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 shall never be used in any length in battery rooms per NEC 350-5(3). Insulation-coated (liquidtight) armored power cable can be longer than three feet.

CONTENTS

Chapter and Section **Page**

Figures

5. Integrated Ground Systems

5.1 Integrated Ground Plane

An integrated ground plane 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.

5.2 Buried Objects

Buried fuel tanks, gas piping, 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 shall be made common with the intentional electrode by bonding them at their entry point with a No. 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

Multiground 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 DC Power Supplies

All DC power supplies in the integrated ground plane shall be grounded to CO Ground. The return side (usually the positive bar) of the principal power source shall be grounded with a separate grounding conductor to the CO Ground system. Where the power plant is a shared plant serving both isolated and integrated ground planes the grounding conductor is connected to the ground window. The principal power source is classified as an external power source. For shared plants or plants serving only isolated ground planes, the size of this reference conductor is specified in Section 8.7. For plants serving only integrated ground planes in a CO environment, this reference conductor should usually be a 750 kcmil (in small CDOs with less than 600 A plants, a 1/0 or larger cable may be used, although a 750 kcmil is still preferred). (For Radio sites and OSP sites, the size of this reference conductor can be found in Sections 7.21, 10.1, 10.3, and 10.5, respectively.)

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 shall 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.

5.4.3 Loads Fed from Internal Power Sources

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

5.5 Frame Ground Reference Buses

Frames containing separately derived AC and DC power sources (e.g., isolating transformers, inverters, and converters) shall be equipped with a grounding bus(s) that is referenced to the ground via the frame-grounding conductors. These buses should have only a single connection to the frame.

5.5.1 Grounding Internal DC and AC Power Supplies

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 ground reference bus. This grounding conductor shall not be used to conduct normal load current. The grounding location can be at the immediate output of the power supply not at the load. Loads shall be powered with separate pairs of conductors and the frames containing the loads shall be grounded.

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 shall 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 shall not be connected to any frame. This violates the single point ground of these power sources.

5.6 Central Office (CO GRD) System

A CO GRD system shall be provided in every U S WEST Central Office Building. It is recommended that a CO GRD system be added to existing buildings when:

- A building addition is added.
- A major addition of equipment is added in existing space.
- Noise on existing communications circuits is determined or suspected to be caused by inadequate grounding.
  - When a major equipment addition occurs, a simple ground system, though previously adequate, may not suffice now. This will not be apparent until the new equipment is put into service, and might be evidenced by noise on talking paths and/or the malfunction of switching devices. For this reason, it is required that a CO GRD system (as described in Chapter 3) be applied to new equipment areas (a retrofit is not needed for existing areas, unless a previous noise or malfunction condition attributable to inadequate grounding existed).
  - Retrofitting of an entire existing office to reduce noise may require a considerable expenditure. Often, the general area of the noise source may be identified. A CO GRD system that serves that area only will generally serve to reduce noise at a minimum cost. It is recommended, therefore, that the CO GRD system be retrofitted into existing equipment areas on a selective basis, aimed at relieving noise conditions only. The additional personnel and equipment protection afforded by a complete CO GRD system is desirable, but not considered essential to the point that the cost of retrofitting a complete system is justified.

5.7 Design Parameters of a CO Ground System

CO GRD busbars are normally designed on a job basis to fit the requirement of the application. 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, since lightning will hit the outside of a building. The busbars shall be insulated from the wall and kept a minimum of 3” from the surface (flash-over distance, and to allow for workspace). The busbars shall be placed so the equipment grounding conductors may terminate opposite from the vertical riser connection (avoid 180 degree turns). Ground is established by bonding the busbars to a large (i.e., 750 kcmil copper) conductor connected at the OPGPB and run vertically in proximity to the column.

The floor CO GRD busbars are made of copper and are usually (1/4" X 4" X 15") 1/4 inch in width, 4 inches high and 15 inches or other required length. The use of aluminum busses in central office buildings of U S WEST is prohibited. All connections to this bar shall be by means of 2-hole crimp connectors.

5.8 Equipment Frame Grounding

All switch frames, fuse bays, relay racks, miscellaneous bays, cabinets, battery distributing fuse boards, and other equipment frames shall be grounded with a minimum #6 AWG. Normally a #2 AWG insulated stranded copper wire is run on top of the lineup with #6 AWG branches to ground individual framework. All painted contact surfaces shall be cleaned so that a metal to metal contact is made. A non-oxidizing agent shall be applied to inhibit corrosion. The connection to the framework shall be made with a two-hole copper crimp connector. Connections to grounding conductors shall be made so that the conductor flows toward the ground source. In the past, a steel pipe used to support the bay framework may have also been used as a grounding conductor. <u>This support pipe is no longer acceptable as a grounding conductor</u> on a going forward basis.

Although the grounding of individual shelves within a relay rack is not generally the purveyance of this Tech Pub, and is generally considered as part of the “internal wiring” of the shelf; there are some guidelines which shall be followed. The termination of more than one lug under a single bolt on the same side of a frame or bus bar is prohibited by U S WEST Tech Pub 77350 (this illegal practice is commonly referred to as “double-lugging”). Where possible, even internal wiring grounding conductors should be bare or have a green-colored insulation; although this is not absolutely required.

In certain electromechanical switching systems; circuit facilities, carrier and manual relay racks; distributing frames; power distributing bays and various other miscellaneous equipment frames are equipped with frame ground busbars. These ground bars, with the exception of Stored Program Control Switching Systems (SPCSS [Isolated Ground Plane]), are mounted in electrical contact with the frame metal. These ground bars thereby form a part of an integrated ground plane in common with frame metal and any other metallic components that are electrically bonded. In an electromechanical switching system or other installation, excluding SPCSS, no effort is made to isolate a system ground plane from incidental contacts with building superstructure or other paths. The integrated ground plane, therefore, 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.

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 ultimately 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 is not totally obsolete. Equipment units mounted on frames are circuit grounded at frame ground busbars in electrical contact with frame metal. Busbars mounted in a frame line are junctioned to form a continuous conductive path. The continuous run is connected at the head of the frame line to a main aisle ground equalizer conductor which extends along the main aisle to allow connection thereto from each frame line comprising the system. This equalizer is in turn 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 equipment ground the frames. This arrangement (including the frame busbars, which may also be known as Equipment frame or Relay Rack Ground Busbars) is referred to as a Combination Discharge-Framework Ground System.

5.10 Relay Rack Ground Busbars

The term "RR GRD", is used extensively on communication systems circuit schematic drawings to denote that equipment units mounted on an equipment frame should be circuit grounded to the frame ground bar. This system requires a 750 kcmil main aisle equalizer with connecting 350 kcmil aisle equalizers. 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 are equipped with ground bars furnished for the primary purpose of providing a direct path to ground for high potential energy intercepted from cables entering the office through the cable vault. 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 along 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 No. 1/0 AWG 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 No. 1/0 AWG is extended from this bar to the CO Ground bar on the same floor in addition a No. 1/0 AWG ground conductor is extended from this point to the cable vault for bonding to the cable sheaths. When the protector frame is located on the same floor as the ground window, an insulated stranded No. 1/0 AWG conductor bonds the ground window to the main ground bar of the frame (lower bar). The No. 1/0 AWG ground conductors serve as a discharge ground path for lightning currents, as a voltage equalizer, and as a frame ground.

Modular or Cosmic type distributing frames (single or double sided) are designed to be grounded with a No. 6 AWG or larger from each frame to a No. 2 or 1/0 AWG to the CO Ground bar and to the ground window if they are both located on the same floor.

5.12 Collocated Local Exchange Carrier Grounding

U S WEST offers several different types of collocation in its COs. There is 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, U S WEST Technical Publication 77350 contains further references to grounding installation, both for U S WEST and CLEC equipment.

5.12.1 The “Horizontal Equalizer” 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 U S WEST by fences, walls, or other barriers. The CLEC installs, monitors, and maintains its own equipment, while U S WEST provides common items such as power, grounding, HVAC, and sometimes an interface point known as the Single Point of Termination or Interconnection Distributing Frame (SPOT frame or ICDF), etc.

For these physical collocators, U S WEST's grounding interface to them is essentially an extension of the nearest COGB. The COGB is extended with the equivalent of a horizontal equalizer to a CLGB (Collocated Local Ground Bar). The CLEC is then free to use this CLGB similarly to a COGB for grounding their equipment frames.

The grounding conductor from the COGB to the CLGB (the CLGB is located inside each CLEC area) shall be a minimum of No. 1/0 if the area is located within 75 ft of the COGB, and if the CLEC area is 100 square feet or smaller. For CLEC area(s) located greater than 75 feet from the COGB and/or greater than 100 square feet, a minimum of a No. 4/0 grounding conductor shall be used. CLEC areas greater than 500 square feet shall have a 750 kcmil feeder from the COGB to the CLGB, regardless of distance. If there are two or more CLECs in a given area, instead of running a separate ground feed to each cage from the COGB, there is the option of establishing a 750 kcmil feeder (horizontal equalizer) around the perimeter of the CLEC area(s), run from the COGB. As a minimum, a No. 1/0 or a No. 4/0 conductor (per the guidelines previously given) may then be tapped off from this 750 kcmil "feeder" down to the individual CLGB(s). The total impedance for the "horizontal equalizer" conductor from the COGB to a CLGB shall not exceed 0.01 ohms. (Note that what is referred to here as a "horizontal equalizer" is a special cable reserved for CLEC use. As a general rule, one of U S WEST's existing horizontal equalizers should not be used, nor should U S WEST connect its equipment to a CLEC "horizontal equalizer".)

Some regulatory agencies have ruled that multiple CLECs in an area should be or can be served by a single CLGB (for example, a few states prefer a model with 4 cages near each other and a ground bar in the center). In those cases, the rules established by the regulatory body take precedence. However, the "horizontal equalizer" from the COGB to the "common" CLGB should be a 750 kcmil cable.

Collocators are generally prohibited from using frames as a battery return path. However, if their equipment uses this method, U S WEST must be informed up front in order to properly size grounding conductors. In those cases, the COGB to CLGB "equalizer" connection shall be a 750 kcmil cable.

The above COGB to CLGB (or drop from the CLEC area horizontal equalizer) minimum cable sizing is summarized as follows:

1/0 AWG: the distance of the run **= 75'**, <u>and</u> the cage size is **= 100 ft^2**

4/0 AWG: the distance of the run **> 75'**, <u>or</u> the cage size is **101-499 ft^2**

750 kcmil: cage size **= 500 ft^2**, <u>or</u> **multiple cages**, <u>or</u> a CLEC with **frame return**

5.12.2 Fence Grounding for Caged Physical Collocation

Most physical CLEC areas (as well as some U S WEST subsidiaries) use chain link fence as the barrier between U S WEST 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 shall 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>Requirements for Cages Without a Fence Top Incidental Bonding Conductor</u>

This fencing shall 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 are chain link or other metallic structure). This connection shall be made with a minimum No. 6 stranded “green-wire” copper conductor. The CLGB connections to bare fencing shall be made with a two-hole crimp-type copper lug (if connected to the incidental fence bonding conductor described below, the # 6 green wire can be connected with an H-tap), which is sized properly for the connection point. This connection shall be cleaned and treated with an anti-corrosion inhibitor. However, 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.

<u>Requirements for Cages With a Fence Top Incidental Bonding Conductor</u>

When this is done, only one No. 6 AWG conductor need be run from the fence top incidental bonding conductor, connected with an H-tap, to the CLGB. If a chain link wall is shared by more than one collocator, there may be attachments to that section from all CLGBs in cages which share the wall, or other “walls” (besides the shared fencing) can be chosen for the required #6 AWG green wire connection(s) from the CLGBs.

5.12.3 Isolated Ground Planes in Caged Physical Collocation

Most CLECs do not desire, but some have and will place switches in their physically collocated space (isolated ground plane switches are generally 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” doesn’t 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. However, U S WEST will not mandate what grounding rules a CLEC follows internal to its own equipment, but is concerned about the interface between the U S WEST grounding system and that of the CLEC. U S WEST 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, U S WEST will not dictate how the CLEC establishes an isolated ground plane, but using the principles defined in Chapter 8, a couple of suggestions can be made. Essentially, U S WEST uses two types of Ground Windows (MGBs): 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 8-6 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 U S WEST will provide power. The CLEC may use the return bar of this “BDFB” as a ground window, following the guidelines of Chapter 8 (Figures 8-10 and 8-11 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 8-6 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 integrated ground plane must be “foreign-object” grounded back to the integrated side of their “ground window”. This includes any chain-link fencing.

Physical collocators who place isolated ground plane equipment should be served with a 750 kcmil COGB to CLGB equalizer, even if they are “cageless physical” CLECs that wouldn’t even normally require a CLGB.

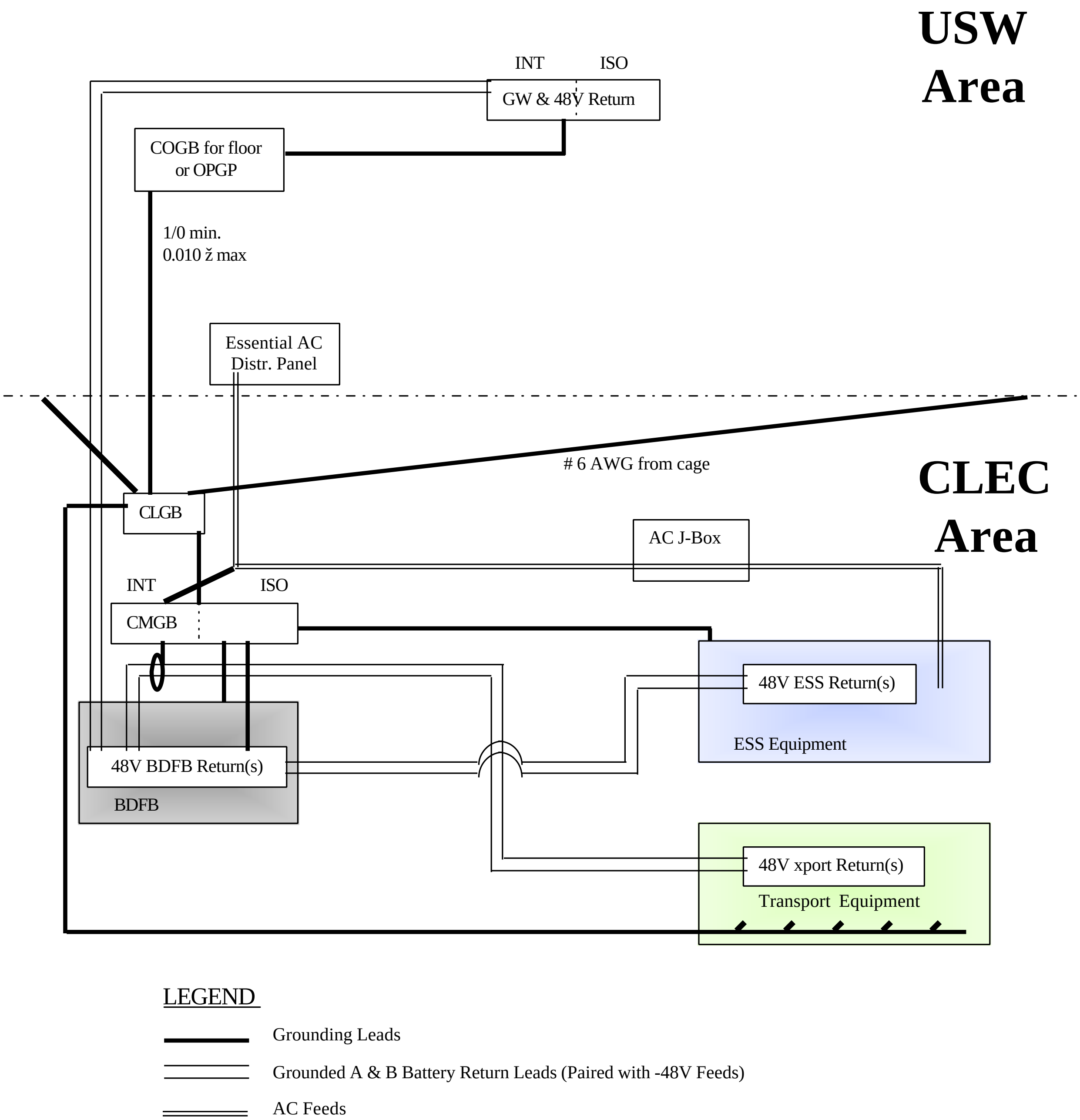


Figure 5-1: Example of a Possible CLEC Switch Isolated Ground Plane Environment

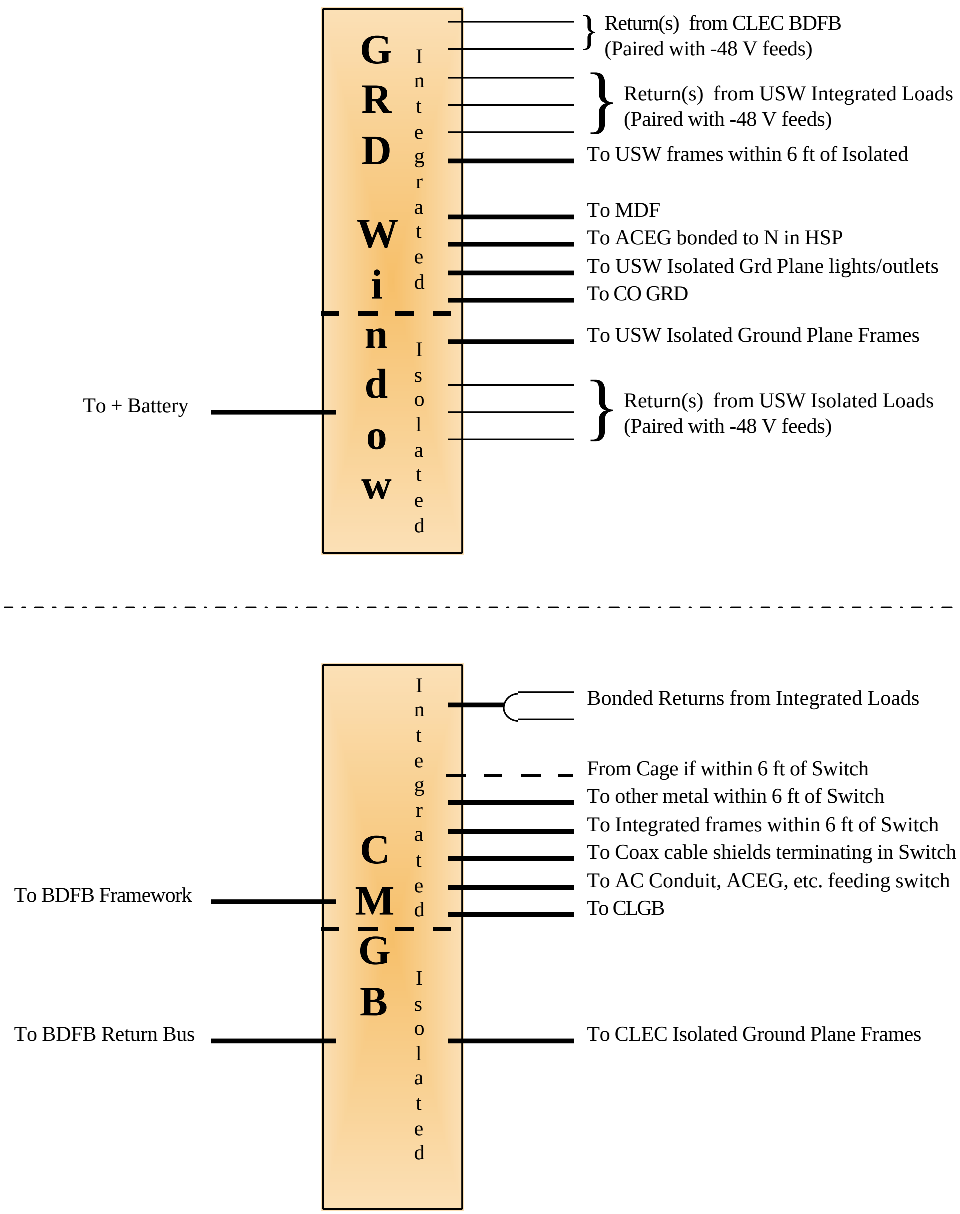


Figure 5-2: Example of U S WEST Ground Window Sequencing and Possible Sequencing for a Separate CLEC Ground Window

5.12.4 Grounding for Other Types of Collocation

There are several other types of collocation offered by U S WEST. In virtual collocation, the CLEC pays U S WEST to buy, install, monitor, and maintain equipment. This equipment is placed in U S WEST lineups, and treated just like U S WEST's own equipment. It is grounded in the same way as any other U S WEST integrated ground plane frame in that lineup, typically with a No. 6 AWG bonded to the framework and then connected to a No. 2 AWG "stringer" which runs down the lineup and back towards the COGB (possibly connecting to a horizontal equalizer extended from the COGB).

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 U S WEST lineups, next to U S WEST frames. But, like physical collocation, the equipment is bought, installed, monitored, and maintained by the CLEC. Because the equipment is often in U S WEST 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.

Another type of collocation offered by U S WEST 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 collocators (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 U S WEST, 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 collocators not separated by a physical barrier, if the shared collocation area is physically separated from U S WEST 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), with the COGB to CLGB feeder sized in accordance with the rules given previously. However, if the shared uncaged area is not separated from U S WEST lineups by at least 6 feet, then the CLEC frames are treated like those of virtual or cageless physical collocators, as far as grounding and quality standards are concerned.

CONTENTS

Chapter and Section **Page**

Figures

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.

6.3 CEF Protection Measures (Bonding and Grounding)

The OPGPB is the location in a CO where all grounding conductors are connected to the earth electrode. The major emphasis of bonding and grounding is to maintain potential equalization between the equipment ground, power ground, metallic cable sheath components, MDF ground, and the central office principle ground point. The metallic sheath components and metallic strength members of all cables entering the central office must be connected to the central office ground as close to the entrance as possible but not more than 50 feet after entering the building structure. A No. 1/0 ground conductor shall be run from the OPGPB to each cable entrance. In addition, a 1/0 AWG shall be run from the CEF to the protector frame. Insulating joints may be required in certain areas, as designated by the U S WEST Electrical Protection Engineer, where corrosion of cable is a problem. Insulating joints do not provide effective protection against hazardous voltages and are not intended for that purpose (see Figure 6-2).

Central Office Without Insulating Joints

In a central office without insulating joints, bond the metallic sheath components and strength members of all entrance cables with No. 6 AWG copper conductor or bonding ribbon to the ground bar or the No. 1/0 AWG copper wire which is run from the CEF to the OPGPB. This includes the metallic shield of paired conductor cables and the metallic sheath components and strength members of optical fiber cables. The routing of the No. 1/0 AWG to OPGPB shall be as direct and straight as possible and routed away from central office equipment that might be affected by current surges in this conductor. Figure 6-1 shows central office entrance cables without insulating joints.

Central Office With Insulating Joints

Figure 6-2 shows an entrance cable with an insulating joint. Insulating joints are no longer generally used; however, where they exist:

- The metallic sheath components and strength members of all entering cables (paired conductor and optical fiber), must be bonded together with No. 6 AWG copper conductor or bonding ribbon on the outside plant side of the insulating joint within the first utility hole adjacent to the office. 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 located as near as possible to the point of entrance to the central office. Insulating joints must be bridged with a capacitor as specified in Figure 6-2 (for single cables, this capacitor is usually approximately 1,000 microFarads; but if one capacitor is used for multiple cables, an approximately 10,000 microFarad capacitor is used).

- On the central office side of the insulating joint, bond the metallic sheath components and strength members of all cables with No. 6 AWG copper conductors or bonding ribbons to a ground bar or to the No. 1/0 AWG copper conductor that is run to the OPGPB. The preferred method is to bring the No. 1/0 AWG conductor into the CEF and connect to a ground bar. Run No. 1/0 AWG conductors to each cable vault vertical, and ground each cable sheath to it with a No. 6 AWG conductor or bonding ribbon.

Note: All grounding connections shall be made by exothermic weld or crimp (compression) type connections. Connections depending solely on solder shall not be used (see NEC 250-115).

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 paragraph.

Bonding and cable continuity in the CEF can be verified using a CORM (see Bellcore 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 bonding and grounding of optical fiber cable metallic sheath components and strength members in the CEF. For example, access to the metallic sheath components and strength members may require a fiber splice. Bonding and grounding of 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 following bonding and grounding alternatives offer adequate protection.

6.5 Grounding of Shield Only in the CEF

If the outermost metallic fiber cable is a full circumferential shield(s), only this shield(s) shall be grounded to the central office ground at the CEF. All metallic components internal to the circumferential shield need 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. Where insulating joints are used at the central office, this method should not be used as it will short circuit the insulating joint.

6.6 Bonding and Grounding of Metallic Components at the Interconnection Equipment

Bonding and grounding may be done only at the interconnection equipment when there are compelling reasons for not bonding and grounding all metallic components, or at least grounding a full circumferential shield 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.

All metallic sheath components and strength members, as well as the interconnection equipment itself, must be bonded and grounded to the central office building ground system. A No. 6 AWG copper wire or equivalent should be used. If there is more than one cable, the No. 6 AWG wires should be joined to a No. 1/0 AWG copper conductor to the central office building ground system. The routing of this conductor should be as direct and straight as possible. It should be routed away from central office equipment that might be affected by current surges carried by the conductor. The bonding and grounding of a single optical fiber cable containing a shield and central metallic strength member is illustrated in Figure 6-3. 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 6-2.

6.7 Location of the CEF in Relation to the AC Service Entrance

In accordance with NEC Article 800-11(c), the CEF should be located within 20 feet of the building AC Service Entrance (HSP). Exceptions are allowed when this is not practical. Consult the relevant Code Sections in Articles 250 and 800 of the NEC.

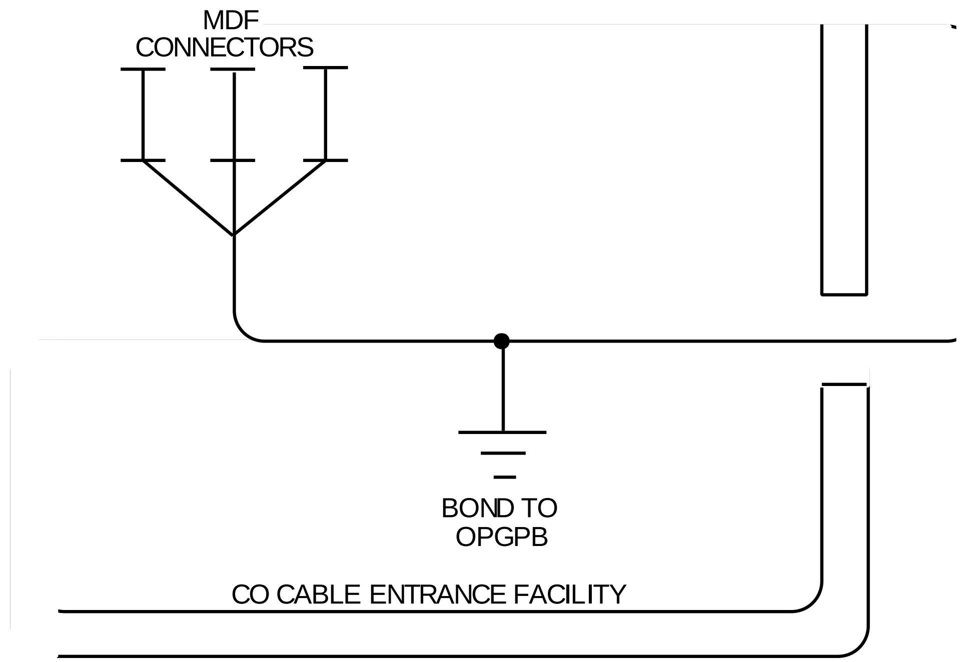


Figure 6-1: Underground CO Entrance with Exposed Entrance Cable

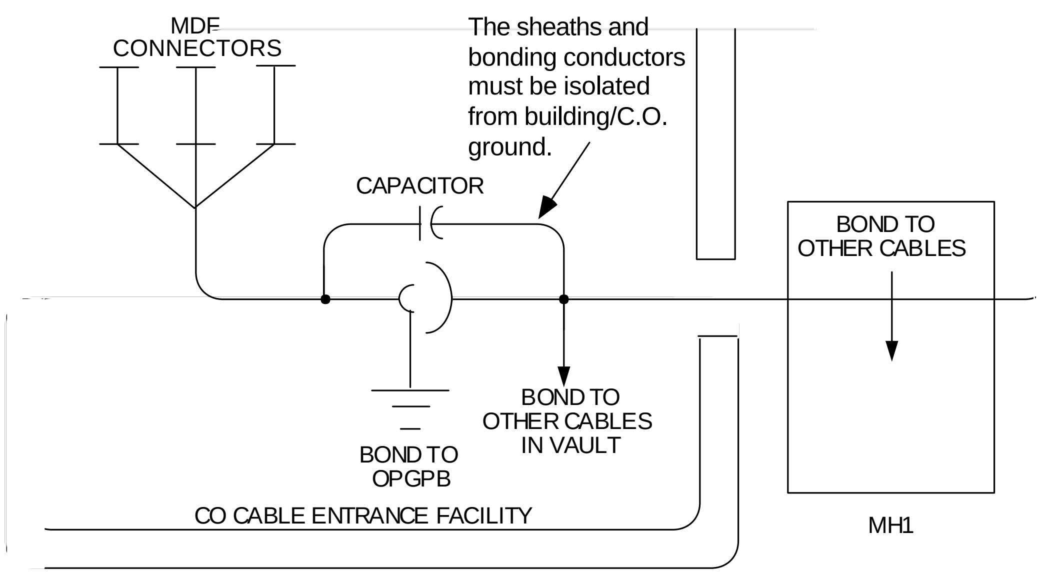
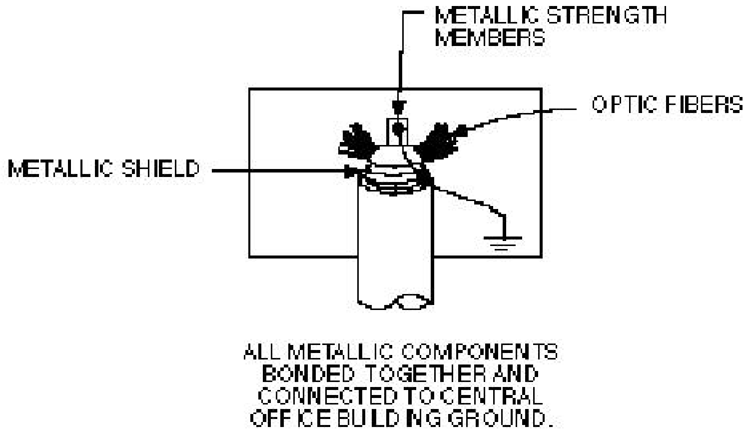
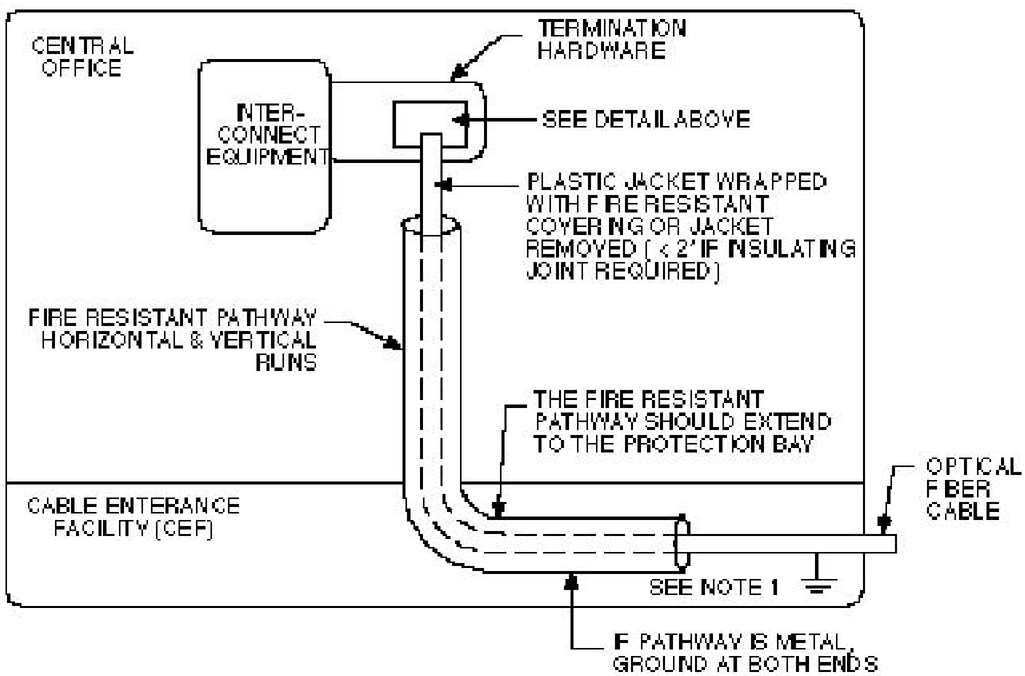


Figure 6-2: Underground CO Entrance Cable Incorporating an Insulating Joint





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 Shall Be placed in the CEF in A Standard Manner.

Figure 6-3: Bonding and Grounding of Optical Fiber Cable in Interconnect Equipment

CONTENTS

Chapter and Section **Page**

CONTENTS (Continued)

7. Radio Equipment Ground Systems

7.1 Driven Ground Electrodes For Radio, Microwave Relay Stations and Fiber Route Buildings

Ring Ground System (RGS) general requirements for establishment of driven ground electrodes for Microwave Radio and Fiber relay stations which 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 strokes) 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 building corners. The method of entry is through nonmetallic conduit where entering conductors are routed vertically on the interior wall to connect to the interior ring grounding conductors. The entire interior ring ground then functions, in addition to its function of lightning protection, as the office principal ground point.

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 that tends to equalize 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 No. 2 AWG solid tinned copper wire buried at least 18 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 connected to the bus at 10 to 15 foot intervals as described in paragraph 3.2 (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.

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 hatch plates. The tower ring portion is bonded with two No. 2 AWG solid tinned copper conductors 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 No.2 needs to be run through the concrete, then it must be routed in a non-metallic conduit.

If the antenna tower has metal guy wires for support, the guy wires must be grounded by adding a buried No. 2 AWG solid tinned copper conductor in a ring configuration and connecting each guy wire to the No. 2 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 No. 2 AWG to the tower or to the building ring ground system (see figure 7-15).

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 3.1.

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):

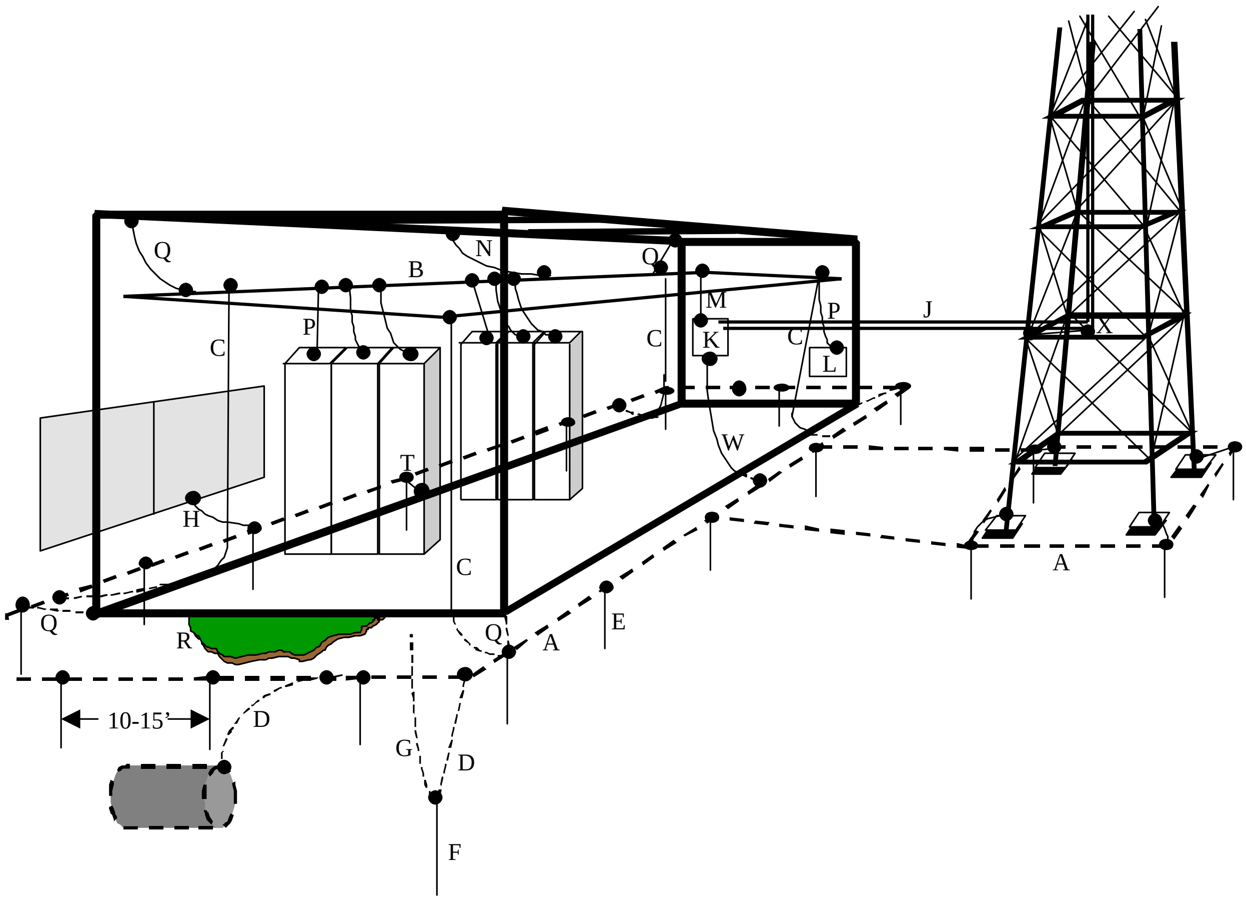
- Rods inserted in drilled holes and backfilled with Bentonite, Calcine petroleum coke or low-grade concrete
- A counterpoise grounding system
- Deep driven rods, or wells cased with steel pipe

Note: Rods enclosed in bags of chemically treated backfill are prohibited in U S WEST 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 shall be No. 2 AWG bare tinned solid copper conductor. Connections to ring conductors shall 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 shall be located so as 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.



LEGEND

(A) Buried Exterior Ring Bus
(B) Peripheral Bus
(C) Inter-Bus Bond
(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 Hatch
(L) Wall-Mounted Cabinet
(M) Hatch Bond
(N) Supplementary Bond
(P) Equipment Bond
(Q) Building Steel Bond
(R) Grade Level
(T) Bond to Metallic Object or Building Exterior
(W) Waveguide Hatch Primary Bond
(X) Waveguide Vertical to Horizontal Transition

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

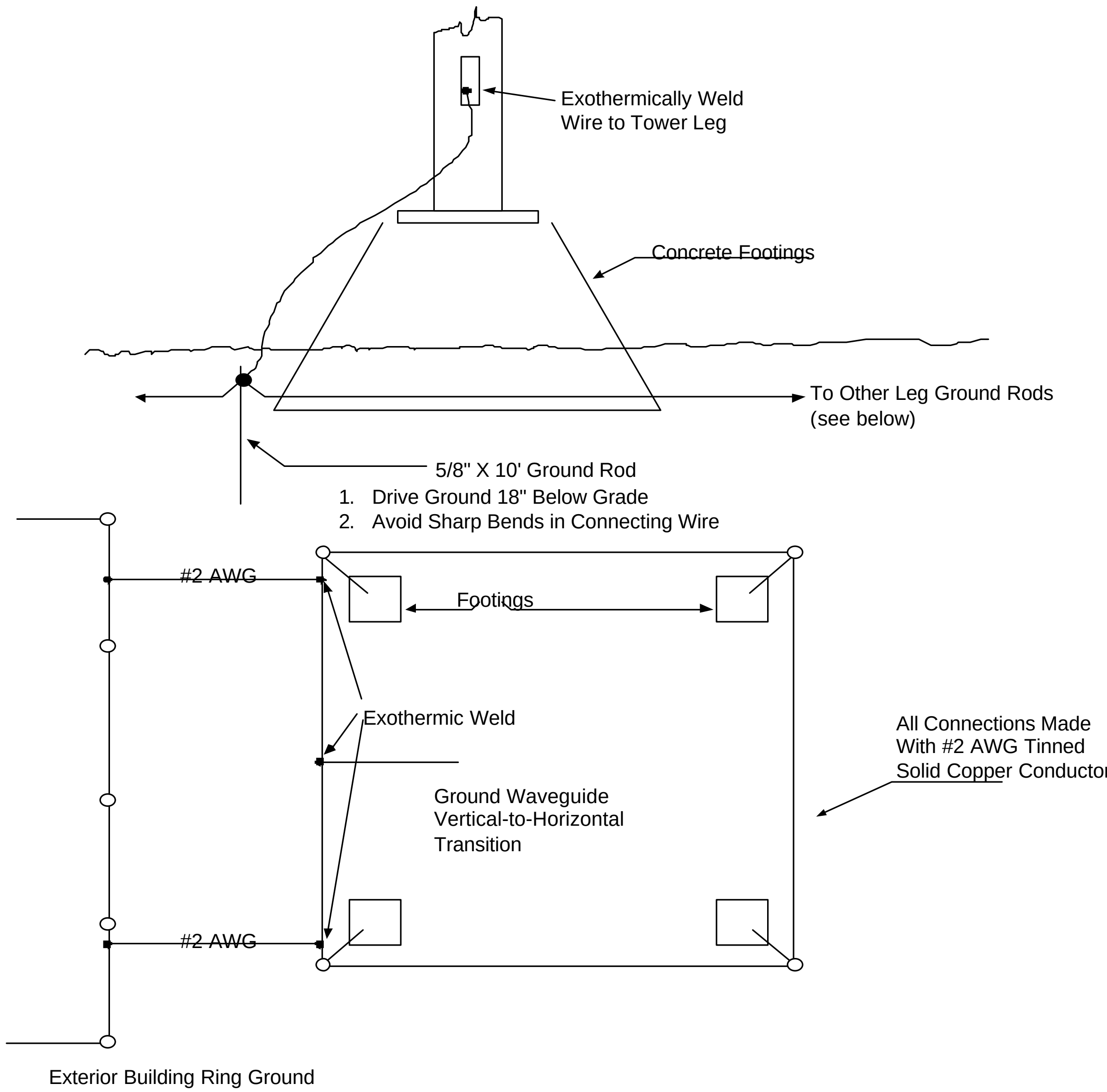
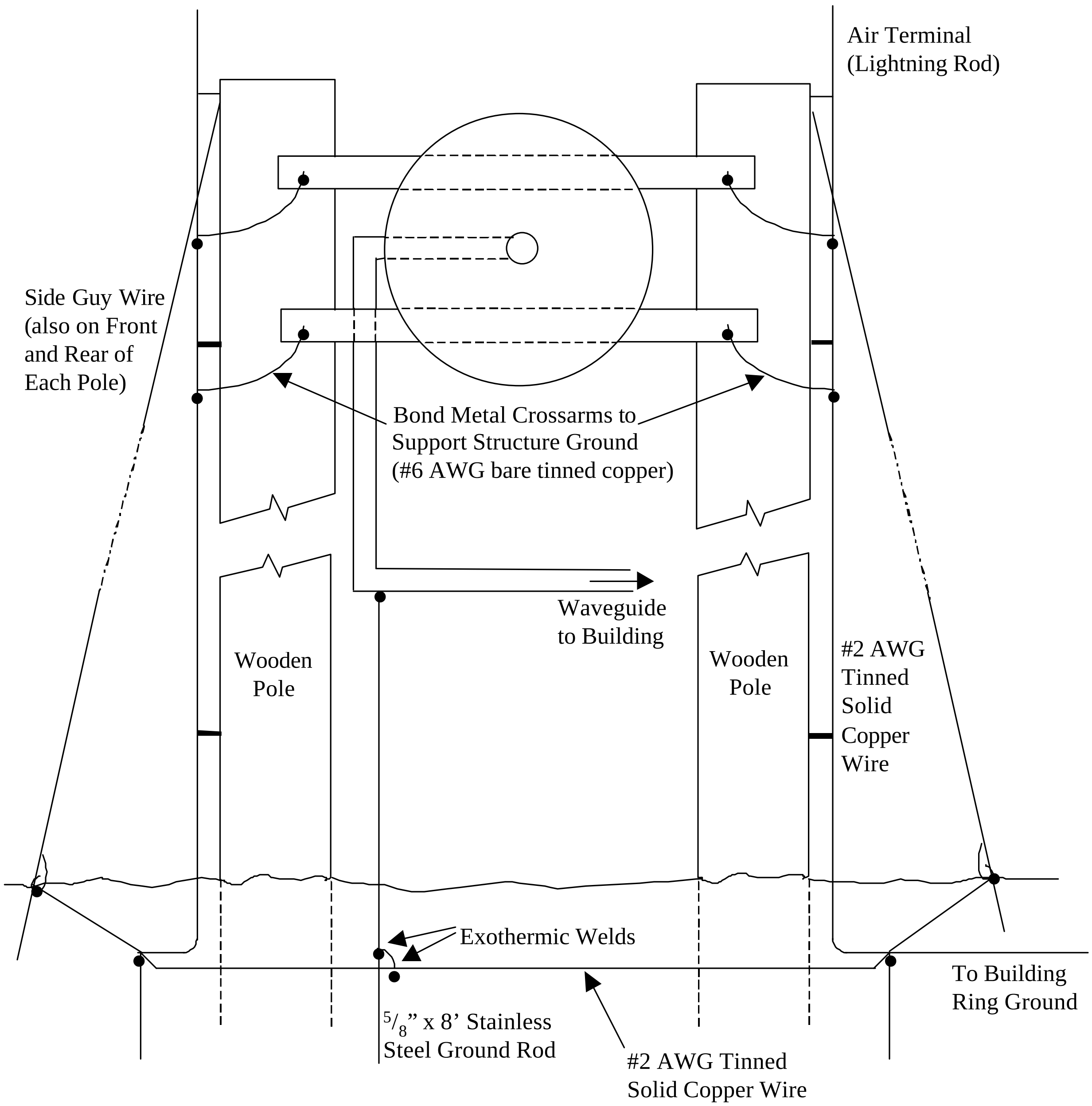


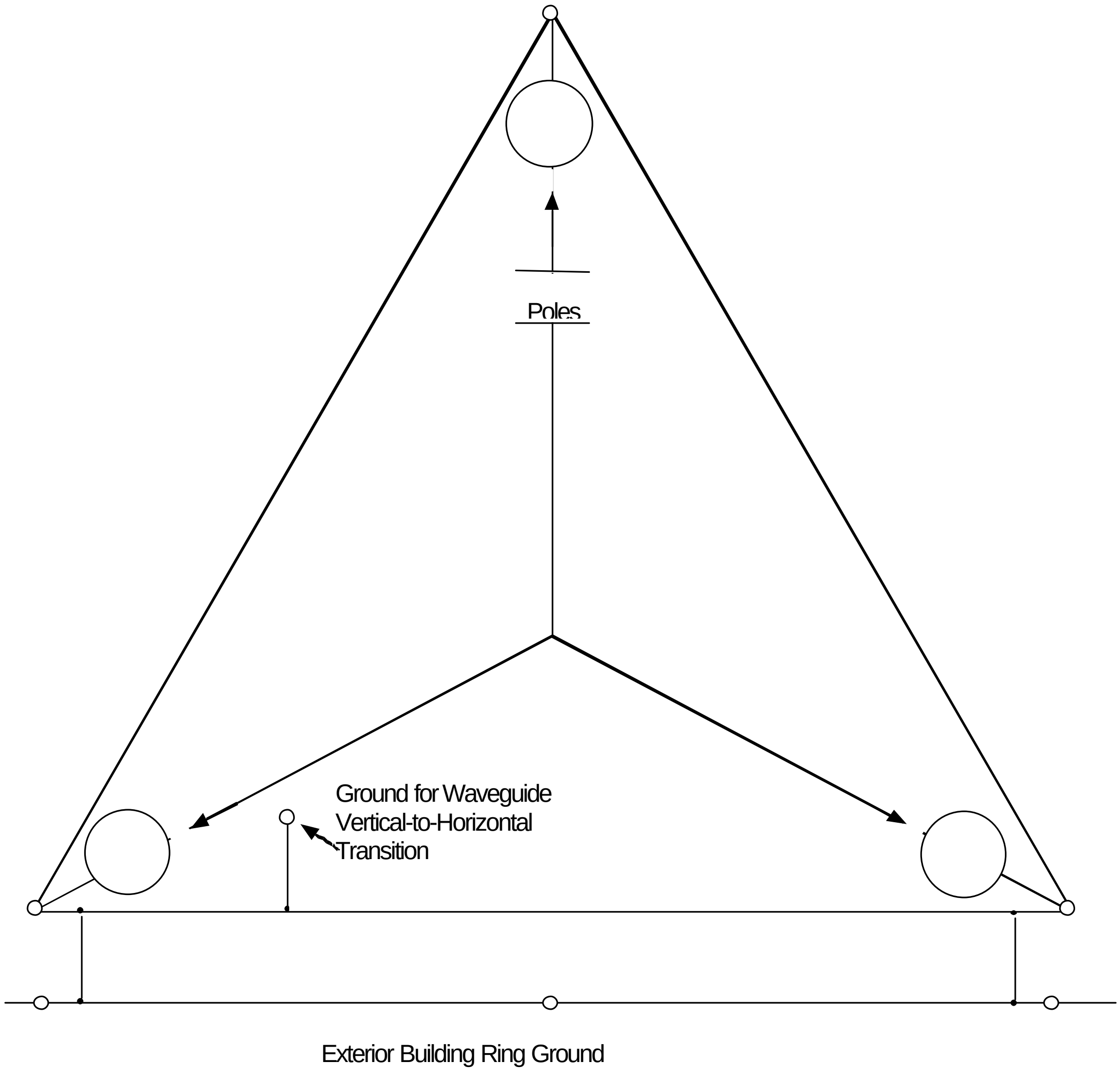
Figure 7-2: Typical Grounding Arrangement for a Metal Antenna Tower



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 No. 2 AWG tinned solid copper wire.
2. All connections to be exothermic process.
3. Add air terminal to top of pole and ground to tower ring ground.
4. Use 5/8" X 8' ground rods 10' - 15' apart.
5. Crossarms and antennas omitted for clarity.

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

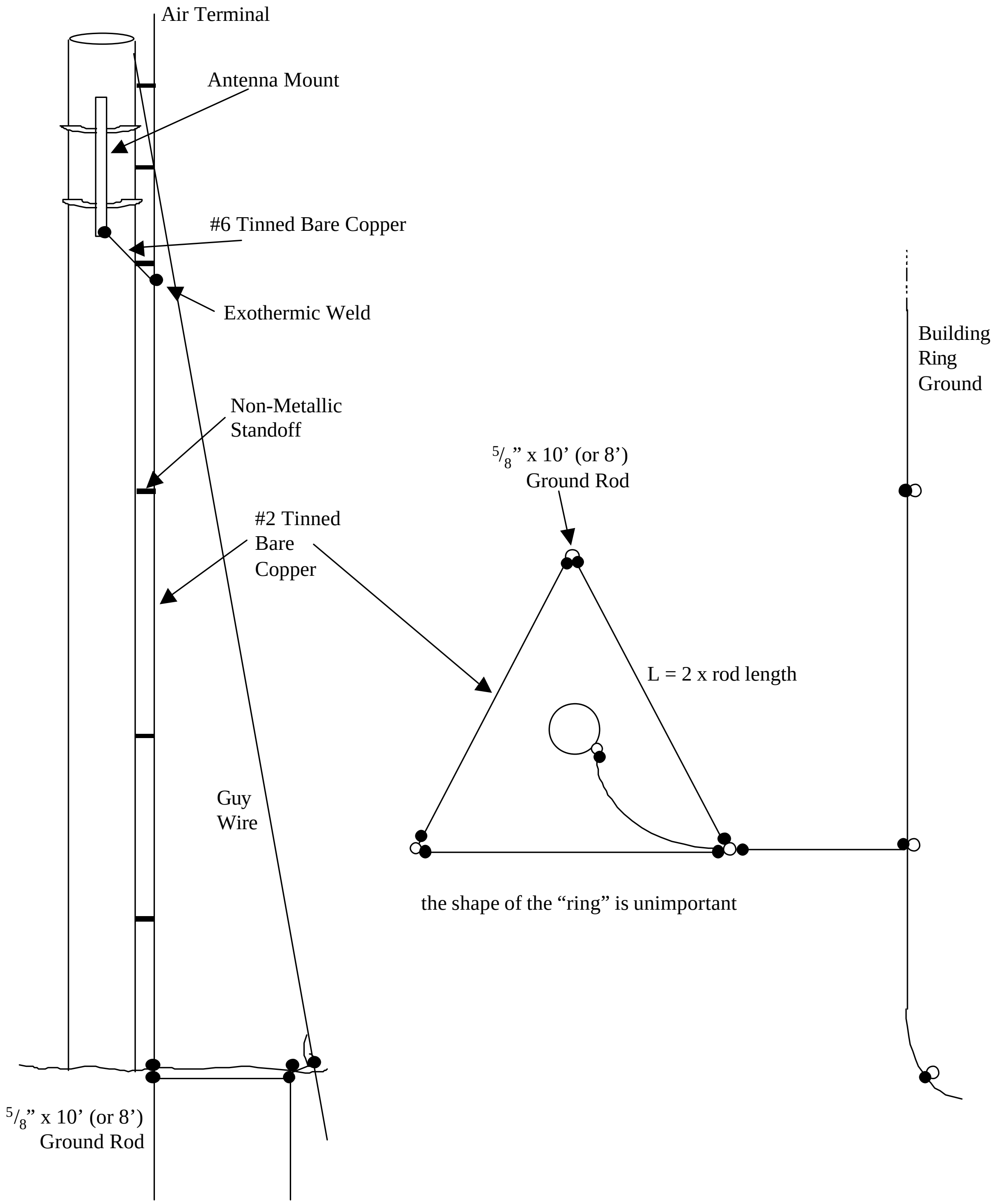


Figure 7-5: Grounding Arrangement for a Single Pole Wooden Antenna Support

7.4 Roof Top Mounted Ring Grounds

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

Rooftop mounted tower structures increase the lightning risk index for the buildings they are placed upon. Due to their increased elevation and lightning risk probability, all buildings with roof top towers shall be equipped with a lightning protection system as outlined in NFPA 780. In addition to these bonding and grounding requirements, the tower support legs shall be interconnected with a bonding ring of No. 2 AWG or larger copper conductor at its attachment to the roof structure. This bonding ring shall also be bonded to the main roof perimeter lightning protection ring by a minimum of two opposing conductors of No. 2 AWG conductor or larger at or within 24 inches of a grounding "Down Conductor". All guy / anchors that attach directly to the building shall also be bonded to the roof perimeter protection ring. Other metallic elements of the roof should be bonded to the roof tower ring ground or perimeter protection ring with a No. 6 AWG or larger copper conductor. If the structure is not electrically conductive, as outlined in NFPA 780, then multiple exterior down conductors shall be used having a minimum current carrying capacity of a No. 2 AWG conductor each.

Transmission lines and waveguides should be grounded where they make directional transitions, particularly the transition from vertical to horizontal at the bottom of the tower. The transmission line should be bonded to the grounded entry hatch both inside and outside of the building structure.

7.5 Non-Metallic Antenna Structures

One, two, and three pole wooden support structures are used in U S WEST . The three pole structure is less susceptible to torsion and is, therefore, preferred. These wooden structures should be grounded as shown in Figures 7-3, 7-4, and 7-5. In using a wooden structure, it is advisable to mount the antennas with their extremities below the top of the structure and add an air terminal (in addition to Figures 7-3 and 7-5, see Figures 7-18, 7-19 and 7-24 for examples of the use of air terminals) on top of the pole, grounded 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 will be kept off of the antenna and transmission lines as much as possible.

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 PCS or Cellular, whose grounding is covered in Section 7.23) should be similar to what is shown in the top halves of Figures 7-16 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 with 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 and straightly 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, where towers are especially high (over 200 feet) and across flexible sections of waveguides (see Figure 7-6). The bond at the bottom of the vertical waveguide run must be applied just above the point where the waveguide bends to the horizontal plane.

7.7 Tower Warning Lights

Towers that have aircraft warning lights shall enclose all AC power conductors in metallic conduit. The conduit shall be supported at least every 10 feet and within 18 inches of any conduit body to meet NEC Article 370-23e,f. Expansion joints for the metallic conduit shall be bonded with a copper conductor of No. 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. The surge protection device shall be grounded to the external rooftop grounding electrode system or to the tower roof ring ground. Questions on this section should be directed to the U S WEST Electrical Protection Engineer.

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 No. 6 AWG conductor or larger. At the building, the waveguides and supporting structure and the entrance hatch are bonded together and the hatch is connected directly to the external ring ground at the station with a No. 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 Hatchplate 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) shall be bonded to the external ground ring at the point of entry. All conductors entering a radio facility shall be bonded to the internal ring ground system within three feet of the entry point.

The waveguides can be bonded to the hatchplate by the mounting flanges furnished with the pressure window section that passes through the hatchplate. If the mounting flanges do not make metal to metal contact to the hatchplate then the waveguides need to be bonded together with a No. 6 cable and grounded to the hatchplate. Waveguide and transmission lines can also enter a building through building entries or feed-through assembly hatchplates. These entries or feed-through assembles allow waveguide and transmission lines to pass through without making metallic contact with the hatchplate and shall be bonded individually and externally on the hatchplate with a No. 6 AWG grounding cable. Where an RF transmission line, other than rigid or elliptical waveguide, passes through the hatchplate, it shall be connected to a Listed overvoltage protection device and grounded before entering the building.

Metallic supportive framework shall be bonded with a No. 2 AWG bond to the hatchplate exterior surface with a two hole compression connector if it is not mechanically connected to establish continuity.

Conduit entering the building in proximity to the hatchplate shall be bonded to the hatchplate 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 also be bonded to the interior ring bus system immediately on entry into the area served by the ring bus.

The hatchplate 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 hatchplates are located in the roof, the primary bond shall be bonded to the roof ring ground. The primary bond shall be connected to the hatchplate on the inside, routed in proximity to, and connected to the interior ring ground. It shall be extended to the CO ground bus in multistory buildings, and to the external ring ground in PVC conduit in single story buildings (see Figures 7-7 or 7-8).

The modern method for bonding and grounding the external hatchplate and entering waveguides is to mount a ground bar below the hatchplate. Bond the hatchplate to this bar as well as all of the entering waveguides. Then tie the bar to the exterior ground ring.

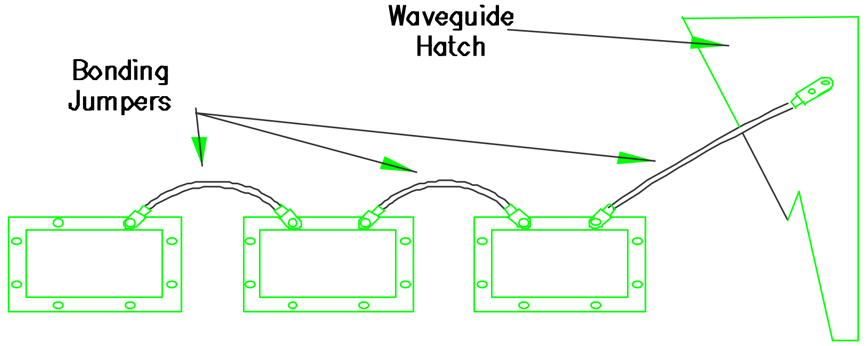
Where a CO GRD system is used for a current path between the interior ring ground and earth, a primary bond to earth is not required. Roof mounted hatchplates shall be bonded to ring ground or supplementary grounding rings near the hatchplates. Wall mounted hatchplates shall be bonded to the exterior ring ground bus as shown in Figure 7-7. It should be noted that the direction of turn of these bonds, and location of connectors at the hatchplates should be applied as shown in Figures 7-7 and 7-8 and as described in paragraph 7.11.

Waveguides require no interbonding to the interior ring ground when the hatchplate is located within 25 feet of the interior ring ground system. When the hatchplate is further away, as when antennas are roof mounted and radio equipment is on a lower floor of a multifloor CO, waveguides shall be bonded to the interior ring ground. Waveguides within 6 feet of each other shall be bonded together with No. 6 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 shall be at the waveguides' entry point into the area protected by the interior ring ground. In this arrangement, the waveguides act as discharge current paths between the hatchplate and interior ring ground system. Primary bonds between such remote hatchplates and interior ring ground may be omitted when waveguides are so bonded (see Figure 7-6).

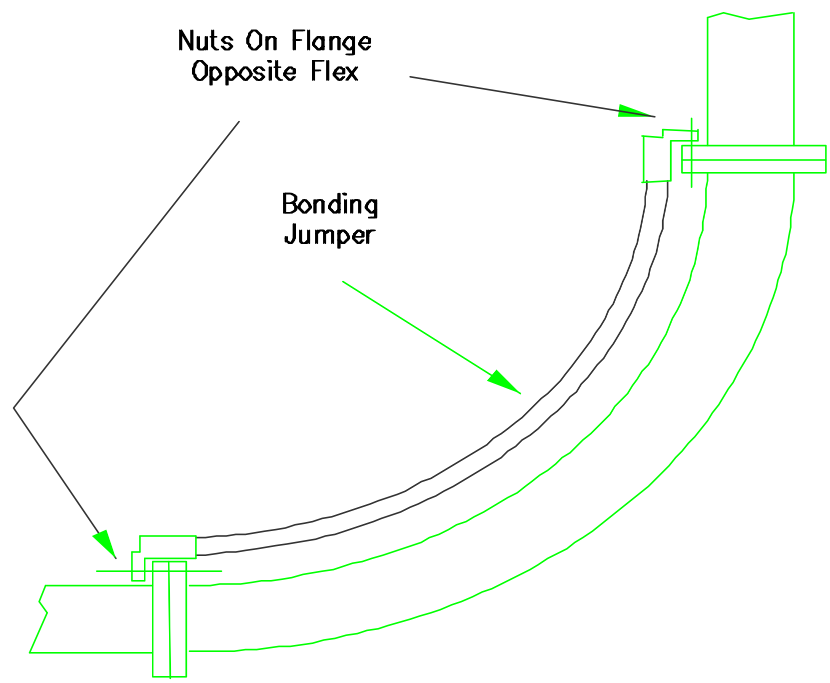
7.10 The Interior Ring Bus System

The Interior Ring Bus System consists of the following:

- A No. 2 AWG insulated stranded copper wire extended around the periphery of the radio equipment area
- A number of No. 2 AWG bonds between the interior ring ground and the exterior buried ring ground
- Supplementary buses
- Unit bonds
- The system is illustrated in Figures 7-7 and 7-8. It provides a means of establishing low impedance between neighboring metallic objects within the communication building, and also 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 hatchplate (or hatchplates) or coaxial cable outer sheath.



Bonding Outdoor Waveguide Flanges To Waveguide Hatch (Typical)



Flex Waveguide Bond (Typical)

Figure 7-6: Bonding of Outdoor Waveguide

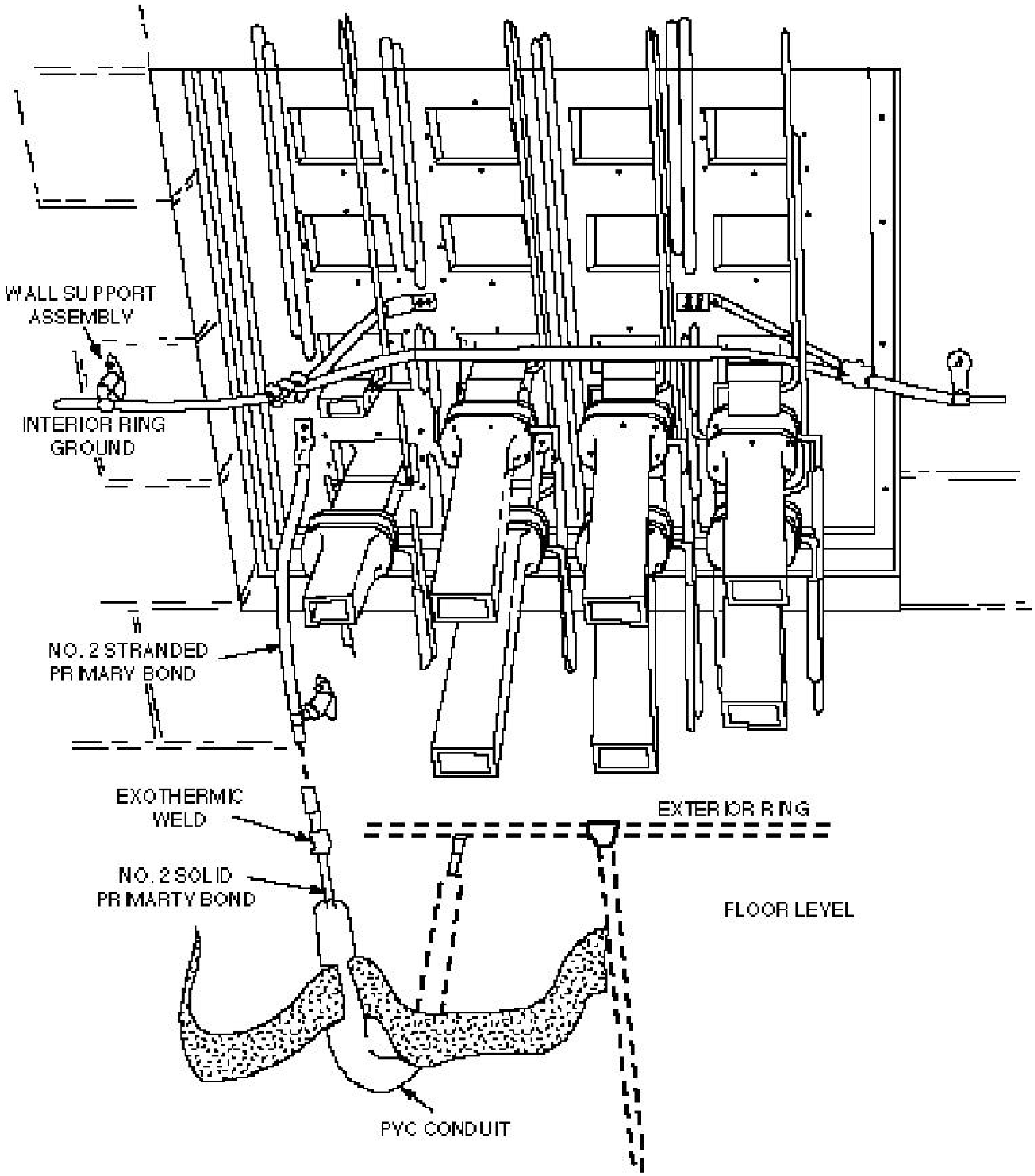


Figure 7-7: Typical Arrangement of Peripheral and Exterior Ring Bus Bonds at Waveguide Hatchplates for Single Story Structures

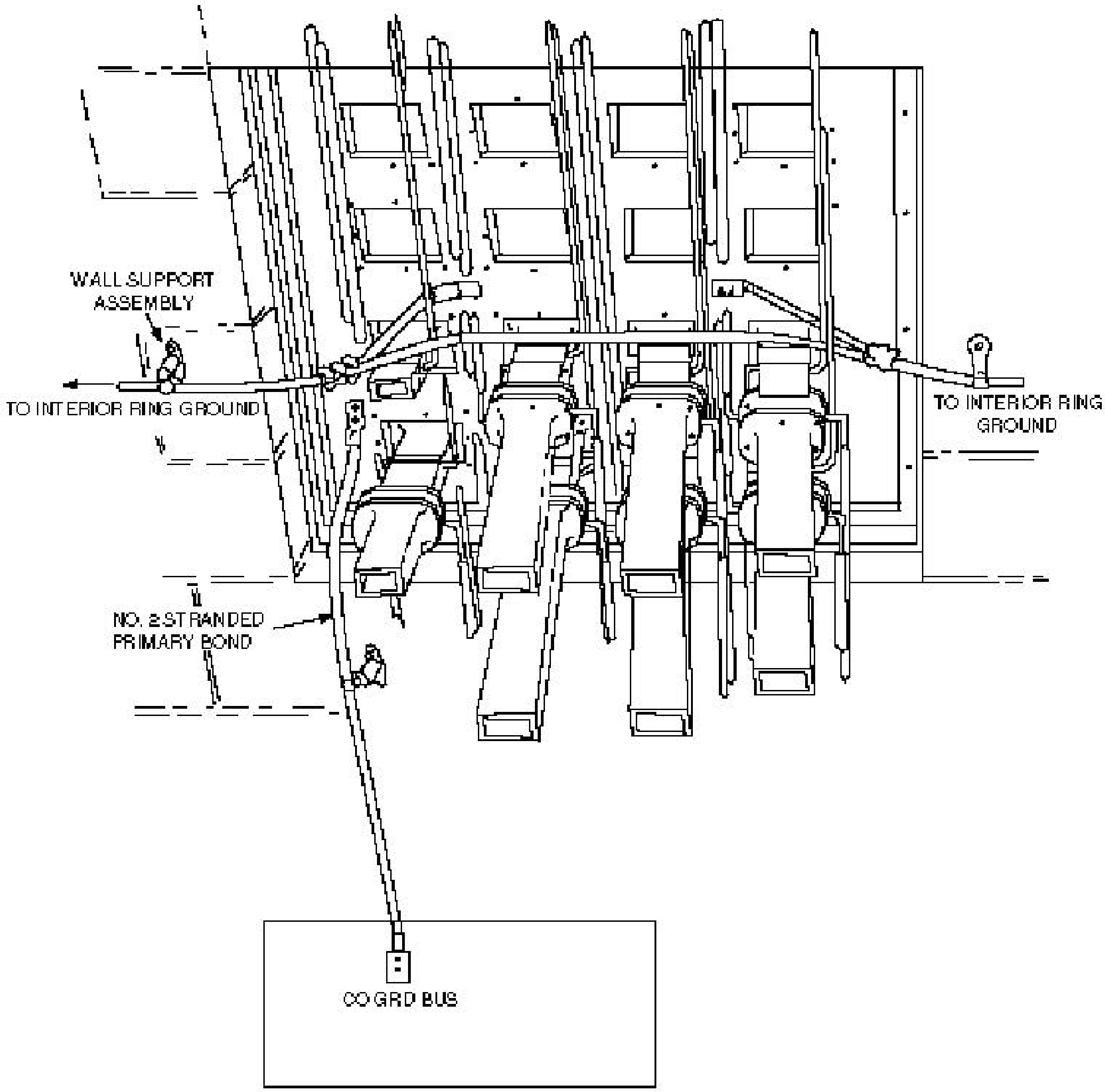
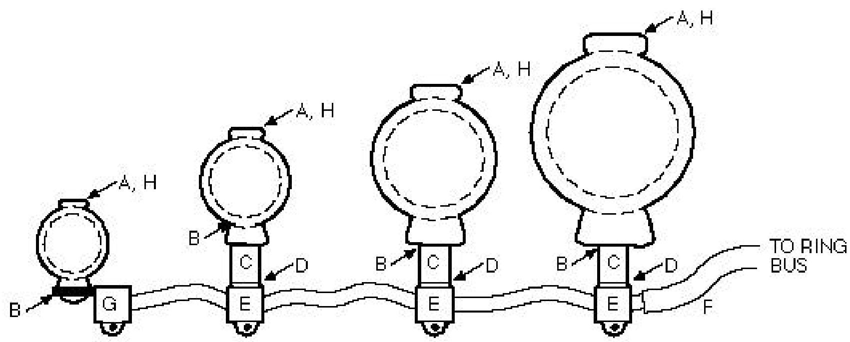


Figure 7-8: Typical Arrangement of Peripheral and Exterior Ring Bus Bonds at Waveguide Hatchplates for Multistory Structures



LEGEND

(A) CONDUIT CLIP
FOR 1/2" CONDUIT
FOR 3/4" CONDUIT
FOR 1" CONDUIT
FOR 1-1/4" CONDUIT
FOR 1-1/2" CONDUIT
FOR 2" CONDUIT
(B) RHM SCREW LOCKWASHER
(C) BRACKET
(D) RHM SCREW LOCKWASHER
HEX NUT
(E) STEEL CLAMP
FOR 6 AWG WIRE
FOR 2 AWG WIRE
(F) NO. 6 OR 2 AWG INS
RHW-LS TYPE STR COPPER WIRE
(G) USE TWO CLAMPS TO
ACCOMMODATE
A 2 HOLE CRIMP CONNECTOR
(H) THE CONDUIT CLIP MUST CONFORM
TO THE CONDUIT SIZE
(INCHES, MILLIMETERS, ETC.)

Figure 7-9: Method of Bonding to ½ -2” Conduit or Pipe

7.11 The Interior-Exterior Ring Bonds

When a buried exterior ring ground system is the site's ground electrode, multiple bonds are required between that system and the interior ring ground. These bonds complete the low impedance current path between waveguide hatchplates and earth.

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 hatchplate 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 hatchplate. Exothermic weld type two-hole bolted tongue connectors must be used to terminate solid wire to the hatchplate. The primary bond wire shall be supported on the interior wall with supports as shown in Figures 7-11 and 7-12. Unnecessary bends shall be avoided. Necessary bends shall have a 12 inch radius or greater.

7.12 Supplementary Ring Grounding

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

(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 going forward], all conduit joints must be bonded together with a minimum #6 AWG conductor.)

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 as possible. In order to facilitate this objective, supplementary buses shall be provided over frame lines within the area bounded by the interior ring ground.
- Supplementary ring ground arrangements are shown in Figure 7-13. 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 (hatchplates) 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 shall 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 7-12 is recommended for support of wire on walls. A nylon expansion anchor, as illustrated, shall always be used. Supports shall 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 basis of need. 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).

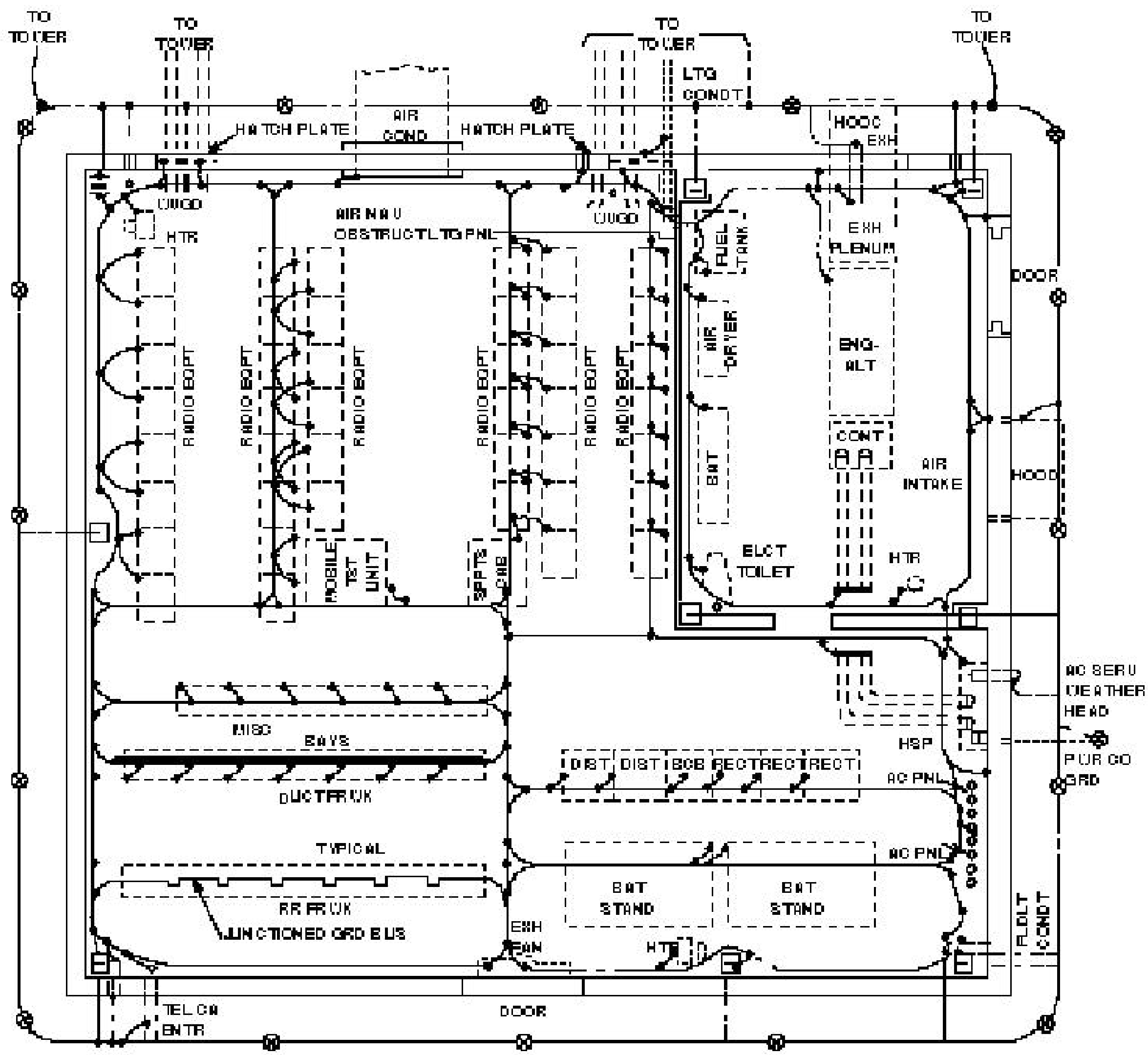
When stranded wire and exothermic welds or crimp type parallel connectors are employed, the interior ring ground need not be installed as a single continuous run of wire. Unnecessary splices should be avoided, but where installation is greatly simplified by installing the interior ring ground in several segments, with the segments joined by an exothermic weld (preferred) or crimp type parallel connector, such segmentation is permissible. Solid wire interior ring ground may be segmented only if segments are joined with an exothermic weld or an approved crimp type connection.

For the purpose of minimizing impedance and 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 1 foot. 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 ring of metal around a ground conductor acts as an inductive impedance to the flow of other than steady state discharge 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 shall never be painted and must be run exposed so that visual inspection of the system may be made, and any point is available for bonding. Routing of a conductor through PVC conduit for purpose of support should be avoided for these reasons.



Notes:

1. ⊗ Driven Rod
2. -·-·-·- # 2 Solid Wire
3. Exothermic Weld or Crimp
4. # 6 Ground Connection
5. 12" min. radius bend in wire
6. For Wall Supports see Fig. 7-10
7. For Crimp Connections see Fig. 7-11
8. For Cable Rack Support see Pub 77351
9. For Conduit Bonds see Fig. 7-8
10. For Hatch Plate Bonds see Figs. 7-6 & 7-7
11. For Framing Channel Support see Fig. 7-13
12. The picture above shows frame unit bonding to individual frames from the ring having one crimp serving two frames. This was permissible in the past, but now going forward each frame should have its own crimp to the ring or aisle feeder

Figure 7-10: Typical Ring Ground Installation in a Microwave Station

7.14 Forming and Support of Supplementary Buses

Supplementary buses are normally supported from cable rack stringers (see Figure 7-13) 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 7-11 SK-A be used at 2 foot intervals. The spring type universal clamp, when mounted on a cable rack stringer, ensures a maintenance free bond to the cable rack. 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 shall not be painted, and the clamp shall not be painted.

Where cable racks are not available for support of supplementary grounding conductors, framing channel superstructure may be utilized (see Figure 7-14). Such channels shall be bonded to the wire at both ends of a bus run portion supported in this manner and at 15 foot or lesser interim intervals when the run portion exceeds 20 feet. The bond shall 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), shall be provided at 2 foot intervals along the channel.

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 shall be made with 2 hole crimp connectors.

When the engine exhaust stack is higher than the building roof, it can serve as a lightning rod. In these cases, it is preferable to attach a # 2 AWG from the external stack, run it outside of the building, and connect it to the external ground electrode field. Also, attempt to bond the thimble (through which the exhaust stack exits the building) to this # 2 conductor. When this can’t be done, ensure to bond the stack per Figure 4-5.

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 3-7 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 1/2 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 No. 6 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 shall be considered as conduit runs. Unit bonds therefrom shall 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 shall be terminated at the point on the unit that serves as the framework ground point for the CO GRD system so as 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 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 for each structure. Recommendations for bonding for structural members to interior ring buses are outlined below:

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

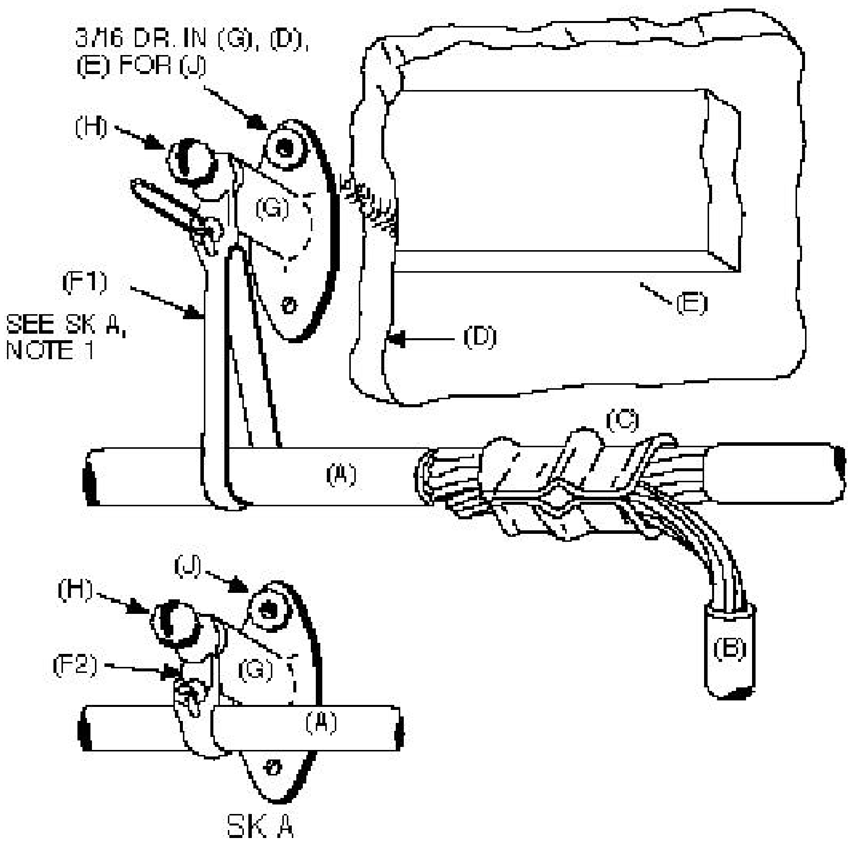
- Steel beams or fabricated metal
- Prestressed reinforced concrete
- Reinforced concrete
- Metal framed opening in walls and roofs

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 hatchplate, 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.



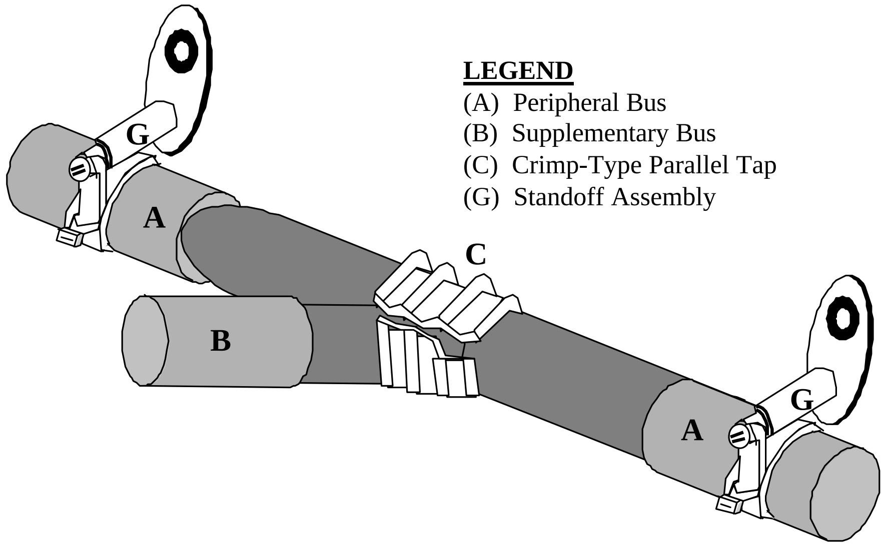
NOTE:

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

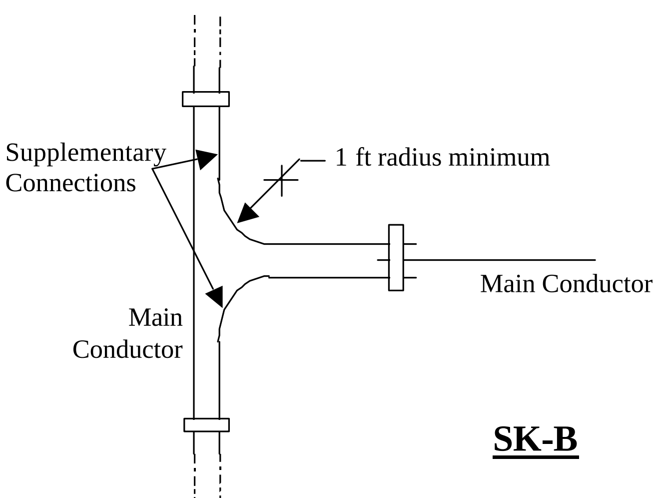
(A) No. 2 AWG Stranded Copper Wire (Peripheral Bus)
(B) No. 6 AWG Stranded Copper Wire (Unit Bond)
(C) Crimp Type Parallel Tap
(D) Drywall (illustrated), Concrete, Brick or Other Wall Material
(E) 1 x 2 Fire-Rated Wood Sleeper 9’8” From the Floor
(F) Nylon Cable Tie: (F1) in Installation Position, and (F2) in Final Position
(G) Nylon Standoff
(H) Fastener Screw
(J) Nylon Fastener

Figure 7-11: Wall Support Assembly for an Interior Ring Ground



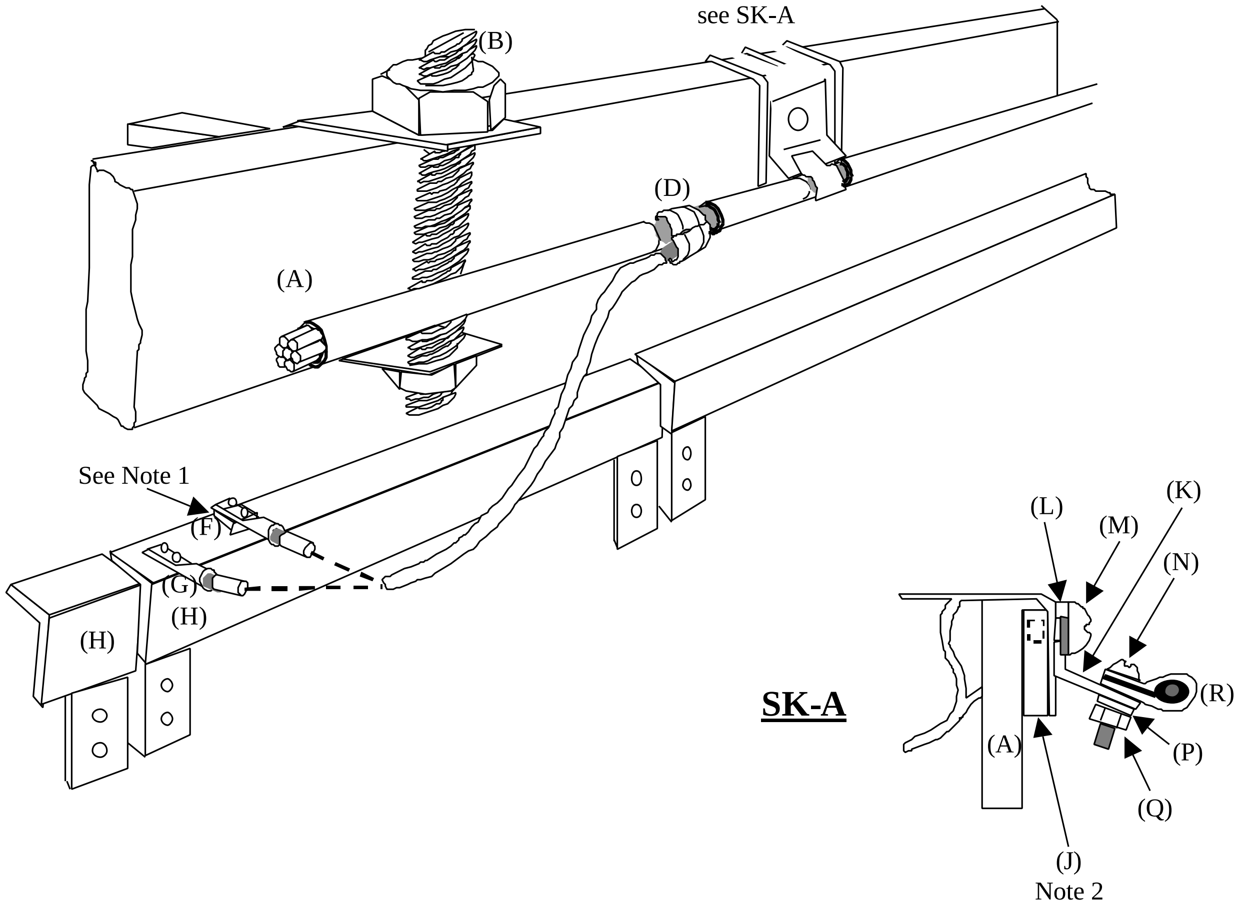
SK-A

NOTE:
Supplementary bus (B) must have continuity to peripheral bus (A) at both ends. The end connected to (A) that is nearest the waveguide hatchplate shall turn in the direction of the hatchplate. The other end shall turn in the opposite direction. When continuity to the hatchplate is virtually equal from both ends of (B) both turns shall be in direction of hatchplate.



SK-B

Figure 7-12: Typical Supplementary Ground Crimp Connections



LEGEND

(A)	3/8" 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)	Lockwasher	(M & N)	RMM screw
(Q)	Hexnut	(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

Figure 7-13: Method of Supporting Ring Bus Wire on Cable Rack and Connection of Bond Wire

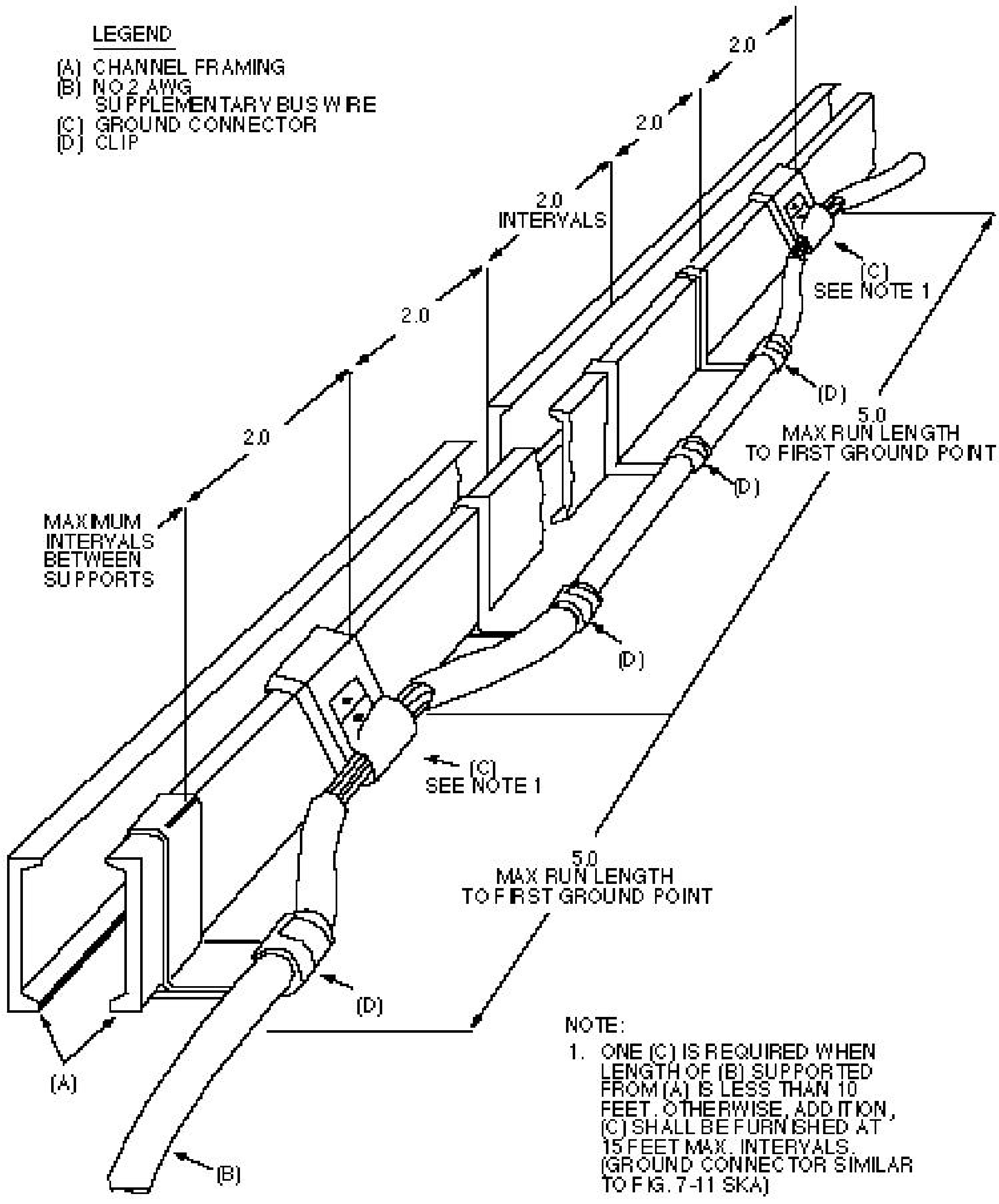


Figure 7-14: Method of Supporting Supplementary or Interior Ground Ring Runs from Channel Framing

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 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, wire 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 bonded 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 job furnished lugs or may have no provision for mounting ground lugs.

Two-hole bolted tongue crimp connectors are required for unit bond connections. Other type lugs must be discarded, if furnished, and replaced with crimp connectors. Where ground lugholes are not provided and a 1/4 inch thick top or upright angle is part of the framework, a universal clamp may be mounted on the 1/4 inch thick angle to avoid the effort of drilling (see Figure 7-13). A two hole bolted tongue crimp connector shall 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 shall be drilled to mount a two-hole crimp connector.

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

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 use of junction plates (these junction plates are an old method that is no longer acceptable on a going forward basis — each frame must have 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 No. 2 AWG supplementary ring ground conductors are extended from crimp connectors mounted on each end of the continuous ground bus and run to the interior ground or other supplementary ring grounds (see Figure 7-10).

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 shall 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, shall also be bonded to the ring ground system.

Metal battery stands and similarly constructed metallic units shall be bonded to the ring ground system. Connection, utilizing two-hole crimp lugs, shall 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 shall 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 No. 2 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.

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 on 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 to have 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.

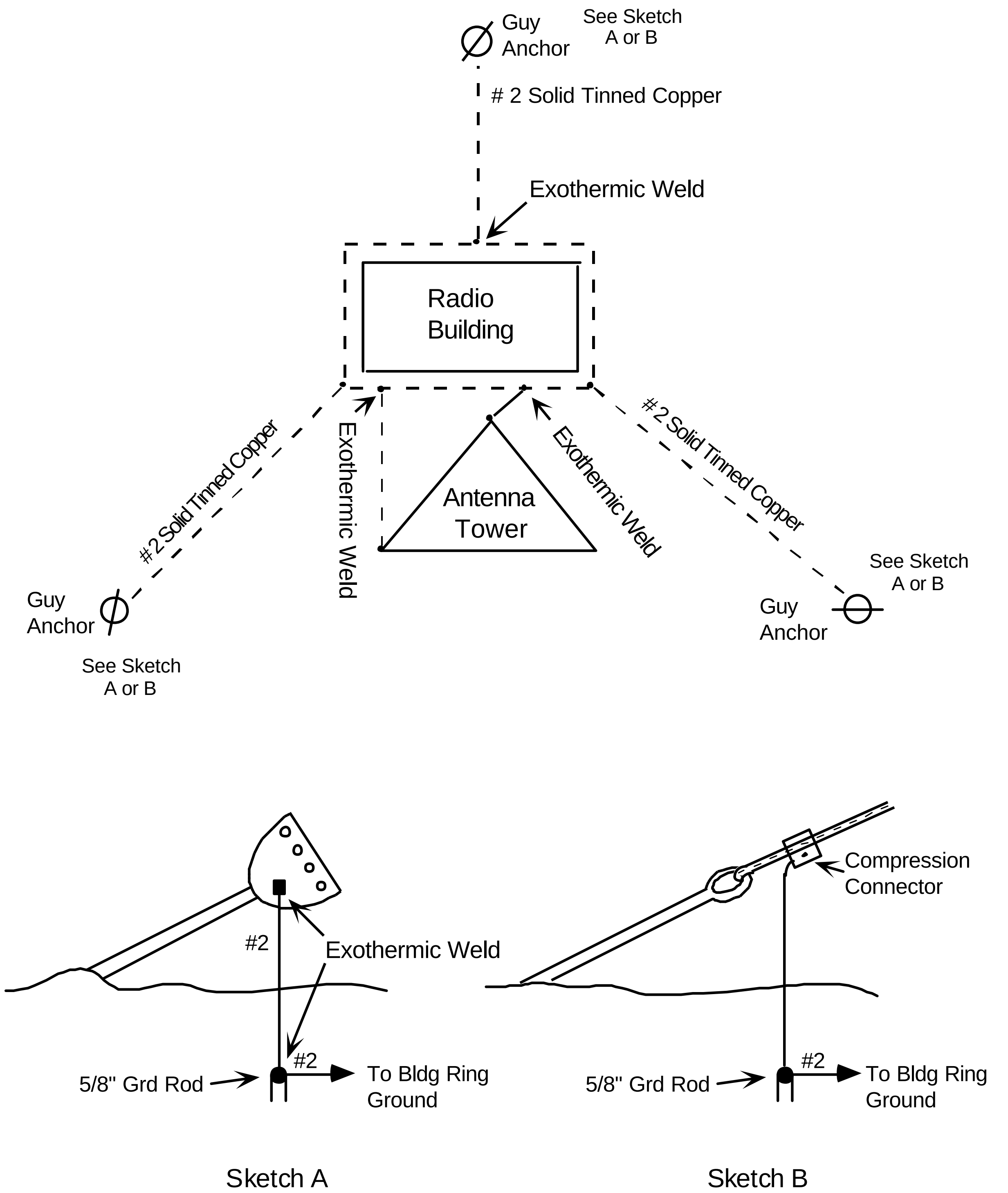


Figure 7-15: Typical Grounding of Antenna Tower Guy Wires

7.23 Grounding Issues Related to Collocated Cellular or PCS Antennas at U S WEST Communications Facilities

Wireless PCS (and in some cases cellular) antennas are now found in large numbers at U S WEST 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.

Complete grounding guidelines for wireless PCS antenna (and which would also be applicable to other wireless antenna such as cellular, LMDS, fixed wireless local telephony, etc.) are found in the internal U S WEST Wireless *PCS Site Guidelines, Specifications, and Design Details* document.

Since this document (Pub 77355) is primarily intended for use by external customers of U S WEST only the most relevant portions of the Wireless antenna grounding guidelines (and especially those relevant to the interface between the wireless equipment and the U S WEST building) will be repeated here.

Some sample drawings reflecting Wireless base station and antenna grounding, as well as the interfaces between the Wireless and U S WEST equipment, are shown on the following pages. They will be referred to in the subsequent sections. This is only a sample of the many documents available from the aforementioned documents. The different sample figures are 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. These figures are sometimes very specific as to manufacturers. The manufacturers listed are only representative of they types of connectors, etc. that can be used. Other similar products from other manufacturers may be used, as long as they are listed and meet the requirements set forth in this document.

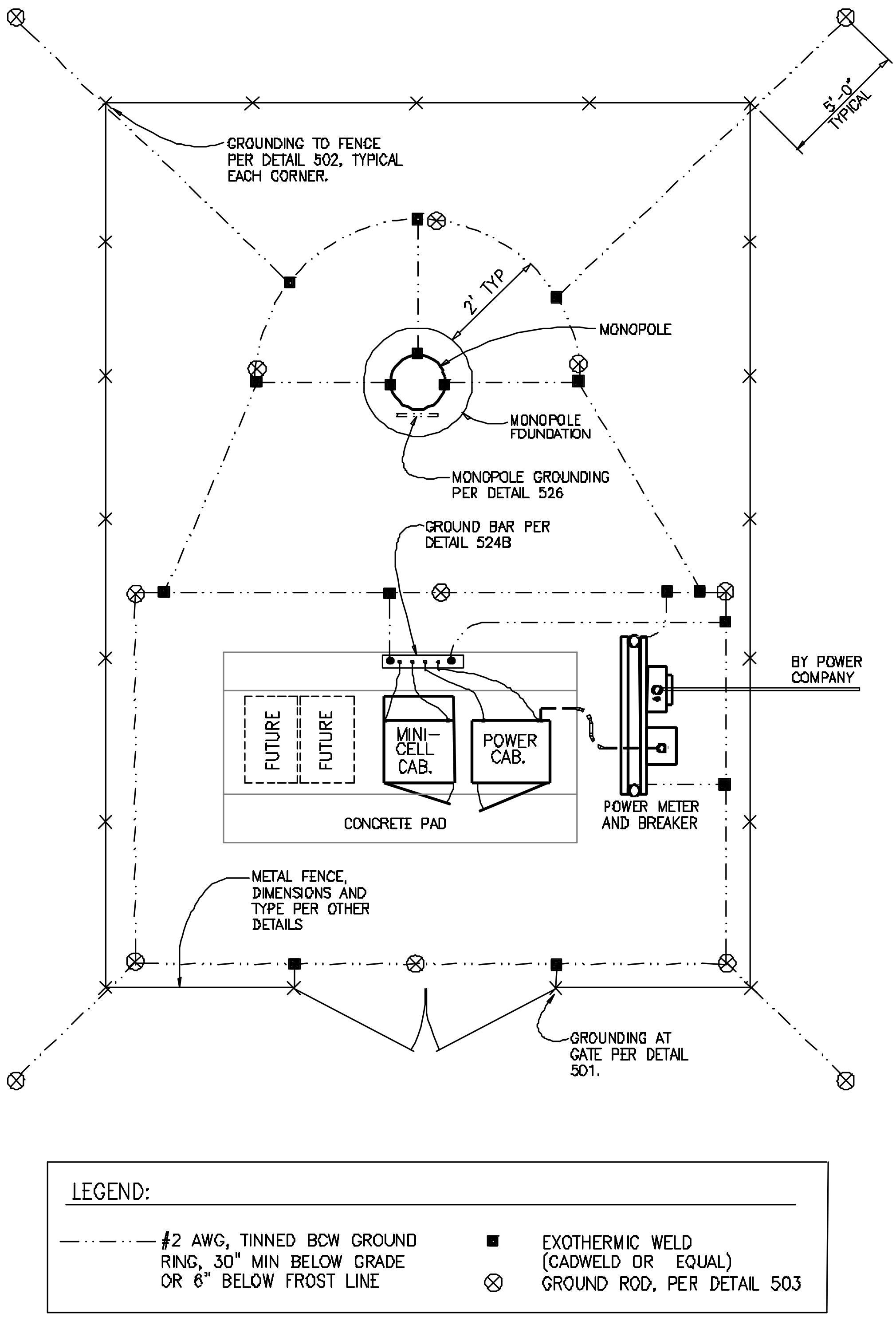
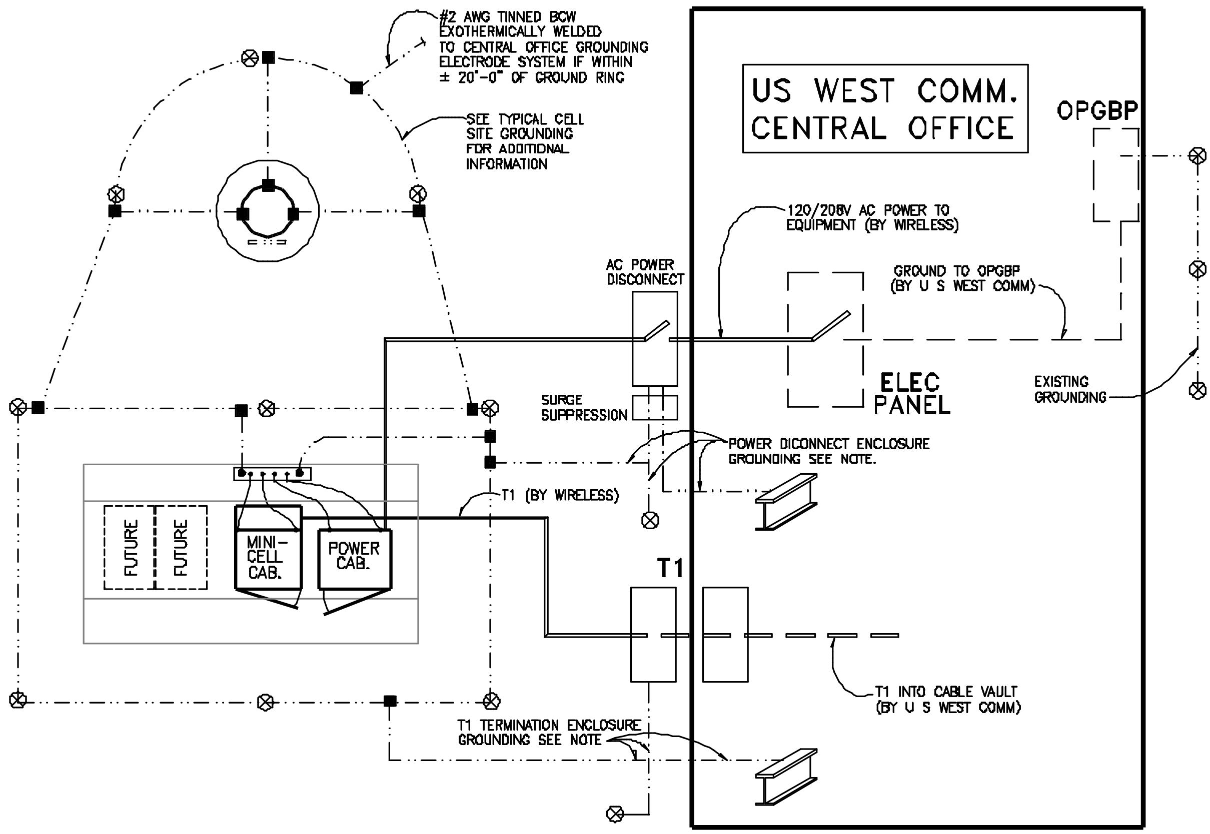


Figure 7-16: Grounding of a Typical PCS Pole Site with a Metal Fence



T1 TERMINATION BOX GROUNDING & 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 BUIDLING 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 BOXES ARE CLOSE, COMBINED GROUNDING MAY BE USED.

SURGE SUPRESSION REQUIRED AT EACH DISCONNECT ENCLOSURE.

Figure 7-17: Grounding Interface between a Typical PCS Pole Site and a CO

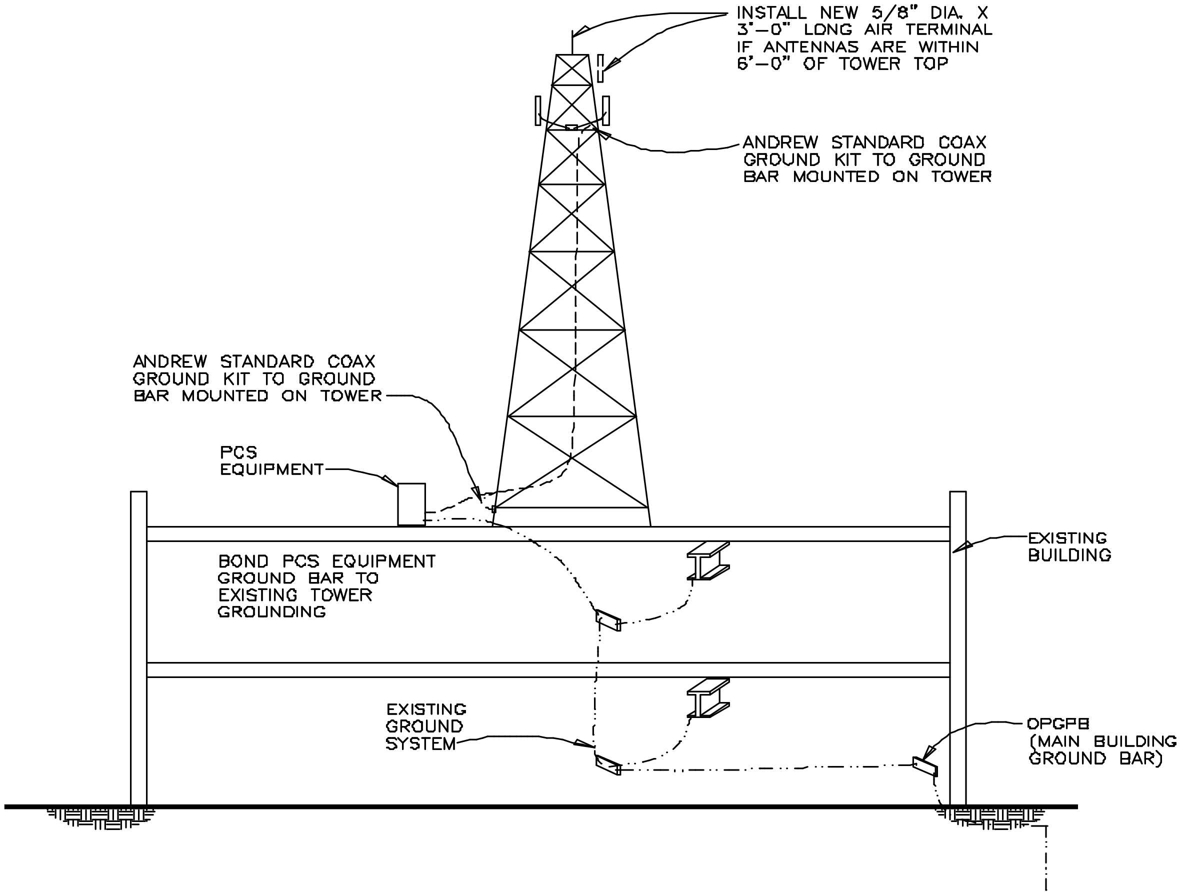


Figure 7-18: Grounding of PCS Equipment Mounted to an Existing Roof Tower

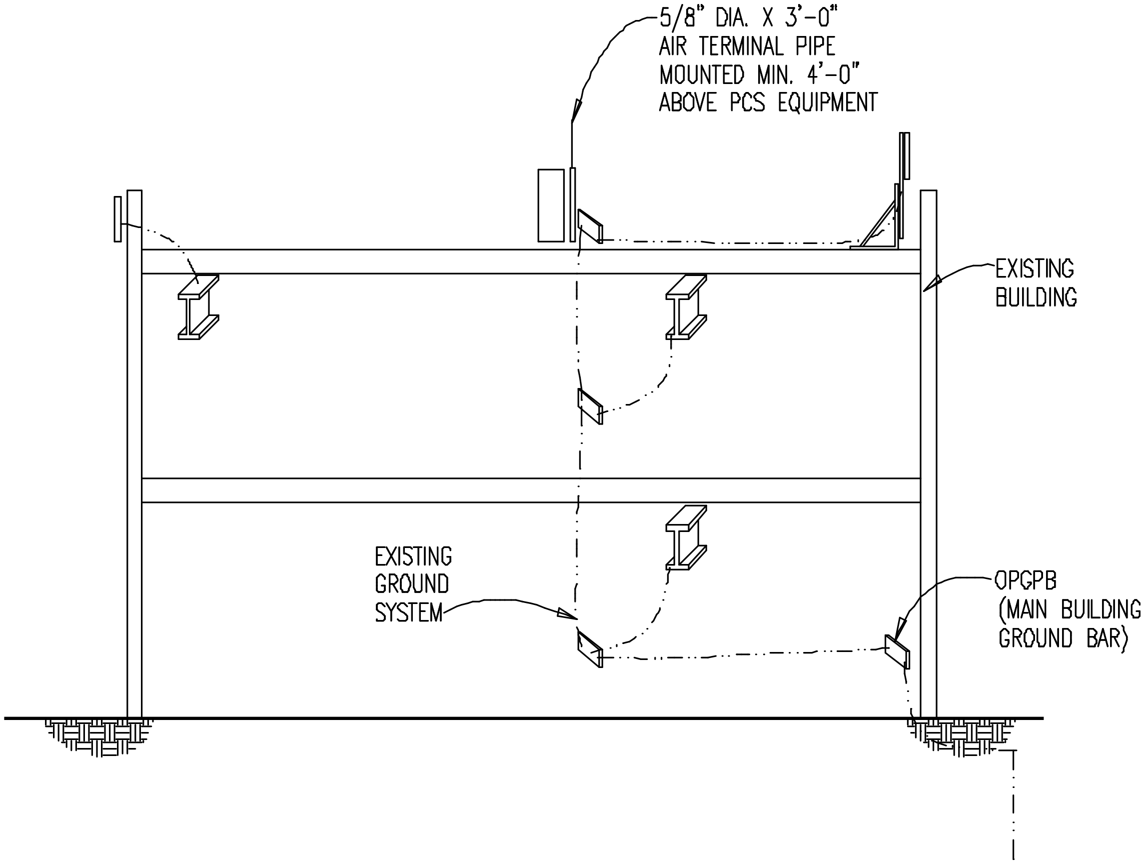


Figure 7-19: Typical Grounding of PCS Equipment Mounted on a Building Roof

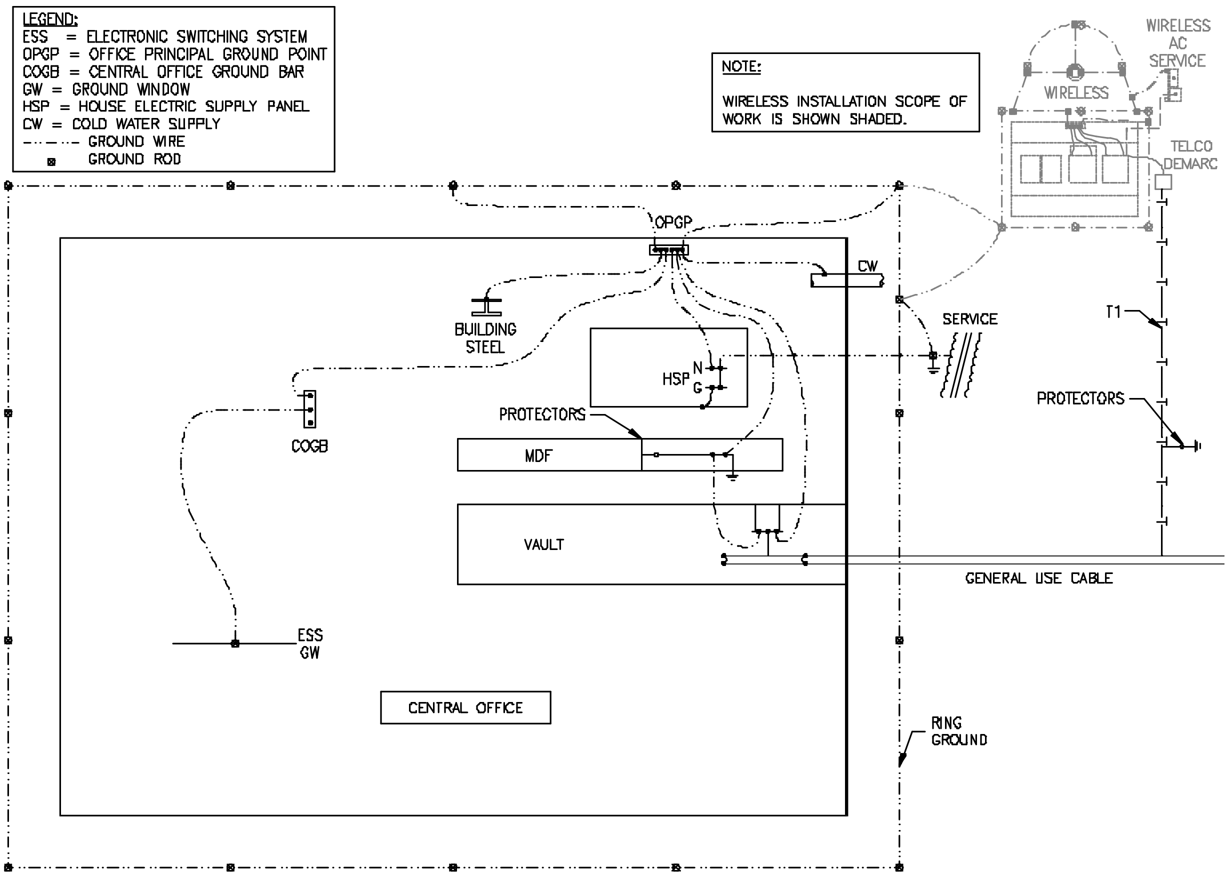


Figure 7-20: Ideal Grounding Interface Between the Ground Electrode Field of a PCS Site and a U S WEST Communications CO Ring Ground

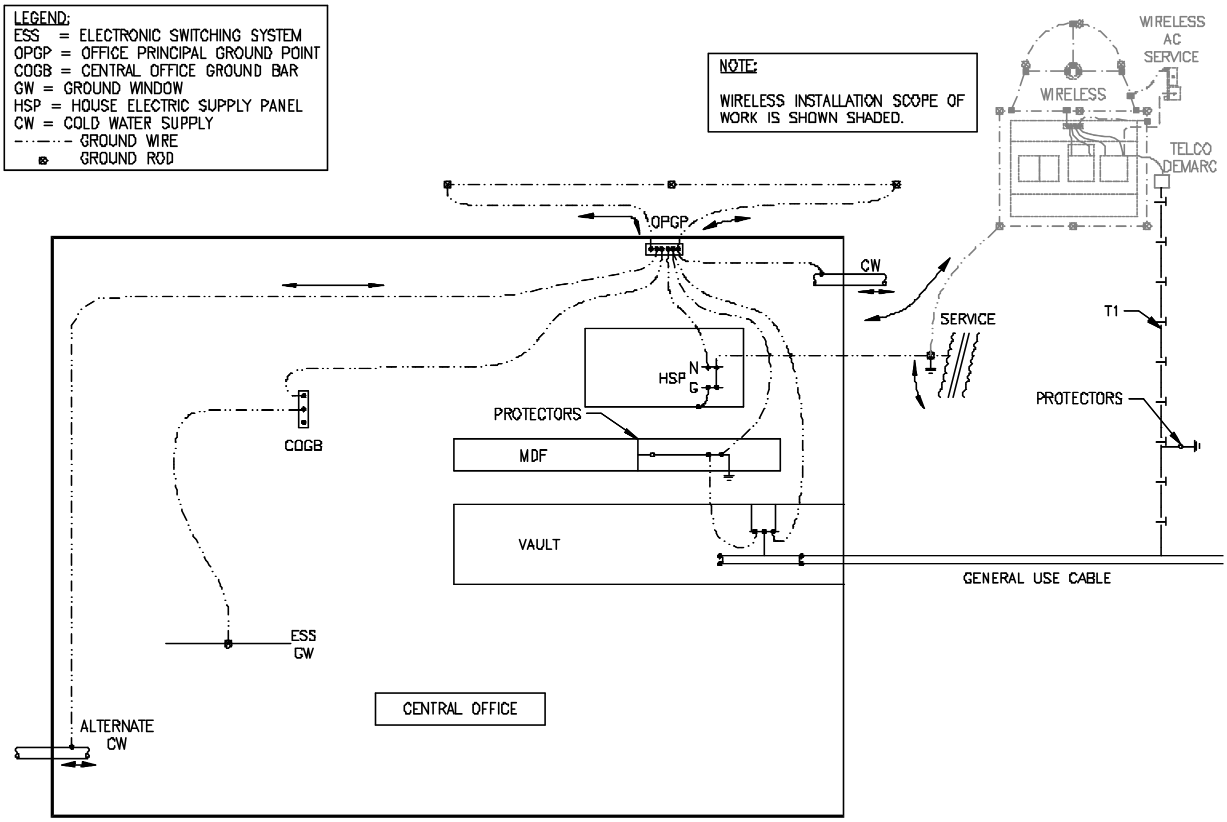


Figure 7-21: Grounding Interface Between the Ground Electrode Field of a PCS Site; and a U S WEST Communications CO Using a Deep Driven Rod, Counterpoise, or Chemical Ground (Ground Well) System

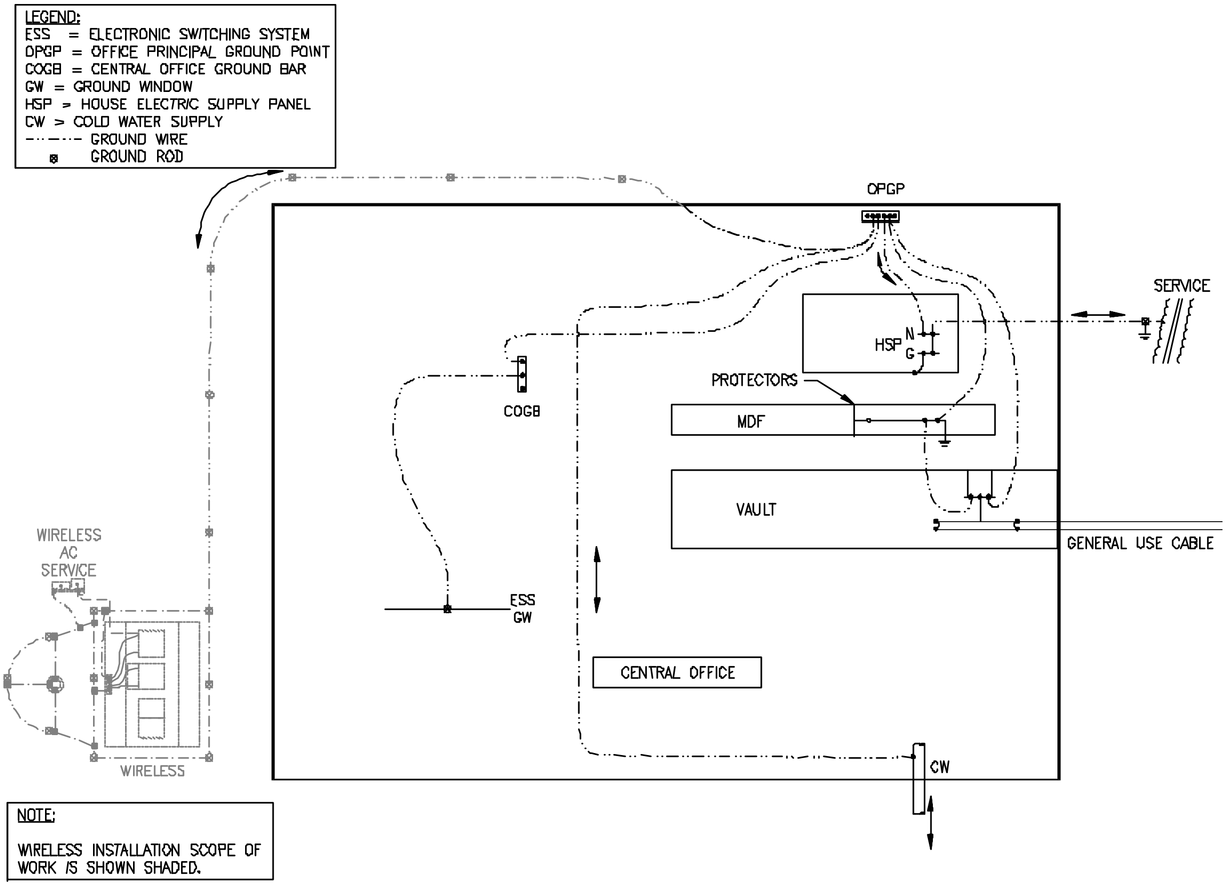


Figure 7-22: Grounding Interface Between the Ground Electrode Field of a PCS Site; and a U S WEST Communications CO that only has the Power Company MGN as a Ground Electrode Field

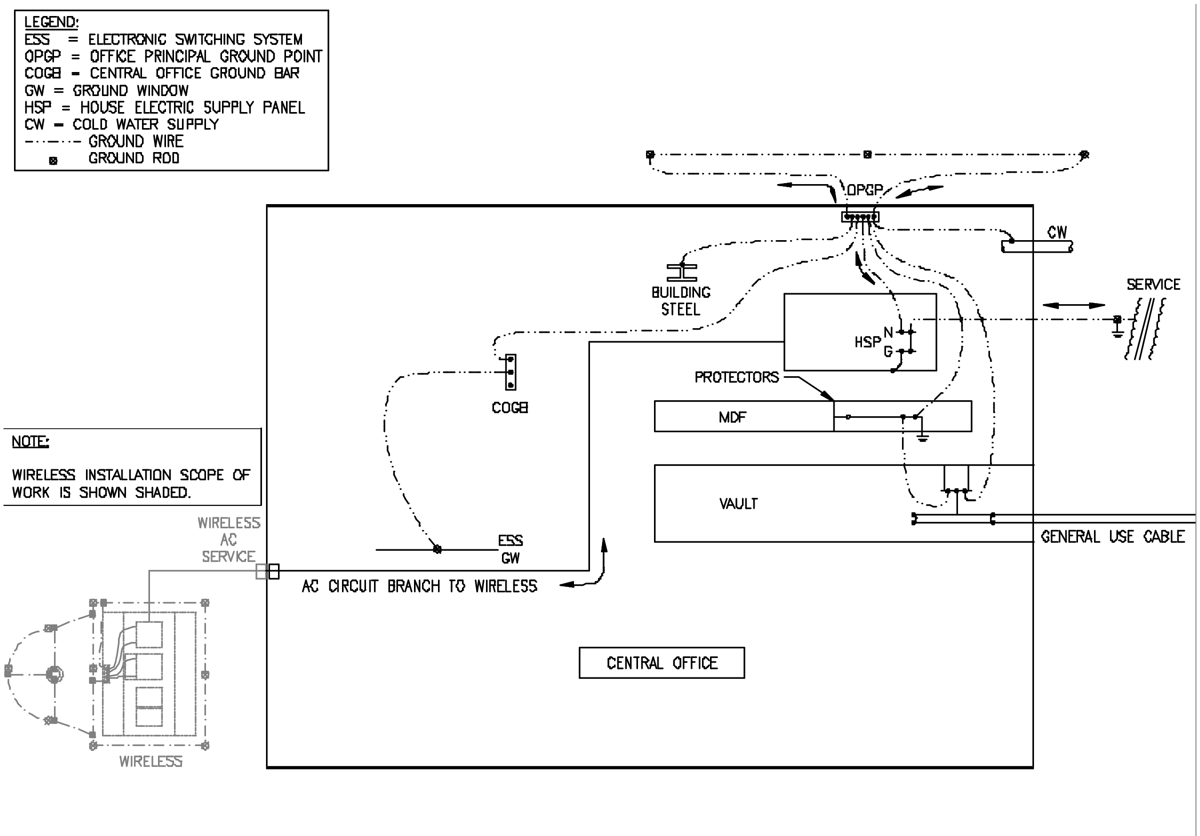


Figure 7-23: Grounding Interface Between a Wireless Site and a U S WEST Communications CO where U S WEST is Providing the AC Power for the Wireless Provider from Within their Building

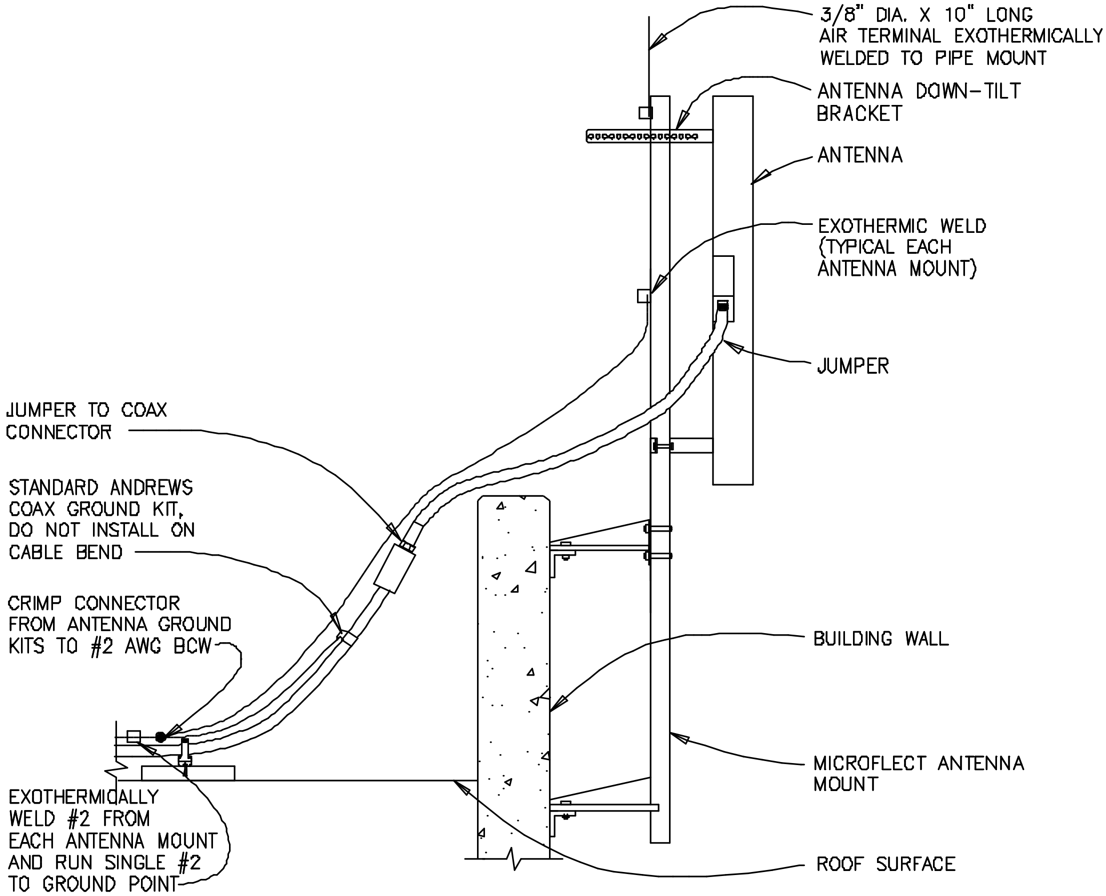


Figure 7-24: PCS Pole Mounted Antenna Grounding Details

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 the local strike density pattern.

The first line of defense against lightning damages and personal injury is a correctly Engineered and 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 7-18, 7-19, and 7-24 hint at some of the requirements of a proper lightning protection system, such as air terminals. (Note that building or tower metallic 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 the conductors into the building as shown in Figures 7-18 and 7-19. 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 energy directly to ground without passing it through the building.)

All of this lightning protection system is tied to an approved grounding electrode field, as specified in Chapter 3. Figures 7-16, 7-17, and 7-20 through 7-23 all show a ring ground electrode system for the Wireless equipment, but any of the other approved ground electrode systems will also suffice. In addition to the ring ground system shown, a counterpoise system (with the counterpoise wires facing away from the building) attached to it is desirable. This additional counterpoise system, if faced away from the building will allow for better dissipation of lightning and transient currents and voltages away from the building, and limit ground potential rise in the direction of the building (thereby limiting voltages and currents that can be induced in nearby metallic objects on or in the building).

7.23.2 Tying the U S WEST and Wireless Ground Electrode Fields 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 the ground systems must be tied together relates to whether humans can come into simultaneous contact with the two separate 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 10 foot separation between metallic objects in the separate planes because this is essentially greater than the limit of human “reach”. Besides the general metallic objects (such as building beams, Wireless site fences, etc.), there may be up to two other metallic connections between the Wireless equipment and the U S WEST CO. If the Wireless equipment receives AC service from the U S WEST CO AC service in any way (either from the Service Entrance, or any building electrical panel), the two ground systems must be grounded together regardless of distance (“shared AC service” is covered in greater detail in Section 7.23.4). The other metallic connection may be a T1 copper interface between the Wireless provider and the U S WEST CO (used by the Wireless provider for transport). Separation between the ground fields can be obtained in this case by the simple use of gas tube protectors (see Section 7.23.5 for further detail). If the Wireless site has its own “AC Service Entrance”, and all of its metal (excepting any metallic T1 connection) is greater than 10 feet from any metallic object in the CO ground plane, no connection between the ground fields is needed; and in fact is somewhat undesirable.

Because the Wireless monopole or antenna lightning protection system is typically tied to a ground ring (or similar ground electrode system) at its base (see Figures 7-16, 7-18, and 7-19), the Wireless ground electrode system needs to be bonded at two places with the other nearby (within 10 feet) metal (which is all tied to the CO Ground electrode system) when there is the potential for touching of both systems at the same time. This is easily accomplished by bonding the ground electrode systems together (preferably external to the building). Nearby metal (within 10 feet) between the Wireless equipment and the building that is not tied to one of the ground electrode systems should be referenced to it. (See Figure 7-17 for an example of how these ground electrode systems should be tied together when there is 10 feet or less of separation between the Wireless Ground plane and the CO ground plane. See Figure 7-23 for an example of how these systems must be tied together, regardless of distance, when the Wireless equipment receives its AC power from the CO. And see Figures 7-20 through 7-22 for examples of how the systems don’t have to be tied together when there is greater than 10 feet of separation between the ground systems.)

The existing grounding electrode system for the U S WEST CO 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 U S WEST building ground electrode field. Or the opposite case may also be true. This poses a particular problem when Wireless equipment, the OPGPB, the T1 cable entrance and/or the AC service entrance are not located near to each other because lightning hitting one of these components may choose to take a path through the building to get to the best ground electrode field. Figure 7-20 represents the ideal situation (everything important to grounding is near each other). When this situation isn't 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 in order to rectify potential interface problems.

The Wireless provider is responsible for their own grounding electrode system, any bonding to the U S WEST and/or Power company's grounding electrode system(s), and the "protection" external to the U S WEST building of any interconnects that they may have to U S WEST Communications (e.g., T1, AC feed, etc.). "External to the building" includes rooftops, as illustrated in Figures 7-18 and 7-19. For example, if placement of a PCS 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. U S WEST is responsible for it's own building ground electrode system and any protection and/or grounding internal to the U S WEST building.

7.23.3 AC Service Entrance Protection for Wireless Equipment

Because Lightning is likely to strike the antenna tower or monopole, the likelihood exists that lightning can get into the AC service (either for the building or for the Wireless equipment). Proper Transient Voltage Surge Suppression (TVSS) equipment installed on the AC Service Entrance will prevent excessive lightning voltages and currents from entering the equipment through the commercial AC.

AC Power for Wireless equipment can be stand-alone (their own metered service), as exemplified in Figures 7-16, 7-17, and 7-20 through 7-22, or it can be supplied from a co-located or shared AC power distribution system, as shown in Figure 7-23.

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 TVSS devices. For a shared AC power distribution system (reference Figure 7-23) additional TVSS devices need to be installed within 5 feet (typically at the Service Disconnect) of where the AC source enters the Wireless equipment that is external to the building. In these cases, both transverse and common mode TVSS should be provided.

Wireless equipment located internal to the U S WEST 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 7-16, 7-17, and 7-20 through 7-22. Where U S WEST provides the AC Power from within its building, that bond has essentially already been made internal to the building (between the House Service panel and the OPGPB) in keeping with the requirements of Chapter 4 (see Figure 7-23).

7.23.4 Protection for a Commercial AC Interface Between U S WEST and a Wireless Provider

When U S WEST provides the power to the external Wireless provider, special precautions should be taken in addition to those mentioned in the previous subsection. Of particular concern is the ability of the AC cable to bring lightning into the office. Even with TVSS at the Wireless equipment, it may be advisable to install additional TVSS at the point the AC service leaves the U S WEST building.

Cable routing through the office is also a concern. If lightning does enter the building on this AC feed going to the Wireless equipment, we do not want it to have convenient points to jump off into sensitive equipment. If possible, The AC feed (and any grounding 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 that more of the AC is run outside the building rather than inside. Figures 7-17 and 7-23 are poor examples of this. 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 7-23). 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 ESS switches. If the AC service is being obtained from a sub-panel (as illustrated in Figure 7-23), try to choose a sub-panel whose feeder conduit (from the main House Service Panel) passes the least sensitive areas.

If AC service is provide by U S WEST , 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 U S WEST and a Wireless Provider

Data lines leave and enter wireless equipment and interconnect with telecommunications facilities. Data lines that use copper members (such as T1) must have electrical transient protection at the interconnect points with telecommunications outside facilities or COs. For copper facilities interconnecting a U S WEST CO with external Wireless equipment, there are basically 4 points of protection: outside the building, at the entrance to the Wireless equipment, in the cable vault, and at the U S WEST frame. Typically, all but the cable vault protection involves TVSS “5-pin” protectors. These are usually of the “gas tube” type.

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

Figure 7-17 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 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 or Vault (see Figures 7-20 and 7-21). This external protection pedestal must be grounded to a ground electrode field. If it is close enough to the CO ground electrode field, and the CO ground electrode field is not connected to the Wireless ground electrode field, it may be connected to it. Do not connect it to the Wireless ground electrode field because this field will rise in potential with a lightning strike. Or, the “protection pedestal” may have its own ground electrode field, preferably made with three rods, similar to configurations shown in Figure 10-7 or Figure 7-21.

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 7-20 and 7-21).

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 331 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.

7.24 GPS Antenna Grounding Issues

In recent years, U S WEST has begun to install GPS antennas on many of it's 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 typically roof-mounted, and because they are placed away from other metal objects on the roof (such as HVAC systems, other antenna towers, etc.), they provide a convenient lightning attraction point. Figure 7-25 details a typical setup for a roof-mounted GPS antenna.

The short mast to which the short antenna is attached is sometimes metallic (in some cases, it might be plastic) and should be grounded if it is metallic. Also, the antenna itself feeds its signal into the equipment in the building via coaxial cable. The coax needs a lightning arrestor gap specifically designed for the coax application.

A metallic (plastic masts don't have to be grounded) antenna mast should be grounded to the building roof ground ring (this 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 copper conductor can optionally be run down the side of the building (a down conductor) and connected to the building ground electrode field with an exothermic weld (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 of these methods is detailed elsewhere in this document). This connection of metallic masts to a down conductor in the absence of a roof ring ground is preferred, but not absolutely required. In fact, if the down conductor cannot be attached to the building ground electrode field (because this field can't be found), it may be preferable to not ground the metallic mast to avoid differences in ground potential.

On some early installations of GPS, 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. 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 down conductor or have a separate down conductor run to the building ground electrode field. It is also most preferable if the coax entrance is through the cable entrance facility for the site. If the protector box is mounted inside the building, it should be located as close to the coax entrance as practical, and should be grounded to the nearest COGB, OPGPB, or CEF Ground Bar. If the building already has a waveguide hatch with spare openings, it is most preferable to use it as the GPS coax entrance and install a lightning arrestor at that point.

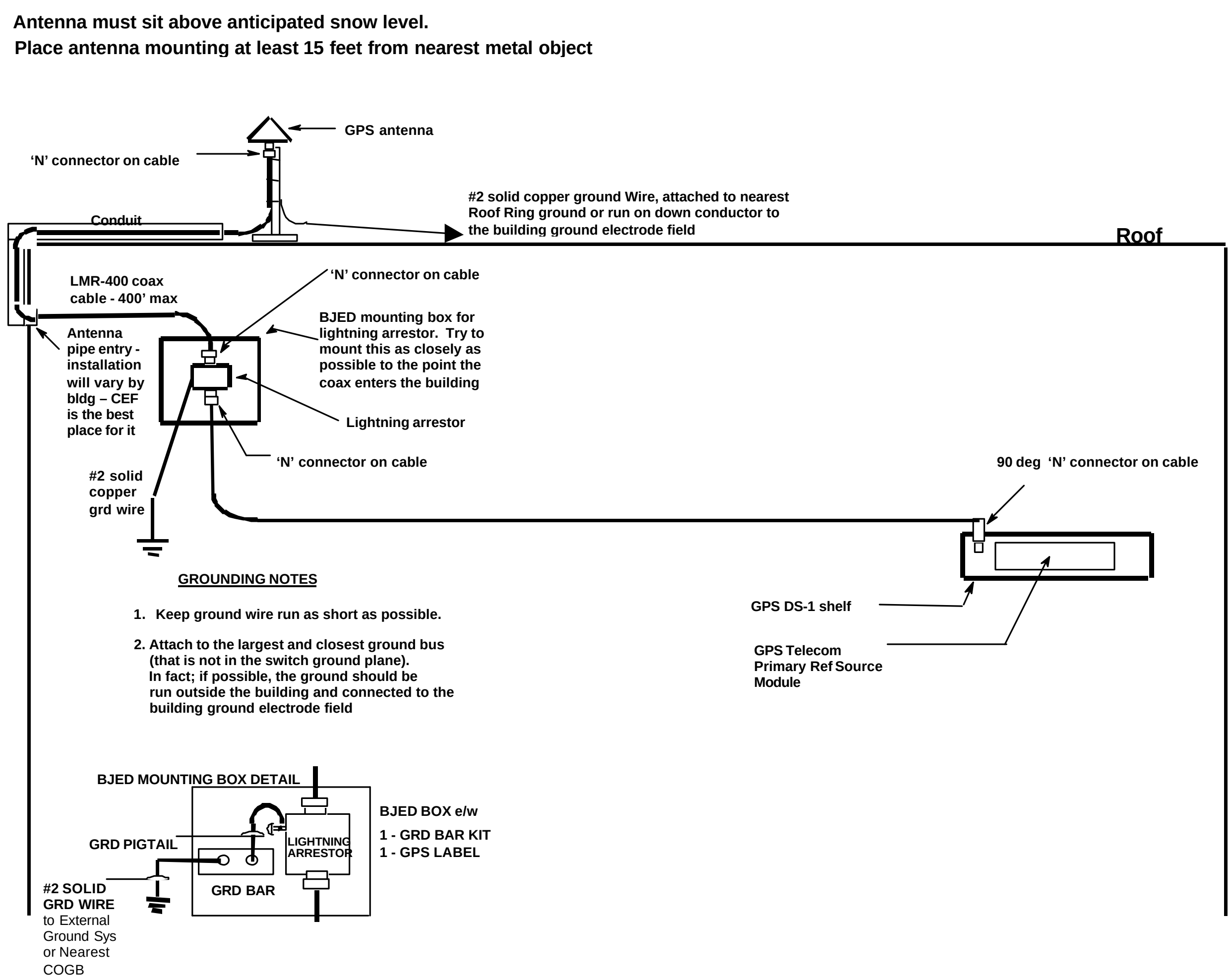


Figure 7-25: GPS Antenna Grounding Detail

CONTENTS

Chapter and Section **Page**

CONTENTS (Continued)

Chapter and Section **Page**

CONTENTS (Continued)

Chapter and Section **Page**

Figures

8. Isolated Ground

8.1 Isolated Ground Plane Principles

8.1.1. Isolated Ground Plane

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. During external fault occurrences in the AC or DC power systems and when lightning current flows in the building, none of these currents can flow in the isolated ground plane because of the single-point connection. Some users and suppliers call an "isolated ground plane" an " isolated ground zone."

8.1.2 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 you know otherwise, you may assume that all of the frames that house a Stored Program Control Switching System (SPCSS), whether Analog and/or Digital, are normally treated as an isolated ground plane. Therefore, all references to SPCSS equipment frames shall normally assume that they are in an isolated ground plane (unless otherwise known).

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 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
- Multigrounded 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 connect 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 and Radial Grounding

Both serial and radial 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 shall be grounded. They know what types of noise and currents to which their switch is susceptible.

8.4 Frame Grounding Methods

Figure 8-3 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 shall 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 Main Ground Bus (MGB) within the ground window. Connect the MGB to the CO GRD bus on the same floor, completing the required connections.

Note: The processor and the SPCSS are grounded radially from the ground window rather than serially. This prevents faults from one set of frames from flowing into the other set.

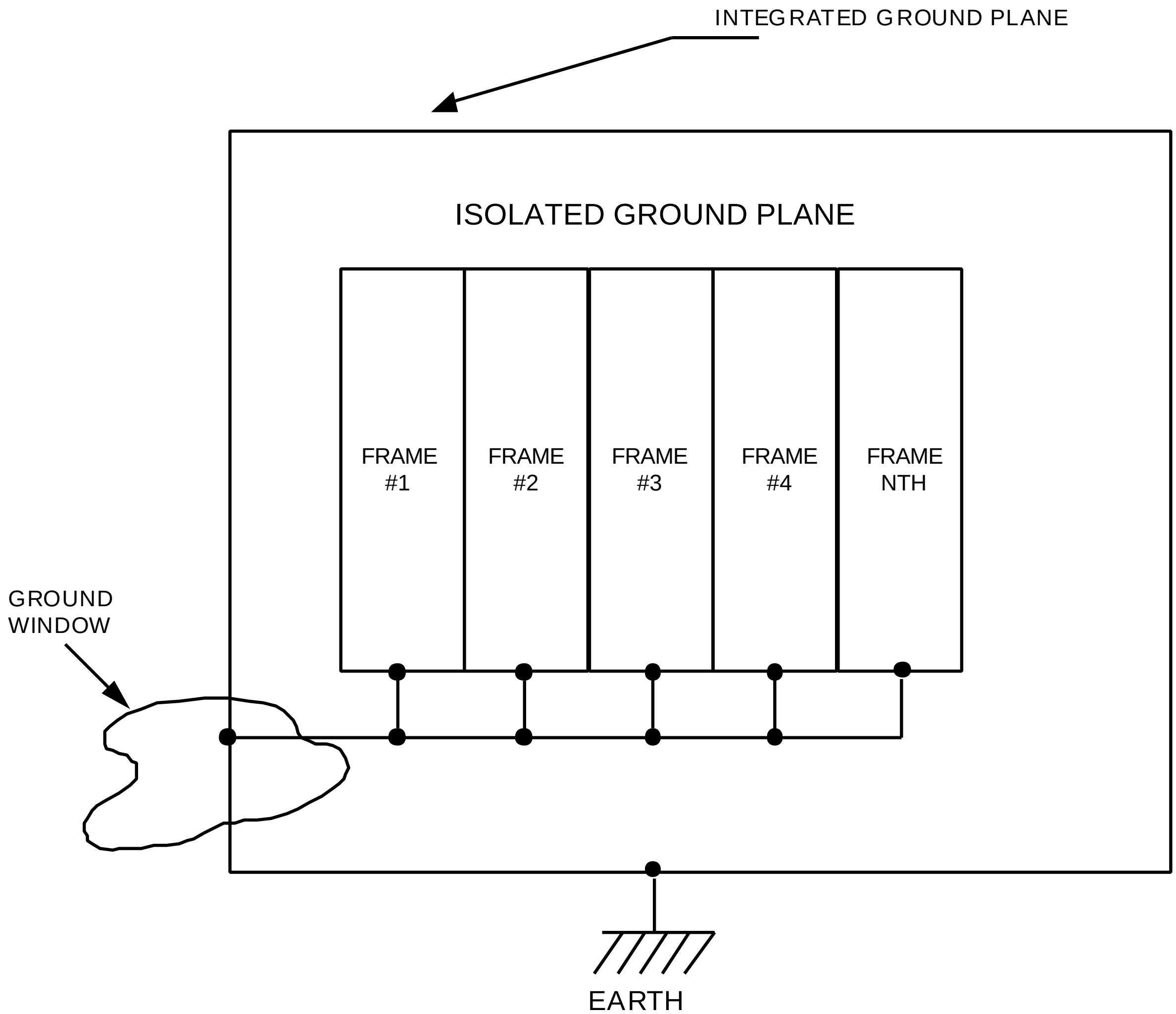


Figure 8-1: Simplified Isolated Ground Plane

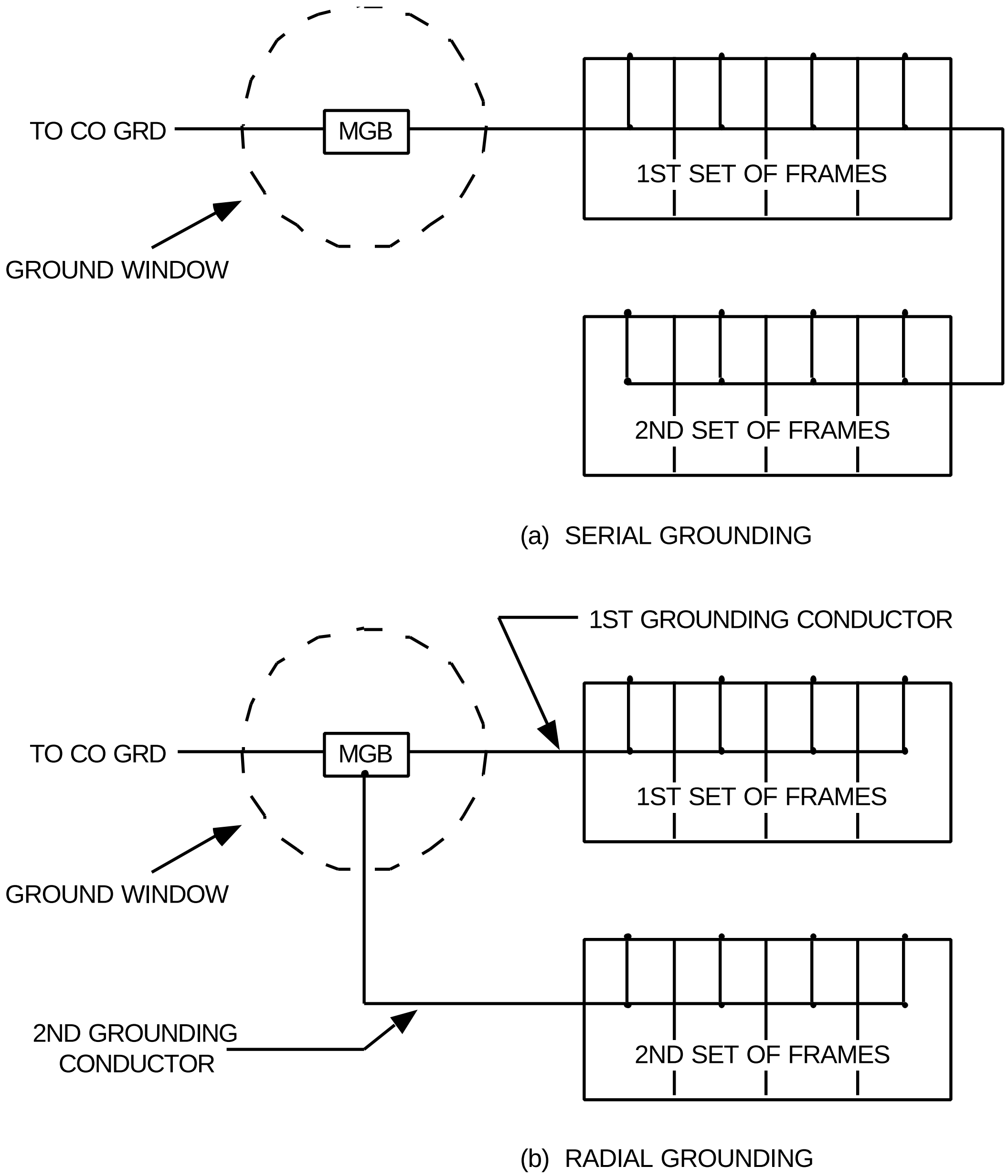


Figure 8-2: Simplified Examples of Serial and Radial Frame Grounding

When using Serial or Radial grounding (see Figure 8-2) do not add grounding conductors that would cause a direct connection between frame lineups (loop between frames). Caution shall be taken to ensure that electrical connections which cause loops are not inadvertently formed by grounded cable shields, metallic cable trays, metallic conduits, or other means, when serial or radial grounding is used.

Reliable frame to frame grounding connections shall be made. Route a minimum No. 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 shall be made with two-hole copper crimp connectors (for existing, working switches that use single-hole connectors, it is not required to upgrade them to two-hole connectors due to the hazards that drilling could pose to the operation of the switch).

4. Establish a ground window (see Figure 8-6 or 9-3) to serve the isolated ground plane. A copper bus (or buses) called the main ground bus (MGB) shall be located within the ground window to provide a place where various required connections can be made. All external grounding wires that enter and serve the isolated ground planes shall be routed through the ground window and bonded to the MGB before connecting them to the isolated ground plane.

   - The ground window can be located over the power plant or at a remote location in the immediate area of the isolated ground plane. Vertically, it shall be no more than one floor from the isolated ground plane. Horizontally, the ground window shall 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 ground plane. In no case, however, shall the furthest unit of equipment in the isolated ground plane be more than 200 conductor feet from the floor CO GRD bus (this requires special care in large offices to ensure good placement of the ground window).
   - The ground window shall be configured as a bar or a set of bars with a designated area for isolated and integrated ground connections. The isolated and integrated areas shall be separated by the 750 kcmil ground connection (see figure 8-6) from the COGB.

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

5. Make a ground connection from the MGB within the ground window to each group of frames. (In some cases a frame grounding bar may be used and located in close proximity to the isolated ground plane to collect frame ground conductors from the various frame lineups. Some switches also require logic reference grounds tied to the MGB since it is a “clean” source of ground. These too may be gathered on “collection bars”.)

   All ground connections from the SPCSS and processor frames going to the integrated ground plane shall 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 shall be isolated from the building integrated ground plane. All integrated grounds serving the isolated ground plane (AC conduit) shall 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 conductors in Figure 8-3 provide fault current paths that permit the 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 currents.

8.5 Power Supply Grounding Methods

Generally, all power sources serving an isolated ground plane shall be single point solidly grounded. <u>Exceptions</u> 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, electro-mechanical, and non-switched circuit equipment) from the same power plant that serves the isolated ground plane loads are permitted to multiground 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.

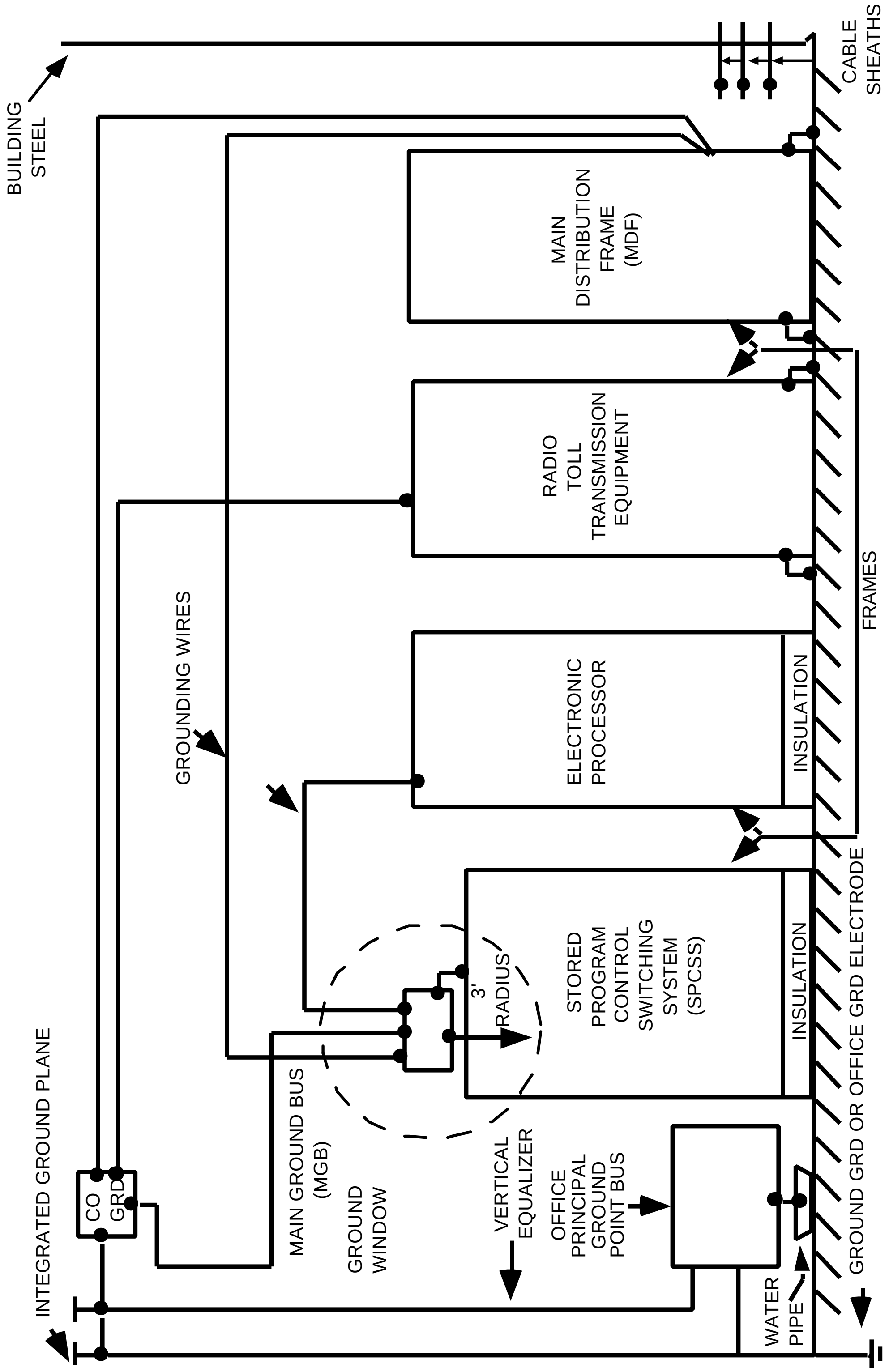


Figure 8-3: Typical Overall Frame Grounding Methods

8.6 Multigrounded Power Source

Generally, multigrounded 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 serving an isolated ground plane shall be single point grounded.

Grounding Locations:

- The return side (usually the positive bus) of the principal power source shall be grounded with a separate 750 kcmil grounding conductor to the ground window associated with the isolated ground plane. The principal power source is classified as an external power source. If the positive bus is designated as the ground window it shall be grounded with a 750 kcmil to the CO ground bar. (If the DC plant serves only integrated ground plane equipment, its return bus still needs a reference to the nearest COGB. 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. Sections 7.21, 10.1, 10.3, and 10.5 specify the power plant return bus ground reference conductor size requirements for Radio Sites, CEVs, DLC cabinets, and Customer Premises installations, respectively.)
- Other external DC power sources (such as 130 volts DC) serving the isolated ground plane shall 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 shall be part of the isolated ground plane.

8.8 Isolated Ground Plane Grounding Conductors

Grounding conductors shall be used only to ground power supplies and frames. They shall not be connected in parallel with battery return conductors unless the SPCS is designed that way. Normally, grounding conductors do not conduct normal load currents. They shall conduct line to ground fault currents only. Their impedance shall be low enough to permit the faulted current to be cleared quickly and safely. The grounding conductors shall be routed in paths that are as direct and straight as possible, without any sharp changes in directions. If the direction must change, it shall do so gradually with a minimum curvature radius of 12 inches. The grounding conductors shall be run exposed. Connections to grounding conductors shall be made so that the conductor flows toward the ground source.

8.9 AC Power Supplies

All separately derived AC power supplies shall be grounded to agree with 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.

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 shall 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.

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 on 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) are prohibited.

8.10 General Grounding Conductor and Connection Requirements

8.10.1 DC Grounding Conductors

DC grounding conductors and connectors shall be made of copper. Aluminum conductors or wire (as well as aluminum equipment frames) are prohibited in U S WEST Communications. Conductors of copper or tinned copper wire, busbar, or braided strap are acceptable. The size of the grounding conductors shall be as specified by the SPCSS supplier. In no case shall the conductor be smaller than a No. 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 shall be insulated. On a going forward basis grounding conductor insulation should be green in accordance with the NEC and the guidelines of Section 3.3.3.

DC Grounding conductors shall not be run on cable racks. They may be secured to the side of cable racks, run on hangars, or any other approved method that makes them visible, as detailed in the Grounding section of U S WEST Technical Publication 77350. 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 segregrated. In these cases, the switch manufacturer and the installation vendor must clearly mark those runs that must be segregrated for noise or other reasons.

8.10.2 AC Equipment Ground Conductors (ACEG)

ACEG conductors (sometimes referred to as the "green-wire" ground) shall be made of copper. Stranded wire or solid wire may be used and must be connected with crimped type connectors. Mechanical connectors are not allowed. 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).

8.10.3 Connections

The following electrical connection requirements are taken from applicable portions of the NEC to conform with the grounding requirements of this publication and shall be followed.

Note: Grounding Connectors shall be made of Copper.

Terminals — Connection of conductors to terminal parts shall ensure a thoroughly good connection without damaging the conductor and shall be made by means of crimp-type connectors.

Splices — Conductors shall be spliced or joined with compression-type devices suitable for the purpose or by brazing or welding with a fusible metal or alloy. 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. (Although it is preferable that ACEG splices are done in this same way, they are governed by the NEC, and not held to the same strict standards as our DC grounding system.)

Connectors — Required grounding conductors and bonding jumpers shall be connected by crimped connectors. Connecting devices with fittings that depend solely on solder shall not be used.

"**Clean Surfaces**" (Excerpt from NEC Article 250-12) — Non-conductive coatings (such as paint, lacquer, and enamel) on equipment to be grounded shall be removed from threads and other contact surfaces to assure good electrical continuity.

8.11 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.

8.11.1 Loops (see Figure 8-4 [A], [B], [C], and [D])

Paragraphs 8.4 and 8.12.5 shall be followed to avoid forming large area inductive loops among the grounding conductors of the isolated plane. Don’t 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.

Of course, in an integrated ground plane, loops are unintentionally formed. So, if a switch manufacturer does not require an isolated ground plane, loops are allowable. Follow the switch manufacturer’s guidelines for internal grounding.

8.11.2 Lightning and Fault Current Carrying Members

The following types of conductors shall be routed a minimum of three 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 8-3).
- Wave guides and coaxial cables from tower mounted antennas.
- Metallic raceways from other systems.
- Cables coming from other external antennas (such as GPS, PCS, etc.).

8.11.3 Nearby Integrated Ground Plane Frames

All integrated ground plane conductive members located within six feet of the isolated plane shall be bonded to the MGB to reduce shock hazards to personnel and minimize surge potential differences between members of the two planes. Steps must be taken to ensure that there is electrical continuity between members of nearby metal. If such continuity cannot be verified by a less than one ohm reading across junctions then the metal objects must be bonded. The bond to the MGB (integrated bar) can be accomplished by running a minimum #2 AWG to the area and bonding all 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
- Circuit Pack (PIC) cabinets (these cabinets need to be grounded to the integrated plane anyway if they are outside of the 6 foot separation).
- Equipment frames
- Miscellaneous Iron (auxiliary framing, metal conduits, air-conditioning duct, cable racks, etc.)
- Lighting fixtures that are not part of the isolated ground plane
- Air ducts
- Metallic raceways from other systems

The AC raceway from the MGB to the isolated switch is technically part of the isolated plane, and is FOG grounded per the list above. It often travels great distances from the MGB to the switch, often changing floors. Along this path, it may pass within inches of a lot of different integrated grounding plane members. However, because of the number of integrated ground plane members it (and other FOG raceway) passes, 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 AC raceway attached to a FOG bar passes while in the integrated area.

8.12 Isolating Ground Plane Frames (Specific Requirements)

8.12.1 Specific Requirements

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

8.12.2 Insulation Resistance

All frames that are part of the isolated ground plane shall be installed in a way that insulates them from the integrated ground plane (building steel and other metallic parts attached to the building steel). Before any ground window or power connections are made to the isolated ground plane, and after all hold down and fastening hardware is installed, the insulation resistance between the isolated and integrated ground planes shall be verified to be 100,000 ohms or more (see Section 8.23.4 for isolation test methods). The isolated ground plane shall be isolated from the building's integrated ground plane by using insulators between points where metalwork and concrete common to the integrated ground plane must be fastened to the metalwork that is common to 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 shall 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 shall be placed between the frames and the floor.
- **Superstructure Supports** - Superstructure supports to the isolated ground plane, where used, shall be insulated.
- **Lighting Fixtures, etc.** - Lighting fixtures, raceways, and cable racks that are part of the isolated ground plane shall be insulated from the integrated ground plane.

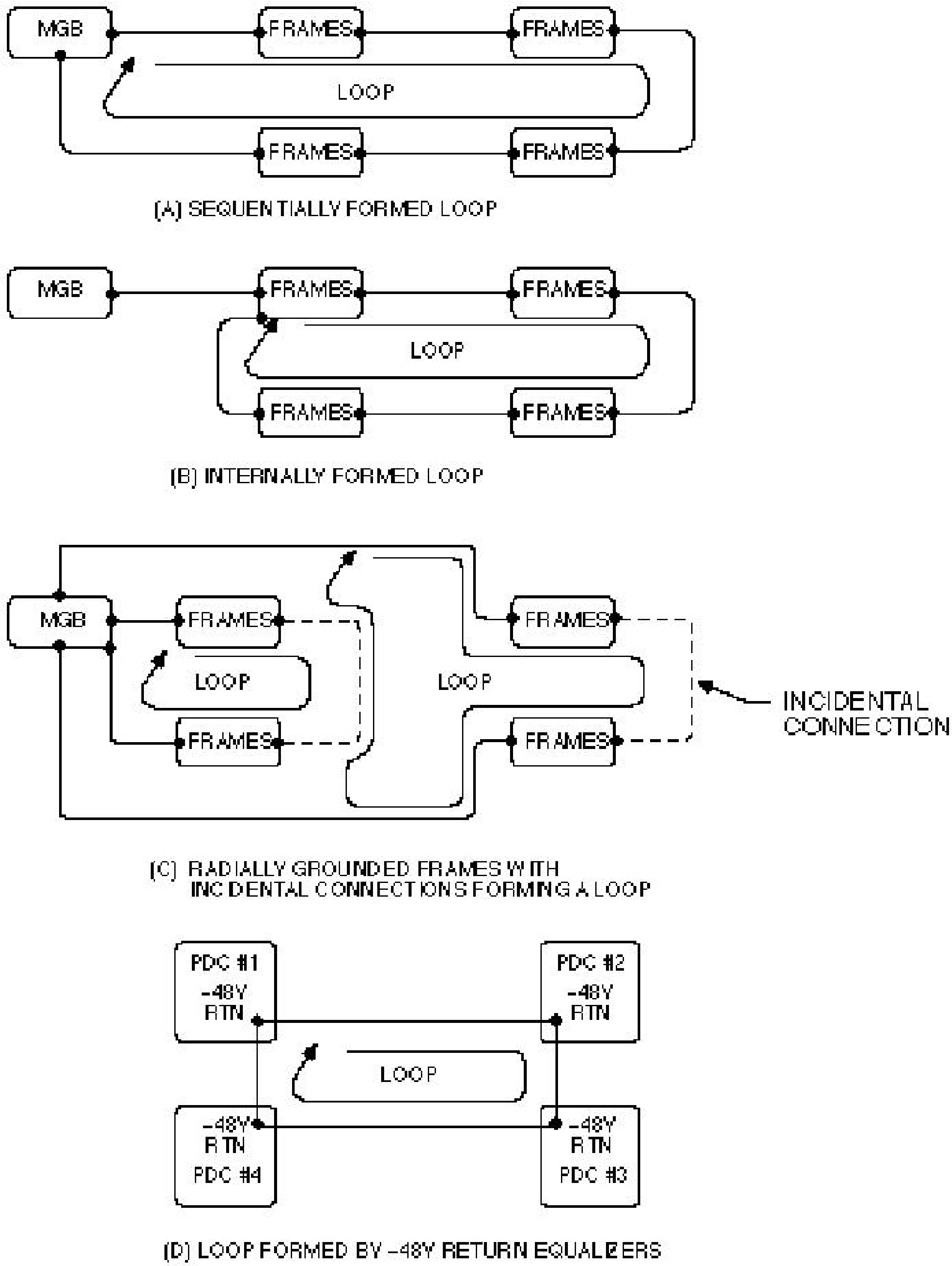


Figure 8-4: Loops (Isolated Ground Plane)

8.12.3 Frame to Frame Connections

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

- Route a minimum No. 6 AWG bare or insulated stranded copper wire along each frame lineup. Using crimp type connectors, connect the ground wire to a grounding 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 shall be equal to or greater than No. 6 AWG stranded copper conductor (about 0.027 square inches).

8.12.4 Grounding Among Groups of Frames

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

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

Either method is acceptable in accordance with the vendor's grounding design strategy. The vendor shall state the method that is to be employed.

The size of the grounding wire used between groups of frames and the MGB shall be a minimum of No. 1/0 AWG.

8.12.5 Serial and Radial Connections Within the Isolated Ground 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 shall 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 8-4).
- 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 might 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 MGB.

8.12.6 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 shall occupy no more than three adjacent floors.
- Only one ground window and one principal power plant shall serve the isolated ground plane. The ground window shall be located in the middle floor of the three consecutive floor configurations.

8.12.7 Peripheral Equipment Frame Grounding

Peripheral metallic equipment frames (e.g., teletype printers, metallic desks, video and hard copy terminals, etc.) shall be connected with grounding conductor(s) to the isolated ground plane (see Section 8.11.3 for a more complete list), and shall be treated as if they were an integral part of the isolated ground plane. Both AC or DC power for these loads shall come from sources within the isolated ground plane or from sources routed through the ground window, as per paragraph 8.18. The grounding conductors associated with these power sources shall be used to extend ground reference to the peripheral equipment's frame without making contact with the integrated ground plane. Peripheral equipment grounded in this manner shall 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 shall 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 then can be established to ground the peripheral equipment frames. This "new" ground window shall be located within one floor of the peripheral equipment. But the ground windows shall not be bonded together.

Note: Its is desirable that isolation techniques, such as optical fiber, current loop, 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.

8.13 Grounding Conductor Requirements

Grounding conductors shall be used only to perform the following:

- Ground frames and power supplies.
- Safely conduct lightning currents.
- Safely conduct the current produced from ground faults.

Grounding conductors shall not be used to conduct normal load currents. 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 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.

8.13.1 Type

All grounding conductors of No. 6 AWG or greater for indoor use shall be made of stranded copper. AC grounding conductors shall be covered with green insulation and shall be listed for the purpose by a Nationally Recognized Testing Laboratory. DC grounding conductors shall be tagged with an appropriate grounding designation at each end. (On a going forward basis, DC grounding conductor insulation [when insulated wire is used] shall also be green in accordance with the NEC and the guidelines of Section 3.3.3.) <u>Aluminum wire shall not be used</u>. Armored cable containing a bare bonding strip to decrease sheath resistance shall not be used as an equipment ground conductor. Armored cable can be used if a separate, green, insulated wire is enclosed in the armored sheath.

Exceptions to these rules are listed below:

- Copper bus and braided-copper equivalent may be used instead of stranded copper to facilitate individual frame-to-frame grounding in an isolated ground plane.
- Frame-to-frame grounding conductors may be bare.

8.13.2 Connections

Only two-hole bolt crimp (compression) connectors shall be used. Threaded pressure connectors shall not be used. Torquing and bolt assembly requirements (for securing the connector) shall be as specified by the connector supplier.

Conductors shall be lightly coated with an appropriate anti-oxidant compound before crimp connections are made. All unplated connectors, braided strap, and busbars shall be brought to a bright finish (bringing a busbar to a “bright finish” includes removing any oxidation by cleaning it with an abrasive such as a steel wool pad) and then lightly coated with an anti-oxidant before they are connected. Tinned or silver-plated connectors and other connection surfaces do not have to be prepared in this manner. All raceway fittings shall be tightened to provide a permanent low impedance path.

Multiple connectors shall not be secured by the same bolt assemblies except on opposing sides of the bus bars (back-to-back with the bus bar in between). 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.

8.13.3 Single Grounding Conductors

Single grounding conductors (conductors that do not have associated phase [hot] or neutral [return] leads) shall not be run in metallic enclosures. Further, the metallic clamps used to hold down grounding conductors shall not completely surround the wire. Examples of this type of conductor are vertical equalizers (illustrated in Figure 8-3) and the AC power grounding electrode conductor (illustrated in Figure 8-8). These types of conductors passing through the floor of a building shall be enclosed in nonmetallic sleeves for mechanical insulation and fire prevention. All grounding conductor paths between points shall be as straightly and directly as possible. Changes of direction should be taken over as wide a radius as possible, with a minimum bend radius of 12 inches. Right angle bends shall not be permitted. Connections to grounding conductors shall be made so that the conductor flows toward the ground source.

8.13.4 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 conductors pass through wall and floors, nonmetallic liners or conduits are preferred; however, steel liners and conduit in lengths up to 3 feet may be used where necessary, since their contribution to increased induced voltage is small. "End-bonds" between the conduit and the conductor shall be made. Because of their larger diameter, liners contribute less induced voltage than conduit, so bonding to liners is not necessary. Where fire codes require metallic liners, a metallic liner with an insulator gap is preferred.
- Other applications where runs of steel conduit enclose single grounding conductors should be avoided. Bonding of the conduit to the single grounding conductor at both ends is still required.
- Fully closed steel supporting rings may cause significant induced voltage when the rings are closely spaced (e.g., at 12-inch intervals), so steel rings should be avoided. "Gapping" a steel ring with fiber bolts is recommended. Rings of nonmagnetic material are preferred. Fiber rings, PVC rings, Steel J-hooks or other similar devices are an acceptable means of supporting single grounding conductors.

8.14 External Principal Power Plant Grounding Requirements

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

8.14.1 The Return Bus

The return bus (usually the positive polarity side of the system) in the power plant shall be 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 8.21.5, Requirements for Plant with a Noninsulated Return Bus.

8.14.2 Grounding the Return Bus

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

8.14.3 Grounding the Plant's Frame(s)

For personnel safety, the plant's steel framework shall be grounded at the nearest ground reference, often the CO GRD located on the same floor with a minimum 1/0 grounding conductor. An additional frame-grounding conductor shall be installed between the plant's framework and the main ground bus within the ground window. This conductor shall follow the path of the plant's ground reference conductor (see Figures 8-8 and 8-9).

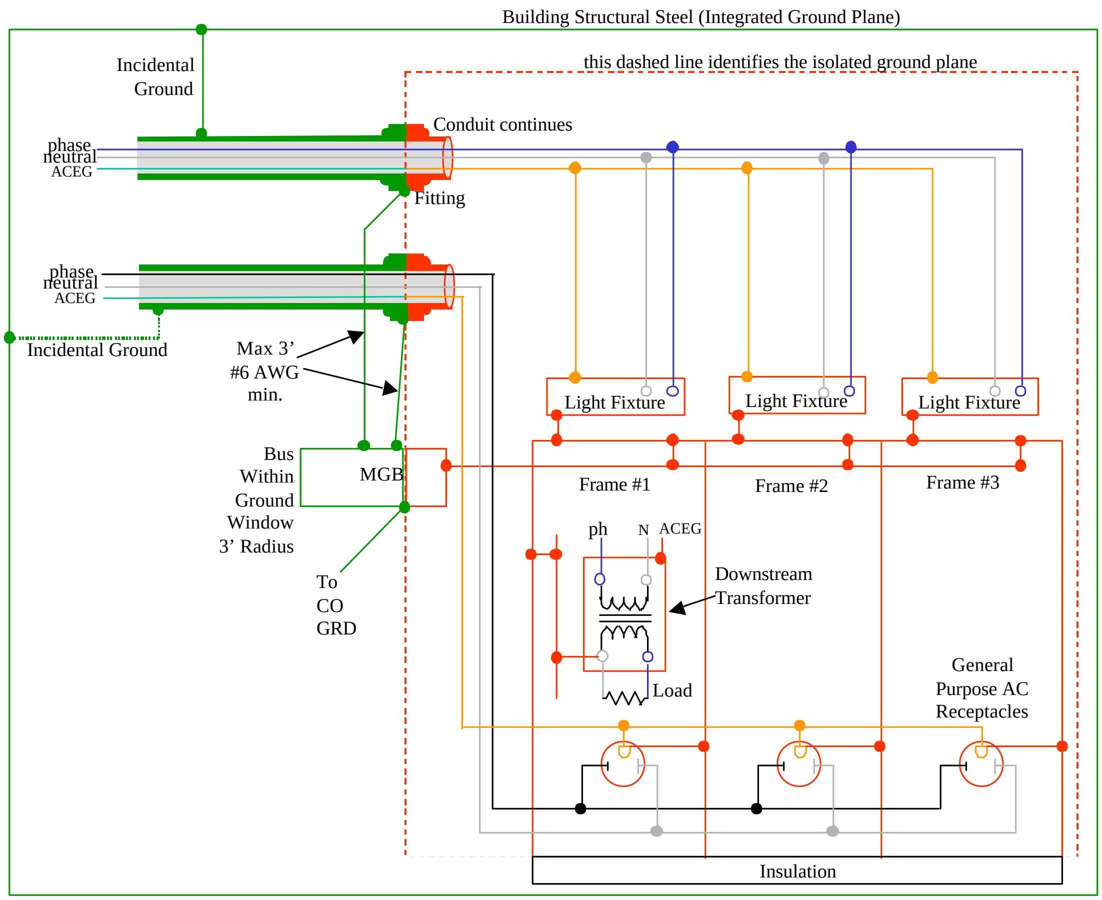
8.14.4 Location of the Power Plant

The location of the power plant with respect to the isolated ground plane is not restricted provided that the -48 volt return bus in the plant is not used as a ground window (see paragraph 8.21.2).

8.14.5 Power Feeders

The power feeds from the principal power source shall be run in pairs to each PDC (or equivalent, since different switch manufacturers give this secondary distribution point different names). The pairs shall be routed in close proximity to 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 conductor in the pair shall NOT be connected to the main ground bus at the ground window, unless the battery return bus is used as the 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 (in the cases where a remote ground window is used) and be bonded to the MGB (see Figures 8-6 and 8-7). For this situation, special exceptions to the pairing rule mentioned in the previous paragraph are allowed (see U S WEST Technical Publication 77385, Section 8.6 for further detail).



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.

Figure 8-5: Typical Grounding and AC Power Feed to an Isolated Ground Plane

8.15 Integrated Ground Plane Loads

Integrated ground plane loads fed from the same principal DC power source that supplies the isolated ground plane loads shall be examined to determine if powering such loads multigrounds the battery return conductor. If the battery return conductor is multigrounded at the distribution point or at the loads themselves, it shall then be routed via the ground window and bonded to the MGB before it is run to the return bus within the power plant. The length of the bonding conductor shall be no longer than three feet (the size of the bonding conductor is specified in Figure 8-7). The battery and return conductors shall be paired to the greatest extent practicable between the power plant and the equipment being powered (see the previous section 8.14.5 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 –48 V plant return bus is the 750 kcmil conductor specified in Figure 8-7. If this cable is carrying excessive current (greater than 300 Amperes) or is hotter than 115 degrees F, more cables may need to be added.

Note: Multigrounding 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 multigrounded).
- 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 multigrounded anywhere along its length or at the load, it shall 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.

8.16 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, multiground the return conductors, these return conductors shall be routed through and connected to the MGB within the ground window before they are connected to the power source return bus.

8.17 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) shall not be connected to any frame. This violates the single-point ground of these power sources.

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

8.18.1 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 Figures 8-5 and 8-7) shall be run from the grounded side of the supply's output to the MGB within the ground window. Load conductors shall be run in pairs and closely coupled.

8.18.2 AC Power Supplies

These power supplies, grounded at the source as described in paragraph 8.17, shall be routed through the ground window. Each grounding conductor and raceway associated with each supply shall 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 8-5 and 8-7).

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.

8.18.3 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.

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

Figures 8-5 and 8-8 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.

8.20 Establishing a Ground Window

A ground window shall be established to serve the isolated ground plane. A copper bus (or buses) called the main ground bus (MGB), shall be located within the ground window to provide a place where various required connections can be made. The MGB shall not be mounted on any of the isolated ground plane frames. The MGB shall be mounted on insulators so that it is insulated from the building integrated ground plane. (The only exception to this rule is if the grounded battery return bar is the ground window.) The ironwork supporting the MGB, however, must be bonded to the MGB. Only one ground window shall be associated with the principal power source serving the isolated ground plane. More that one set of isolated ground plane frames may be served from a single ground window.

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

8.20.1 Dimensions

The ground window's dimensions shall be those of an imaginary sphere with a maximum radius of 3 feet (a 6 foot sphere). The MGB (on the integrated side) shall be a maximum of six conductor feet in length from the COGB connection integrated-isolated split point.

8.20.2 Location

The ground window can be located in the principal power plant as the battery return bar. The ground window can also be located in a remote area as close as possible to the isolated ground plane it serves. Vertically, it shall be no more than one floor from the isolated ground plane. Horizontally, the ground window shall 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. In no case however, shall the furthest unit of equipment in the isolated ground plane be more that 200 conductor feet from the floor CO GRD bus.

8.20.3 Connections

A number of possible connections can be made on the MGB within the ground window, depending upon the needs of the various installations. Figures 8-6 and 8-7 show typical detail connections. The MGB shall be configured to separate isolated and integrated ground connections. The MGB can be thought of as the transition conductor between the integrated and isolated ground planes. The sequence of connections shown in Figure 8-7 should be followed. Figure 8-7 identifies sizes and classifies the conductors shown in Figure 8-6. No connections shall be made between the isolated ground plane and the integrated ground plane other than through the MGB. All conducting materials that are part of the isolated ground plane such as cable racks, cable troughs, conduits, armored cable, enclosed conductors, and the SPCSS frames shall be insulated and kept separated from the integrated ground plane.

As a special note for lead 9 in Figures 8-6 and 8-7 (which represents multigrounded integrated ground plane load –48 V return conductors), Figure 8-7 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. Due to length and load, sometimes the return conductors for a single load may be multiple cables. In these 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).

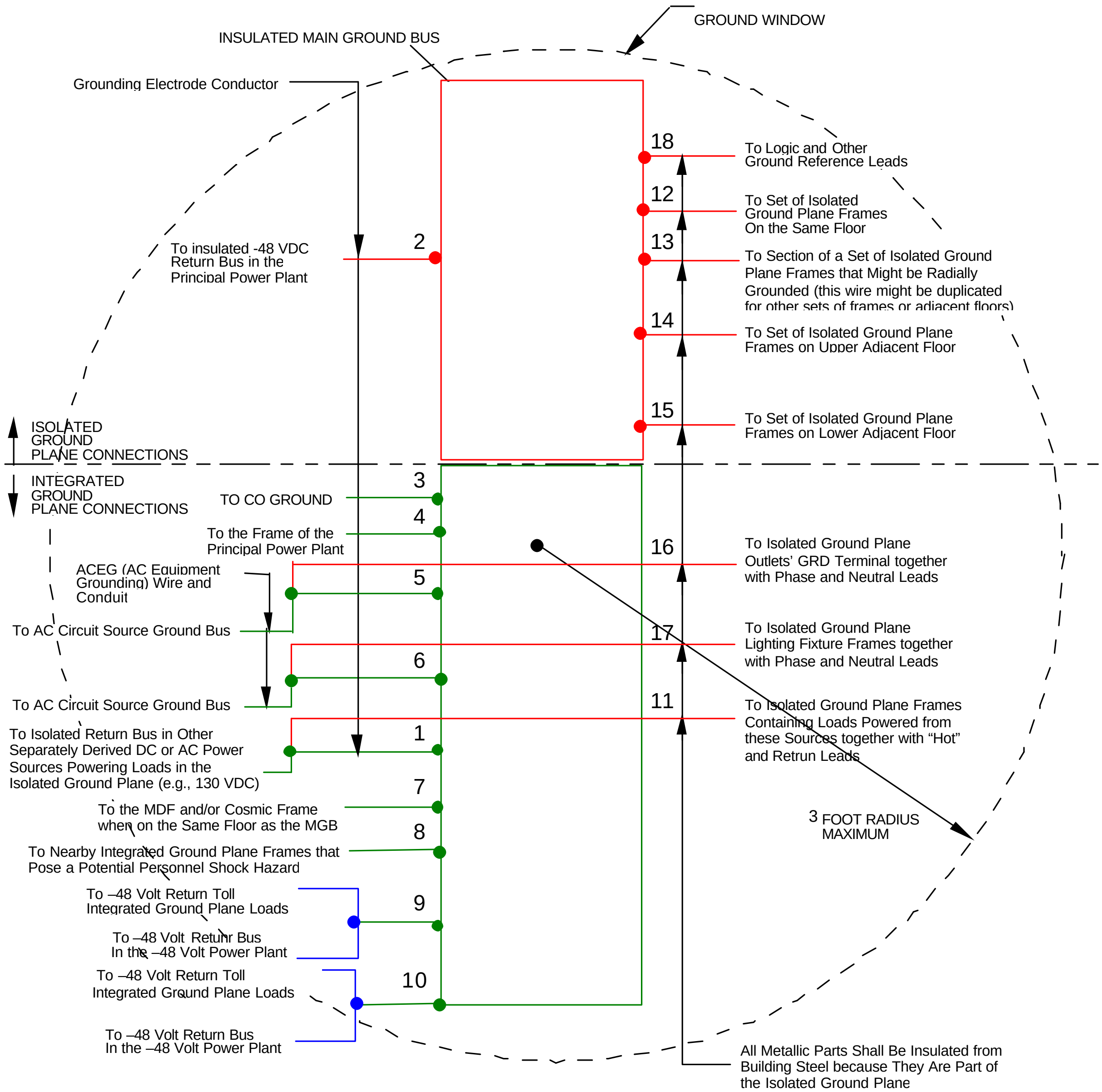
8.21 Ground Window Configurations

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

- A separate ground window (remote).
- A ground window developed from a plant that has an insulated battery return bus.
- A ground window developed from a plant that does NOT have an insulated battery return bus.

8.21.1 Separate Ground Window

Requirements for this type of plant are covered in paragraph 8.20 and Figures 8-6 and 8-9.



NOTES

1. Lead numbers on this figure are listed in the Conductor identification column of Figure 8-7.

Figure 8-6: Typical Sequence of Connections to a Separate Ground Window

Conductor Identification (see Figure 8-6)		**Can Conduct**				**Required in All Plants**		**Required in Some Plants (Yes)**	**Wire Size** (AWG)
		Lightning Current		**Fault Current**					
		Yes	**No**	**Yes**	**No**	**Yes**	**No**		
1	External Power Sources Grounding Conductors	**x**		**x**			**x**	**x**	#6
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 Grounding Wire	**x**		**x**		**x**			#6: <70' 1/0: 70-240' 2/0: >240'
5 **6**	External Power Sources Grounding Conductors	**x**		**x**			**x**	**x**	#6
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 Nearby Integrated Ground Plane Frames that are a Shock Hazard	**x**		**x**			**x**	**x**	#6
9 **10**	Toll (Integrated Ground Plane) Loads' –48 V Return Load Conductors	**x**		**x**			**x**	**x**	same size as the load conductor (maximum 1/0)
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 Ground Reference Leads in the Isolated Ground Plane			**x**			**x**	**x**	per switch vendor requirements

Figure 8-7: Tabulation of Typical Ground Window Connections

8.21.2 Using the Return Bus as the Ground Window

In some locations, it's 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 noninsulated 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 8.21.3 and in Figure 9-1, 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. In some offices, this may preempt the use of the power plant return bus as the ground window.

8.21.3 Requirements for Both Kinds of Plants

The plant shall be located within one floor of the isolated ground plane it is powering, although location on the same floor is preferred. Integrated ground planes that might be powered from the same power plant have no restrictions on their location.

In plants that have a common return and charging bus, the charging leads from the rectifiers should be connected to the same section of the bus as the -48 volt return leads that feed the isolated ground plane loads (these connections are not shown on Figures 8-10 and 8-11).

8.21.4 Requirements for Plants with an Insulated Return Bus (see Figure 8-10)

All grounding conductors and return conductors that can conduct lightning or fault currents shall be grouped together along one section of the bus (integrated) and in the sequence shown in Figure 8-10. This bus section is the ground window, and should be as short as practical but in no case longer than six feet. Figure 8-10 identifies these conductors with an asterisk. The return conductors that serve loads in the isolated ground plane should be grouped along the end of the bus, out of the direct path of lightning or short circuit currents. This section (isolated) is at the bottom part of the return bus (see Figure 8-10).

8.21.5 Requirements for Plants with a Noninsulated Return Bus (See Figure 8-11)

Lightning and short circuit currents can flow along the entire length of the noninsulated return bus because the bus is connected to the plant's frame. Consequently, if the return conductors serving the isolated ground plant loads were connected to this bus, dangerous voltage differences between these conductors could be generated when these currents flow.

One way to prevent this is to add an insulated auxiliary bus to the plant and then at a single point, connect it to the multigrounded bus as shown in Figure 8-11. This arrangement is equivalent to an insulated bus plant, because now the return conductors serving the isolated ground plane loads can be connected to the insulated bus section on which no significant lightning current can flow.

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

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

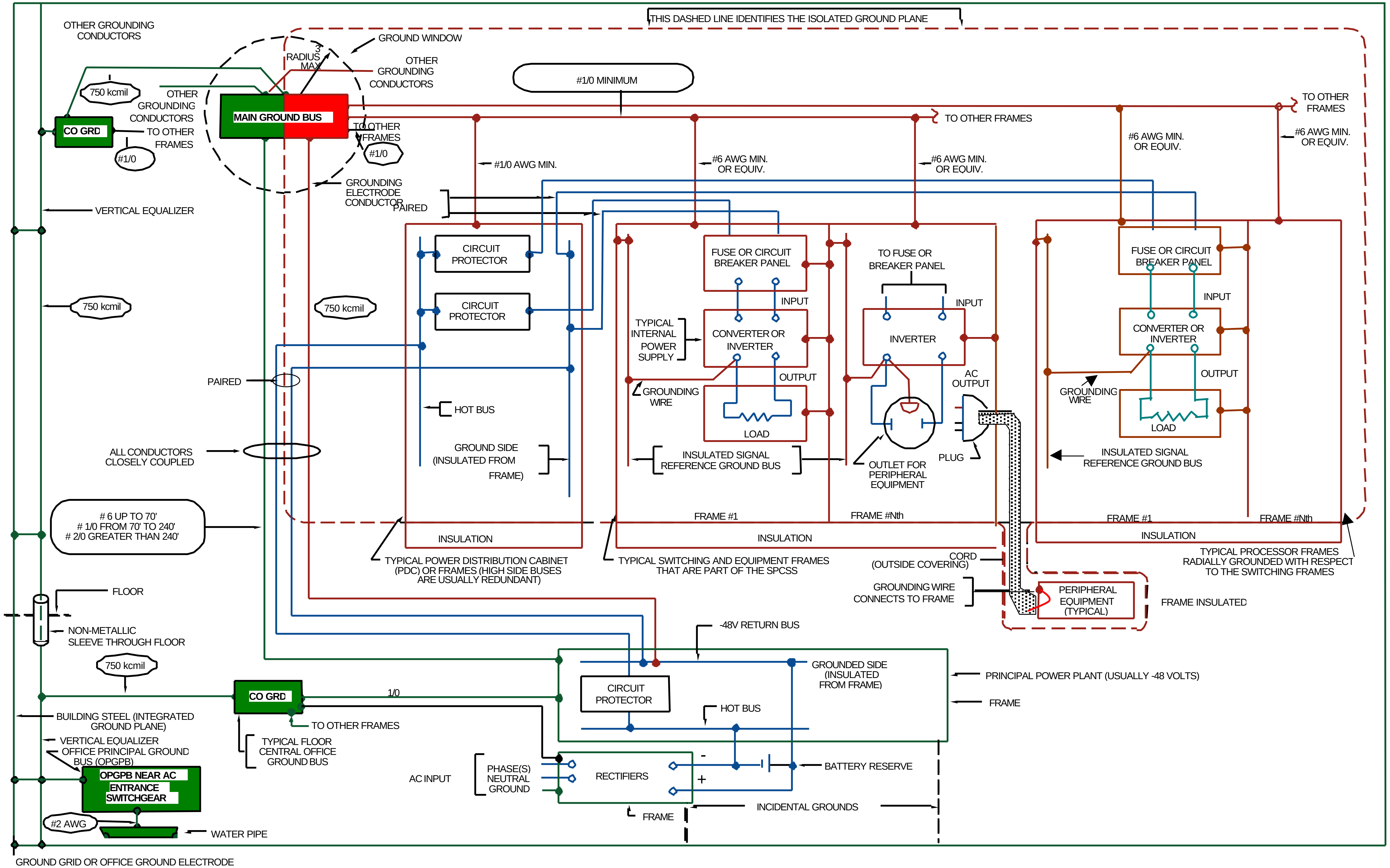
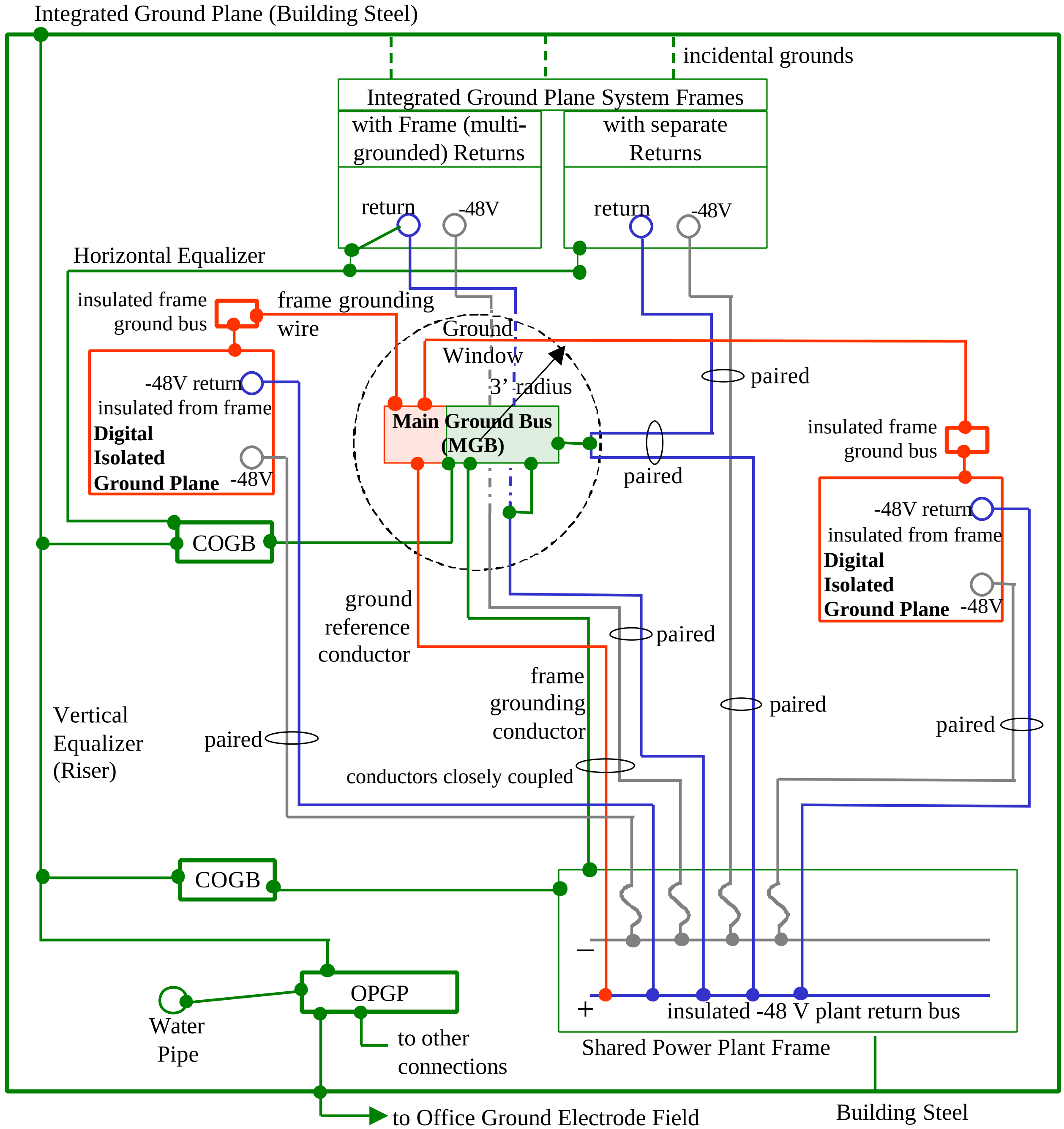


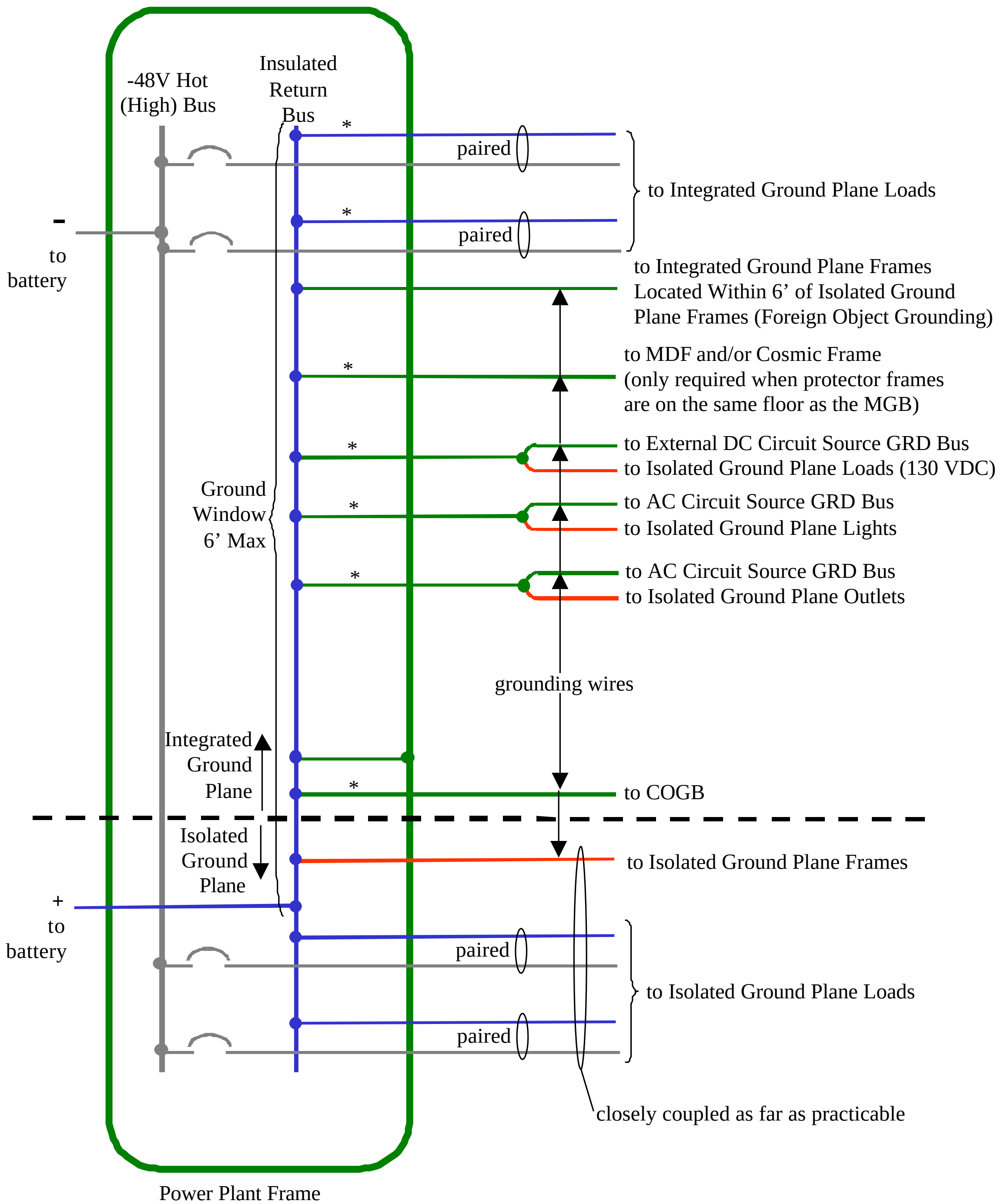
Figure 8-8: Typical Grounding and Power Feed from a DC Power Plant Powering Isolated Ground Plane Loads



NOTE:

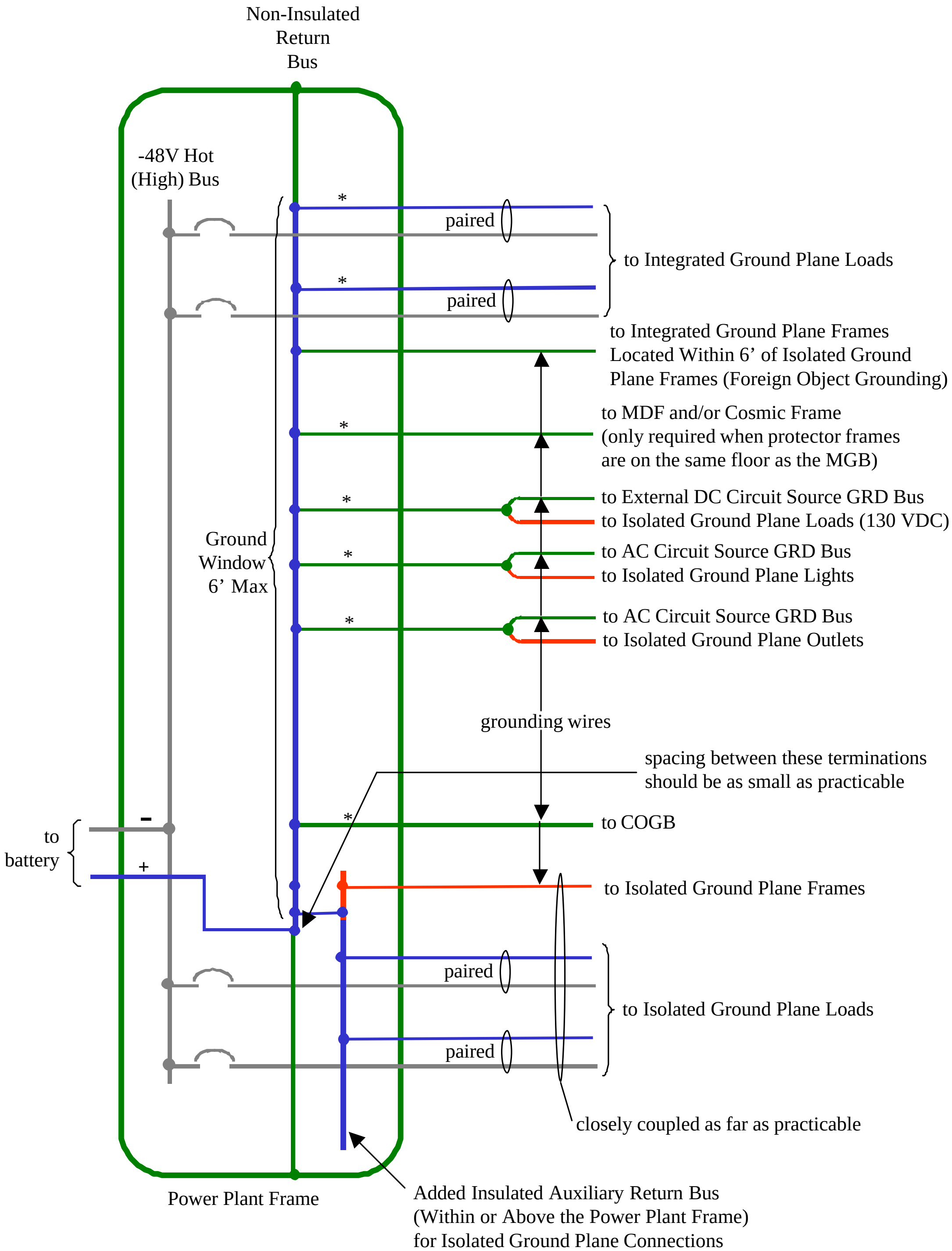
All Isolated Ground Planes Shall Be Within One Floor of the Ground Window

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

8.22 Methodology for Establishing an Isolated Ground Plane

The procedures listed below shall 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 shall 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 8.11.3.)
- 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 shall 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 per this publication.
- Connect peripheral equipment to the isolated plane as required per this document.
- Run required prepower tests.
- When all these conditions have been satisfied, power up the equipment.

8.23 Performance Verification and Test Procedures

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

8.23.1 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 shall not be in contact with any other elements of the integrated ground plane.

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

Peripheral equipment that is part of the isolated ground plane shall 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.

8.23.2 External Power Supplies

All DC power supplies shall be grounded at the MGB within the ground window.

All separately derived AC power supplies shall be grounded at their immediate output (isolating [orange] receptacles are prohibited).

8.23.3 Internal Power Supplies

All internal power supplies shall be grounded at the signal reference bus (see paragraph 8.17)

Ground Window Conductors - Check that all required conductors are connected to the ground window (see Figures 8-6 and 8-7 for a checklist). Check for the following:

- Wire Size
- Two-holed Crimp Connectors
- Tightness of Connections
- Conductors are Stranded Copper
- Condition of the Connecting Surface
- Separation of Integrated and Isolated Ground Connections

Listed Label and Wiring - Each AC power system component in the isolated ground plane shall be checked to ensure that it is listed by a Nationally Recognized Testing Laboratory, labeled and that the wiring is in accordance with the NEC.

Power Feeds - Check to determine that the power feeds 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 shall not be permitted.

8.23.4 Insulation Test

Each frame (or group of frames) that is part of the isolated ground plane shall undergo the following insulation tests after being secured to the floor. This shall be done before connecting any power or grounding conductors to the isolated ground plane. These tests ensure that the necessary insulation has been provided between the hold-down fasteners and the integrated ground plane. When growth frames are added, the 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 shall 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 shall be 100,000 ohms or greater. 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 Bellcore BR 802-010-100, 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.

8.24 Isolated Ground Plane Noise Circuit Test

8.24.1 Abnormal Current Flow in Grounding Wires and Frames

While the telecommunications systems are up and 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.

Under practical conditions, some circuit arrangements can cause current to flow in these conductors. Tests can identify the amount of current flow on the ground paths and, if necessary, remedial circuit arrangements can be made.

8.24.2 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.

In any case, no single filter shall inject more than 3.5 milliamperes (AC or DC) into the frame.

8.24.3 Correcting Improperly Wired Circuit Arrangements

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

- Multigrounded AC and DC power sources - This test concerns downstream interconnections between the AC neutral and the AC EG, or between the -48 volt return and the equipment frame.
- Test to determine if these sources are multigrounded by making a low-voltage measurement on an operating circuit between the return conductor of the source and a nearby frame downstream from the point at which the power source has been properly grounded. If the voltage measured is less than 0.1 V, multigrounding generally exists. If the voltage measured is greater than 0.1 V, then it is unlikely that multigrounding exists. This test should be performed at the following locations:
  - **For AC Circuits:**
    - At selected general-purpose receptacles on the frame
    - At the AC input to lighting fixtures that are part of the isolated plane
  - **For 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

8.24.4 Overvoltage Protectors

All overvoltage protectors should be connected from the line to the return conductor(s). When an overvoltage protector is incorrectly connected from the line-to-frame, current is injected into the isolated ground plane. Therefore, the line-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 connected from the return conductor to the frame. Thus, with two protectors connected, one from line-to-return and the other from return to frame, no current is injected into the isolated ground plane.

8.24.5 Improper Load Connections

Loads that are wired between line and ground (rather than between line and return conductor) inject large amounts of current into the isolated ground plane. 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.

CONTENTS

Chapter and Section **Page**

Figures

9. Grounding Methods

9.1 Frame Grounding

Figure 8-3 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 shall be insulated from contact with other grounded metalwork in the building.
- 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 AWG conductor (this does not mean that the PD frames must have their own direct connection to the MGB — they can be simply connected to the serial or radial stringer).
- All other equipment frames or cabinets shall be bonded by a No. 6 AWG copper conductor to a grounding conductor that is routed along the top of each equipment lineup.
- Isolated ground plane equipment lineups shall be interconnected with a minimum No. 6 AWG copper conductor to a frame ground bar or a grounding copper conductor (typically a No. 2 AWG lineup feeder or “stringer) which are bonded to the MGB within the ground window.

9.2 DC Power System Grounding (for PDCs)

The battery return busbar of PDC cabinets (or similarly named switch secondary distribution points) is electrically isolated from the PDC framework. Splice plates located above the PDCs 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 PDCs 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.

9.3 Isolated Power Plant and Integrated Ground Plane Equipment Application

The following is required when an isolated battery return DC power plant is used to power both the Digital switch and other transmission and miscellaneous equipment that is part of the integrated grounding system:

- 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 the isolated ground plane frameworks and the frameworks of integrated grounded system equipment, when possible, to avoid the possibility of personal contact between the two ground systems.
- A grounding conductor shall 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 PDs of the digital switch.
- The Main Ground Bus (MGB) of the ground window shall be bonded to the CO GRD bus 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 shall be bonded to the CO Ground bus on the same floor. The power plant framework shall 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, size of the conductor 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).
- All DC feeders serving systems in the integrated ground plane shall be routed through the ground window and bonded to the MGB.

9.4 Ground Window

The ground window is a dimensional transition zone consisting of a sphere with a maximum three feet radius, which is the interface between the building's integrated ground plane and a given isolated ground plane. It is the opening (a window, if you will) where all AC and DC grounding conductors (including metallic raceways) serving an isolated ground plane "see" 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 MGB shall be within three conductor feet of the center point of the sphere (see Figure 8-6). Any number of individual isolated equipment subsystems may exist in an isolated ground plane and can be referenced to a single ground window. After passing through the ground window and being bonded to the MGB, all of the grounding conductors associated with the isolated ground plane are insulated from the building integrated ground plane because they have become a part of the isolated ground plane. Conductors serving integrated ground planes that multiground the return side of the principal power source and are energized from the same power plant serving the isolated ground plane must be routed through and connected to the MGB within the ground window.

Figure 9-1 illustrates the maximum number of floors over which one or more electronic type offices (Analog or Digital) 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 ground plane except for a single bond connection to the CO GRD bus on the center floor.

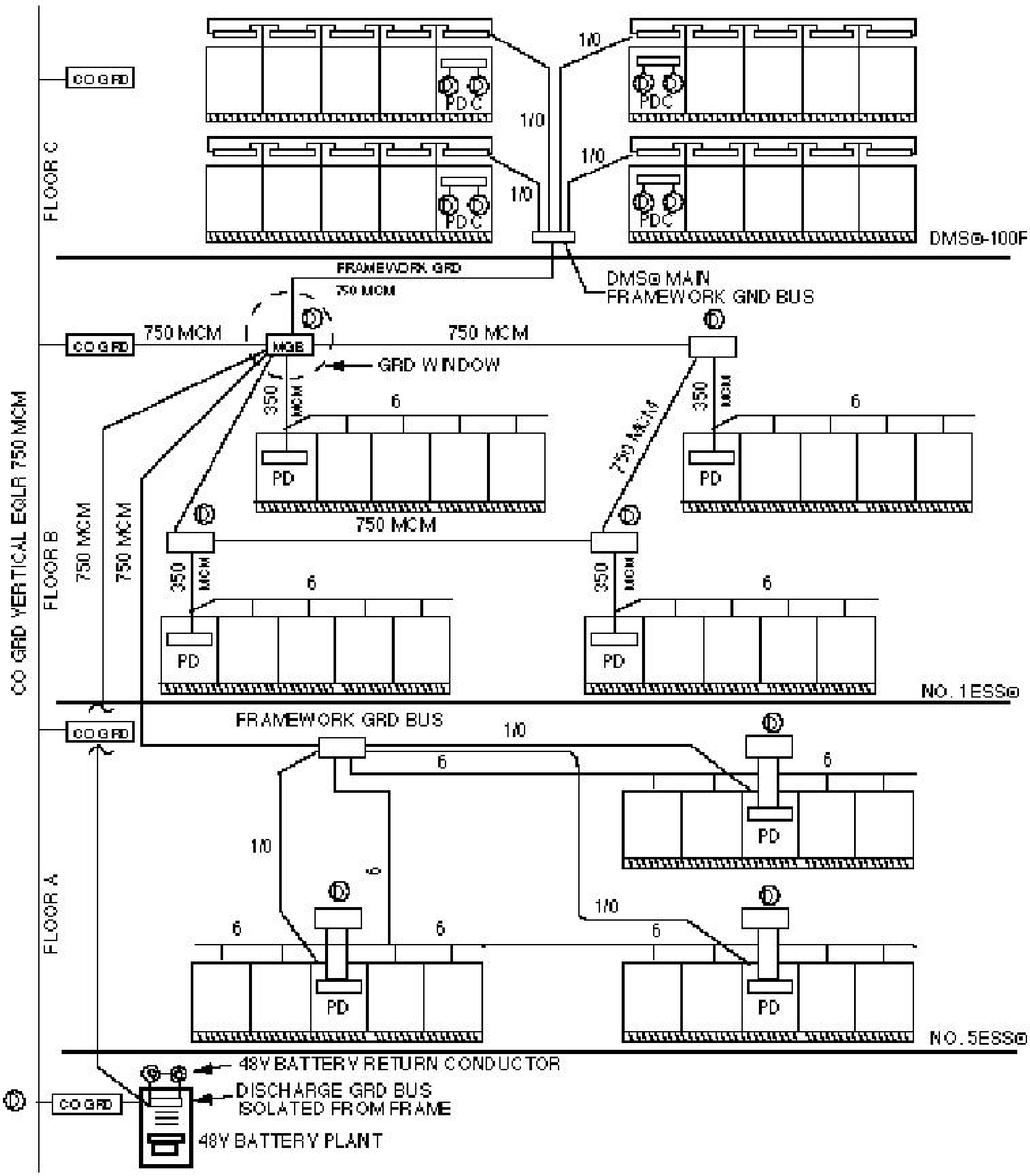
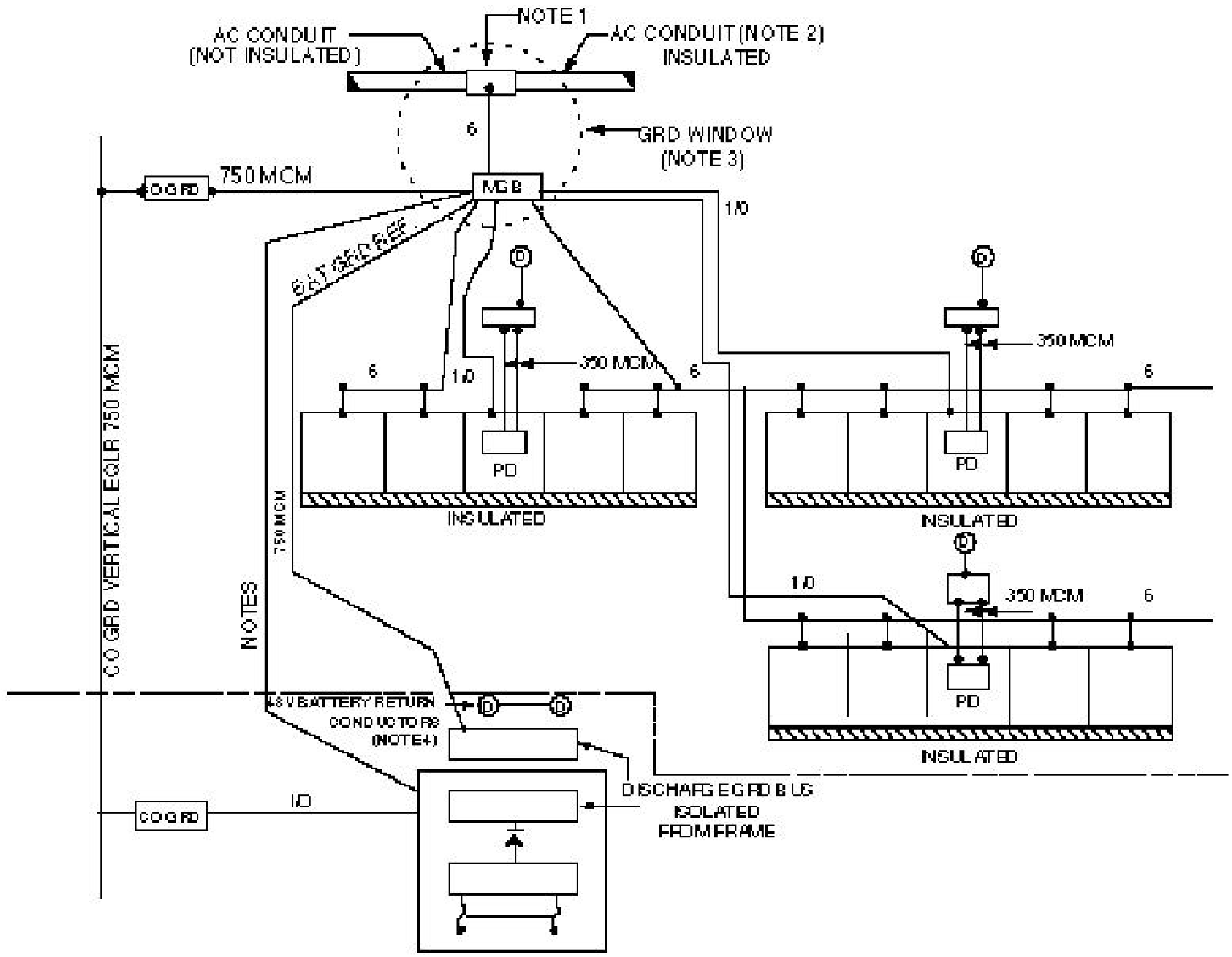


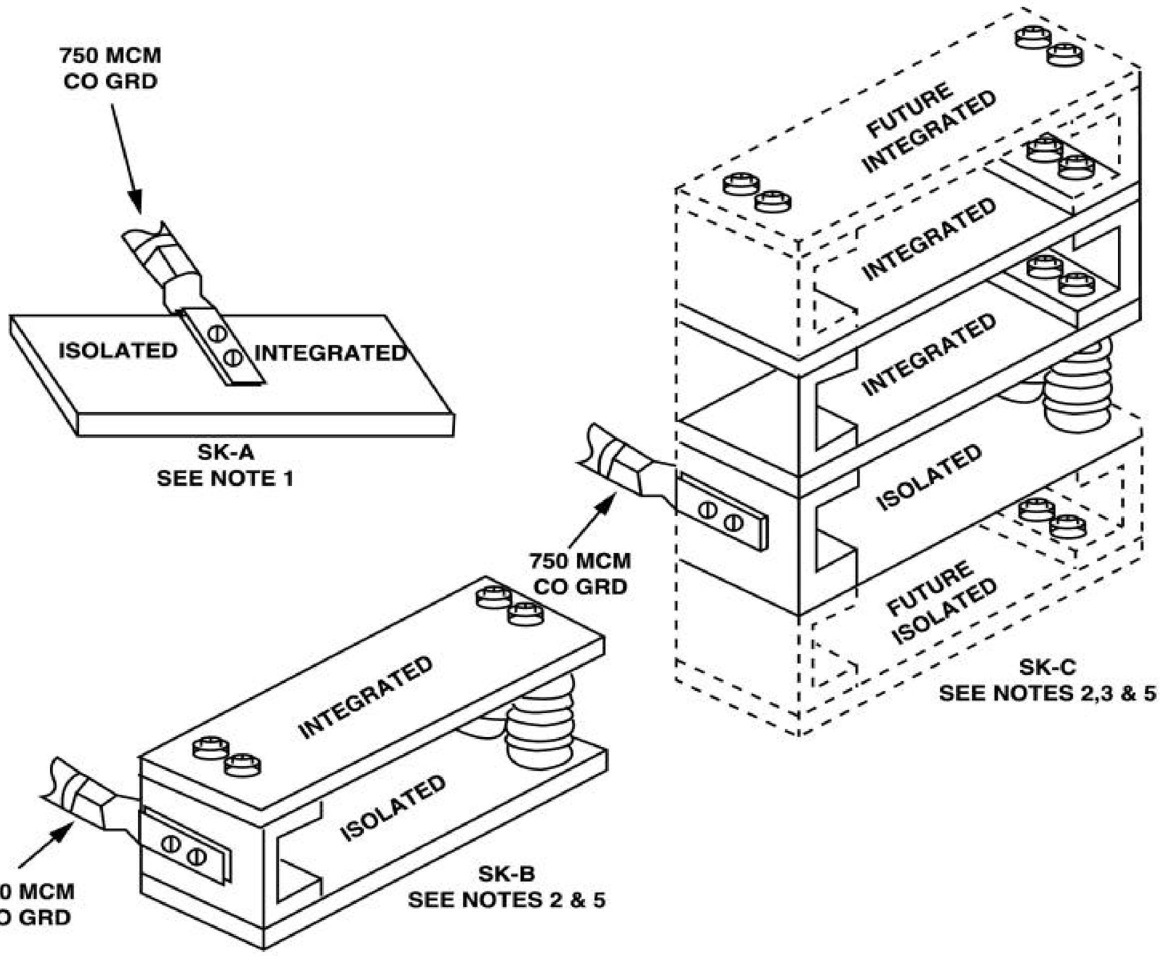
Figure 9-1: Maximum Multifloor Ground Plane Spread Using a Single Power Plant



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, and be electrically continuous from the source of the loads.
3. The Ground Window shall be located as closely as possible to the Isolated Ground Plane(s) it serves. Vertically, it shall 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 #6 AWG up to 70’, 1/0 from 70’ to 240’, and 2/0 greater than 240’.

Figure 9-2: Digital Switch Isolated Power Plant Application



Notes:

1. The 750 kcmil conductor 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 shall 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 shall be stamped or identified by tag 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., only insulators would be used on the right hand side). This allows the integrated side (which is limited to 6 linear feet) to be stacked up to 3 feet high with 3 foot bars extending to the right.

Figure 9-3: Ground Window Busbar Configurations

The following restrictions are necessary to protect solid state components and printed wiring boards from possible damage in case of a lightning stroke on 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.
- Under no circumstances shall any Stored Program Control Switch System (SPCSS) framework that comprises a portion of the isolated ground plane be more than one floor away from the ground window.
- These restrictions limit the spread 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 9-1, 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 stroke 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 9.3. In a single floor SPCSS layout, it may be expedient to establish the ground window in a location that would facilitate routing of conduits or power ground feeders that must pass through the ground window. Where the power plant serves three floors, the ground window must be established on the middle floor. The main ground bus should be located in the SPCSS area, which in a 3-floor installation may be presumed to include any point of the middle floor that intervenes between upper and lower floor SPCSS installations. It may be mounted on cable rack, a column or a wall or other positions accessible for cabling. It should be noted that conduits and AC EG leads serving the SPCSS equipment must be bonded to the MGB within the ground window before extension to the SPCSS equipment on adjacent floors.

- If space for termination of ground leads on the MGB has been exhausted, supplementary ground buses may be installed. This bus shall be located within the 6 foot sphere of the ground window (i.e., within three feet of the MGB) and shall be connected to it with 750 kcmil conductors (if it's a remote ground window, only one 750 kcmil is required; however, 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) or preferably with a copper channel bus. Any ground leads that normally would be connected to the main ground bus may be terminated on the supplementary ground bus. A supplementary ground bus should not be used unless necessary.

The ground window with supplementary buses is constructed as follows:

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

9.5 Establishing a Separate Ground Window

A ground window, as previously defined above, shall be established to serve the isolated ground plane. A copper bus (or buses) called the main ground bus (MGB), shall be located within the ground window to provide a place where various required connections can be made. The main ground bus shall not be mounted on any of the isolated ground plane frames (see paragraph 8.20 for requirements when the principal power plants return bus is used as a ground window).

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

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

Only one ground window shall be associated with the principal power source serving the isolated ground plane. 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 8.20).

9.5.1 Dimensions

The ground window's dimensions are that of an imaginary sphere with a maximum radius of three feet.

9.5.2 Locations

The ground window shall be located as close as possible to the isolated ground plane it serves. Vertically, it shall be no more than one floor from the isolated ground plane. Horizontally, the ground window shall be not further than 100 feet from the floor Central Office Ground (CO GRD) or 100 feet from the furthest member in the isolated ground plane. In no case, however, shall the furthest unit of equipment be more than 200 conductor feet from the floor CO GRD bus.

9.5.3 Ground Window Connections

A number of possible connections can be made on the MGB within the ground window, depending upon the needs of the various installations. Figure 8-7 shows typical detailed connections. The MGB can be thought of as the transition point between the integrated and isolated ground planes. The sequence of connections shown in Figure 8-6 should be followed. No connections shall be made between the isolated ground plane and the integrated ground plane other than through the MGB. All conducting materials that are part of the isolated ground plane such as cable rack, and cable troughs, conduits, armored cable, enclosed conductors, and the SPCSS frames shall be insulated and kept insulated from the integrated ground plane. The COGB tie point on the MGB that separates the isolated and integrated ground planes is often thought of as the center of the ground window sphere. No connection on either side of the MGB should be more than 3 or 4 electrical feet from this point.

9.6 Insulation

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 —** Analog or Digital equipment frame anchor bolts may come in contact with grounded structural metal in a floor. An insulator must be used to separate studs and bolt heads from frame metal.
- **Bottom of frames —** Insulating material shall be placed between frames and floor.

- **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 shall 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.

9.7 Typical Bonds from the Main Ground Bus

The MGB 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 possible extent. Such equalization tends to reduce the incidence of sparkover between the two planes and possibility of shock hazard to personnel interposed between the planes.

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

- The floor CO GRD bus (see Figures 8-6 and 9-2)
- Main Distributing Frame when on same floor as the ground window. (see Figure 8-6)
- AC conduit and AC equipment ground conductors (ACEG) that serve the isolated ground plane. (see Figure 8-6)
- 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.

In offices not equipped with a CO GRD system, a CO GRD system shall be installed.

Note: Sharp turns or bends should be avoided in grounding systems to minimize the inductive reactance that is introduced by steep wavefront currents. The higher reactance increases the included voltage and thus reduces the overall effectiveness of the grounding system. Minimum bending radius is 12 inches.

CONTENTS

Chapter and Section **Page**

Figures

10. Outside Plant Equipment Enclosures

10.1 Controlled Environmental Vaults (CEVs)

CEVs that house telecommunication equipment shall be properly grounded to meet the general requirements as stated in paragraph 2.1. A driven ground electrode system shall be engineered and installed in accordance with the requirements listed in paragraphs 3.1 and 3.2. Before installing an earth electrode system a soil resistivity measurement may be made to determine the earth resistivity of the surrounding site and to determine what type of ground electrode system should be used. After installing the ground electrode, the system should be tested and recorded prior to connecting the system to other ground electrodes. The impedance of the ground electrode system measured with an earth megger (a clamp-on resistance meter should generally not be used for this measurement — see the guidelines in Section 3.1) should be 5 ohms or less. If a 5-ohm impedance cannot be obtained, contact the local U S WEST Electrical Protection Engineer for assistance (in some cases, the 25 ohm maximum specified by the NEC may be the best we can get, and good enough).

(When OSP Equipment Enclosures [EEEs] such as CEVs are placed within a quarter mile of an electrical substation, special grounding precautions may need to take place. Contact the U S WEST Electrical Protection Engineer for assistance in determining ground rise potential, high voltage protection needs, and ground field considerations.)

The preferred method is to install a driven ground rod system underneath or adjacent to the CEV assembly. After the earth excavation has been opened for the CEV, at the bottom of the excavation open a 12 to 18 inch deep trench for the ground ring conductors. The placement location of this trench must allow for the placement of the ring conductors and rods (see Figure 10-1).

- Drive the 5/8” dia. by 8' ground rods as shown in Figure 10-1. Insure that a minimum spacing of 10 feet and no more than 15 feet is maintained between rods. A rod shall be located on each corner of the CEV as a minimum.
- Place a continuous length of #2 solid copper wire in the open trench. Exothermically weld the #2 AWG wire to the top of each rod to form a ring. Connect two #2 solid copper conductors at opposite ends of the ring ground and route these two #2 conductors in separate entries into the CEV for connection to the ground bar. (Stainless steel rods and tinned solid #2 wire are best, but not absolutely required.)
- Backfill the ground trench with removed dirt (don’t backfill with gravel or sand).

- After the CEV is set in place, route the two #2 AWG ground conductors through the designated PVC conduits cast into the CEV wall. Place a moisture proof dam around the end of the conduit and the #2 conductor to prevent moisture from entering the CEV (see Figure 10-2). (After the #2 conductors have entered the vault, they may be connected to stranded conductor by exothermic weld, if desired.)

A ground bar shall be installed inside the CEV at a convenient location for ease of grounding of all equipment framework. This ground bar will be a combination of PGPB and CEV Ground bar. The two #2 ground conductors shall be connected to the ground bar by crimping each conductor to a two hole copper connector and connecting them to the CEV ground bar (or alternately by exothermic weld).

After the CEV is assembled with upper and lower housing, electrically connect the two housings together by making a cable assembly and connecting to the upper and lower housing ground plates. The cable assembly shall be made with a #2 stranded tinned copper conductor. Exothermic weld, or crimp a two hole copper connector at each end and connect to the CEV ground plates with two bolts. Apply a non-oxidizing compound between the connector and the ground plate (see Figure 10-3).

Two ground connections are required between the upper and lower ground plates of the CEV to the ground bar. On the opposite end of the CEV connect both upper ground plates to the interior ring ground or the lineup grounds. These connections shall be done with a #2 copper stranded insulated wire. All bar and ground plate connections shall be done with exothermic weld or two-hole copper crimp connectors.

For new installations the ground connections required inside the CEV are (see Figures 10-4 and 10-5):

- A CEV ground bar at the end of the CEV for connecting all grounding conductors.
- Add a grounding conductor from the AC neutral bar at the service entrance, sized per the NEC (Article 250), and terminate it on the ground bar.
- Add a #6 bonding conductor from the AC distribution panel cabinet metal to the CEV ground bar or interior ring ground.
- Add a #2 AWG stranded copper conductor from the cable entrance for bonding of cable sheaths.
- Add a minimum #2 stranded copper conductor run along each equipment lineup. Connect #6 stranded copper insulated branch cables from the #2 “stringers” for grounding individual frameworks.
- Add a #2 ground reference conductor to the power plant battery return bar (+).

- Add a #2 ground conductor for grounding the power plant framework (this can be connected directly to the bar or to the lineup “stringer”). Racks holding batteries only may be grounded with a #6 to the stringer, just like any other frame.
- Add a #6 stranded insulated copper conductor for grounding miscellaneous frameworks or other units.
- Add a #6 bond to the CEV’s metallic entrance hatch.
- Bond upper and lower sections of the entrance ladder to the #2 conductor with a #6.
- Bond around flexible HVAC system ductwork with a #6 AWG stranded cable / wire.
- Ground the protector frame cabinet and the splice cabinet with a #2 conductor.

All connections shall be made with two hole crimp type connectors. All connections on cable to cable shall be made with copper crimp type connectors (C or H taps). All contact surfaces must be cleaned so that a bright metal to metal contact is made. The connection surfaces must be treated with a non-oxidizing compound to prevent corrosion. All grounding conductors shall maintain a minimum bending radius of 12 inches; sharp bends or 180 degree bends are not permitted. All connections shall be made so that the conductor flows toward the ground source.

All ground electrode conductors must be tagged with a "Do not Disconnect" tag. All grounding conductors must be identified as to far end terminations.

Existing CEVs can be upgraded by installing a grounding electrode and bringing the inside grounding up to the current grounding requirements. The following items and Figures 10-5, 10-6 and 10-7 should be considered:

- If the existing CEV does not have a ground electrode, a ground electrode must be installed as the cement encased electrode is not considered a reliable grounding electrode. Add a ground electrode per Figures 10-6 or 10-7 depending on existing conditions. If a driven rod ground system is installed, place the rods at least 18 inches below grade and at an approximate distance of 1/2 the rod length from the CEV exterior wall. Connect the ground electrode with #2 solid copper wire and bring in two conductors inside the CEV at two points apart from each other and connect to either a ground bar or to the interior ring ground. Two holes can be drilled on the upper housing for access inside the CEV. These holes must be properly plugged to prevent moisture or other contaminants from entering the CEV.
- Add a #2 stranded copper conductor ground ring on the inside wall just above the cable rack level.
- Bond the #2 ring ground to each ground plate of both the upper and lower sections of the CEV (two on each end of CEV).

- Bond the ring ground to the AC neutral at the service entrance with a conductor sized per the NEC.
- Ground the power plant's battery return bar to the ring ground using a #2 AWG stranded conductor.
- Ground each equipment frame with a #6 stranded wire using parallel taps and two-hole crimp connectors.
- Ground the Protector frame cabinet and the Splice cabinet with a #2 AWG conductor.
- Ground both sections of entrance ladder and the upper metallic entrance housing with a #6 stranded copper conductor.
- Bond the AC distribution panel to the ring ground.

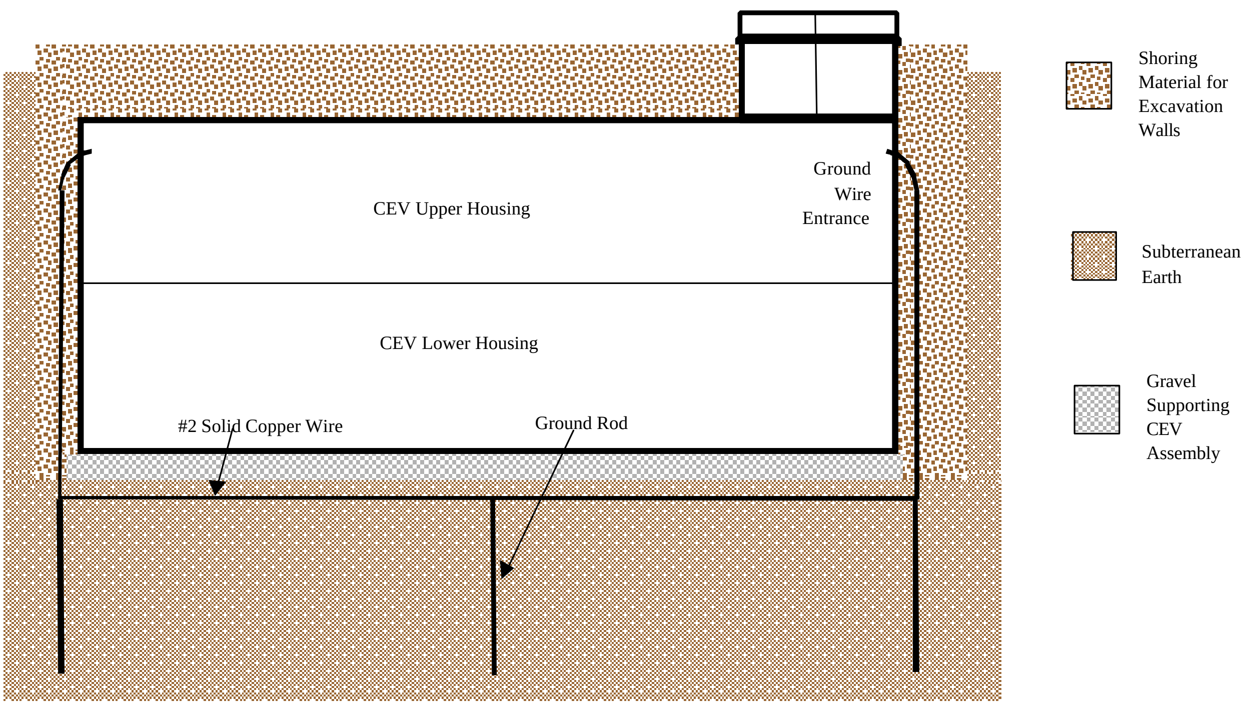


Figure 10-1: CEV Sectional View of Excavation and Ground Rod Installation

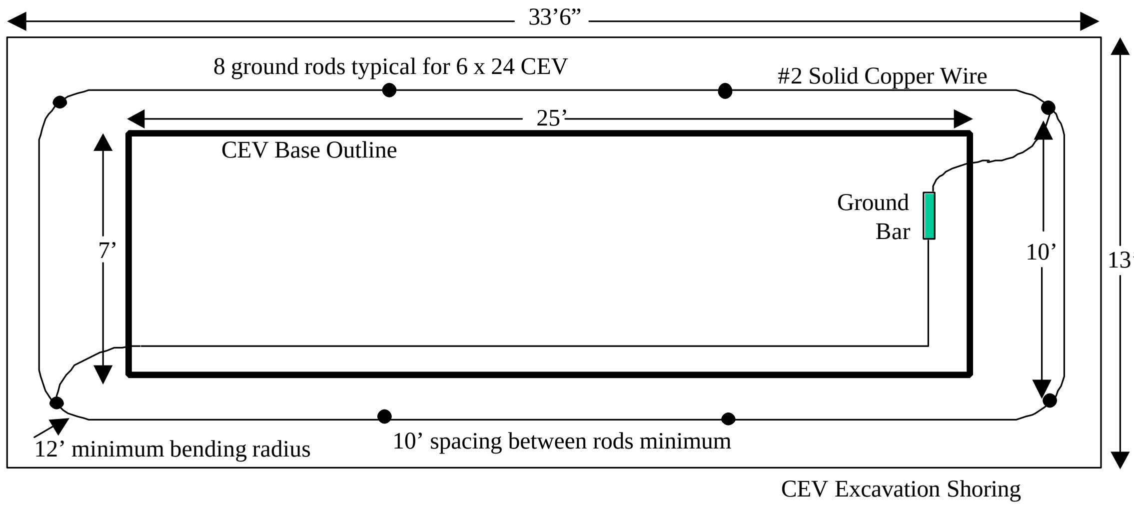


Figure 10-2: Typical CEV Excavation and Driven Ground Rod System

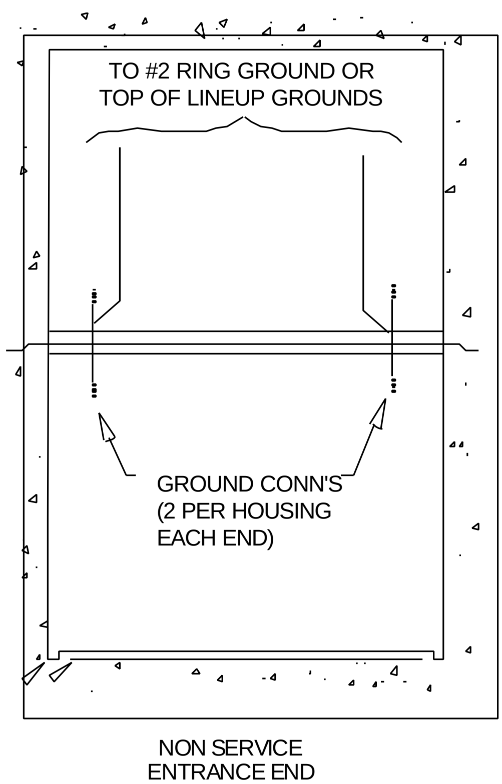
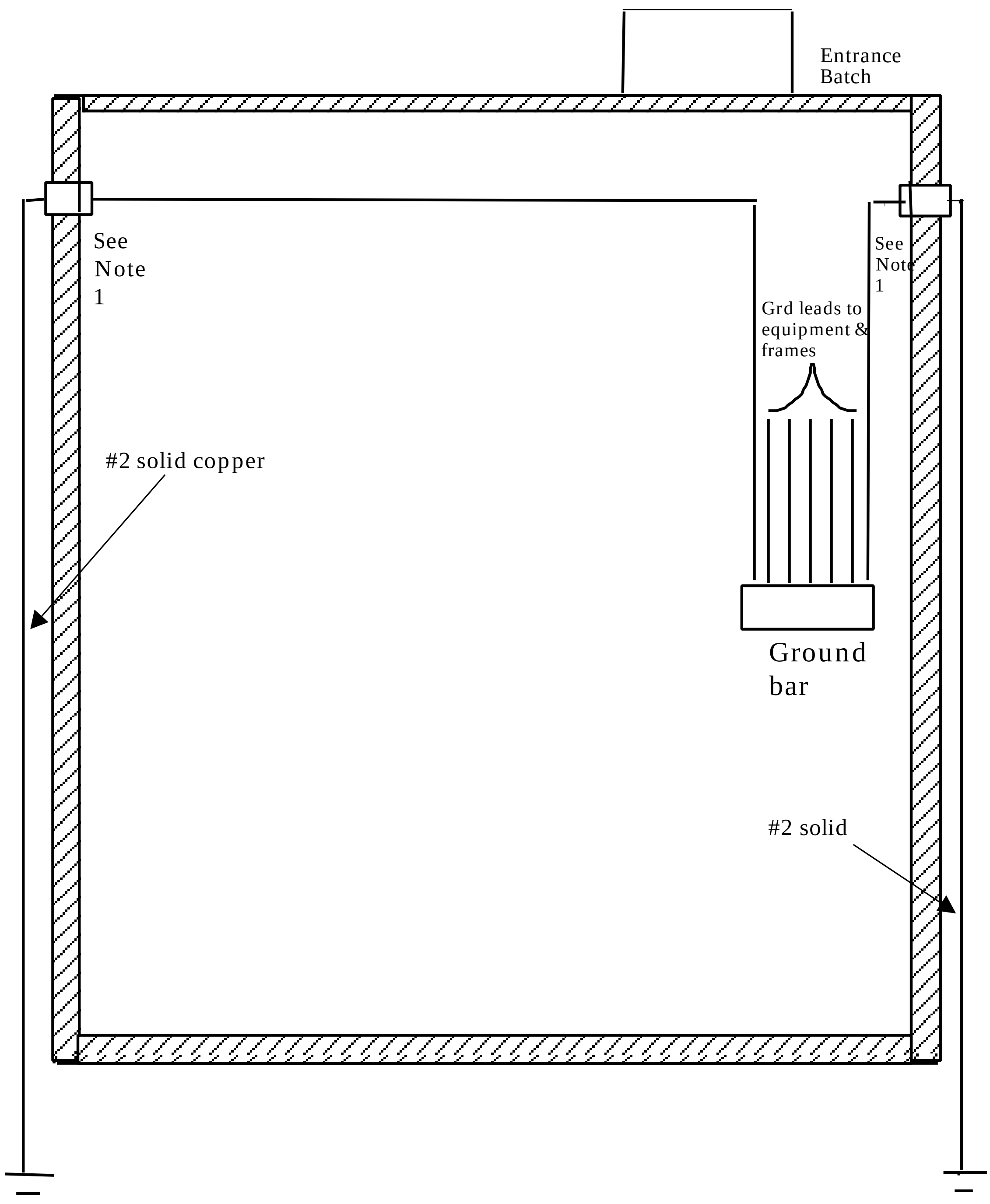
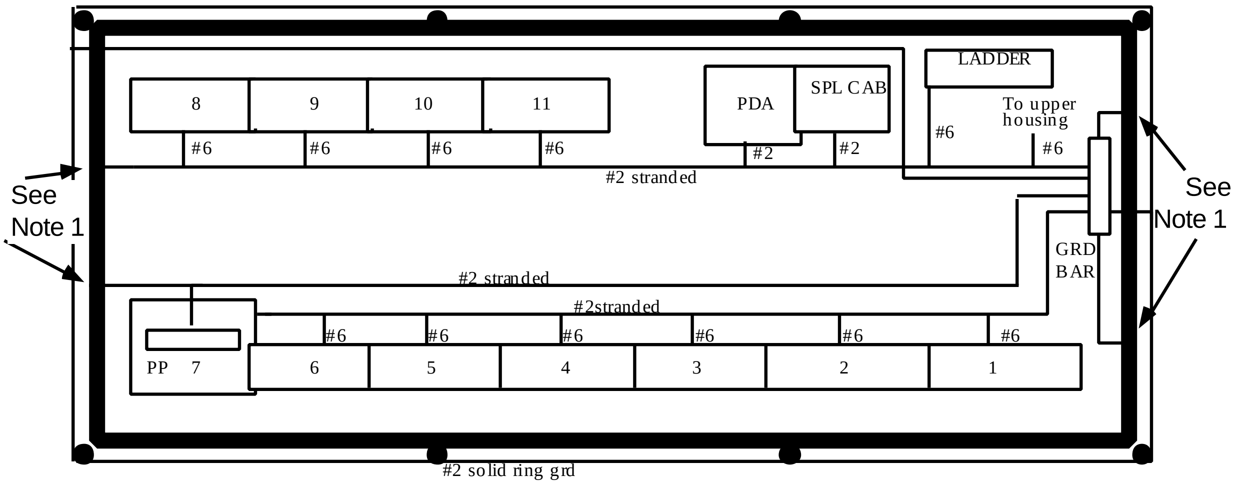


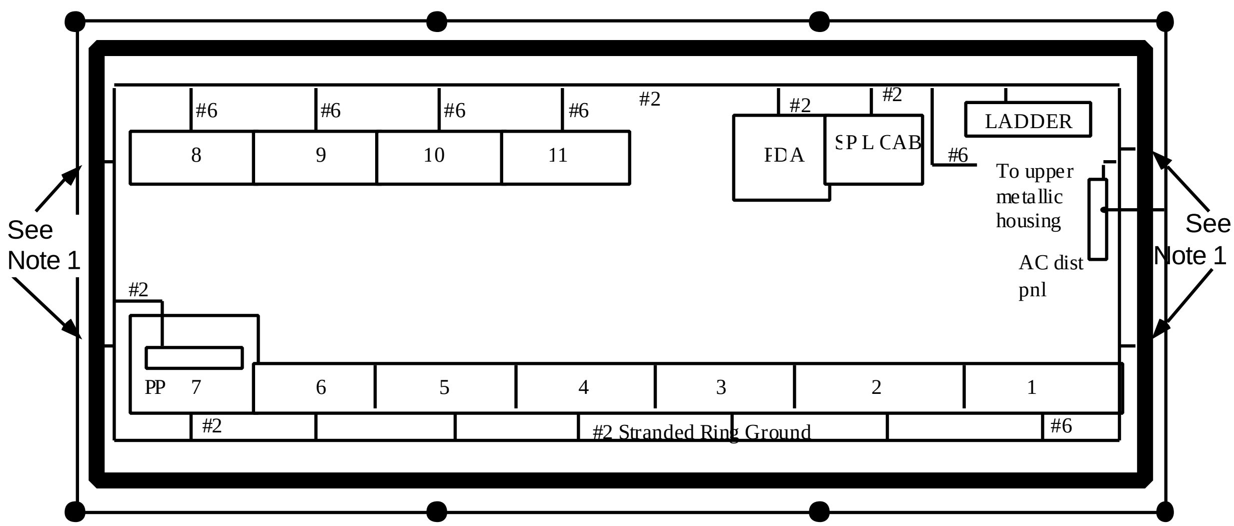
Figure 10-3: Typical CEV Bonding of Upper and Lower Housings



Note 1: Ground Entrance Coupling Provided by Vault Manufacturer

Figure 10-4: Typical Grounding Arrangement for CEVs





Note 1: Connect to upper housing ground plate.

Figure 10-5: Typical Inside Grounding for CEVs

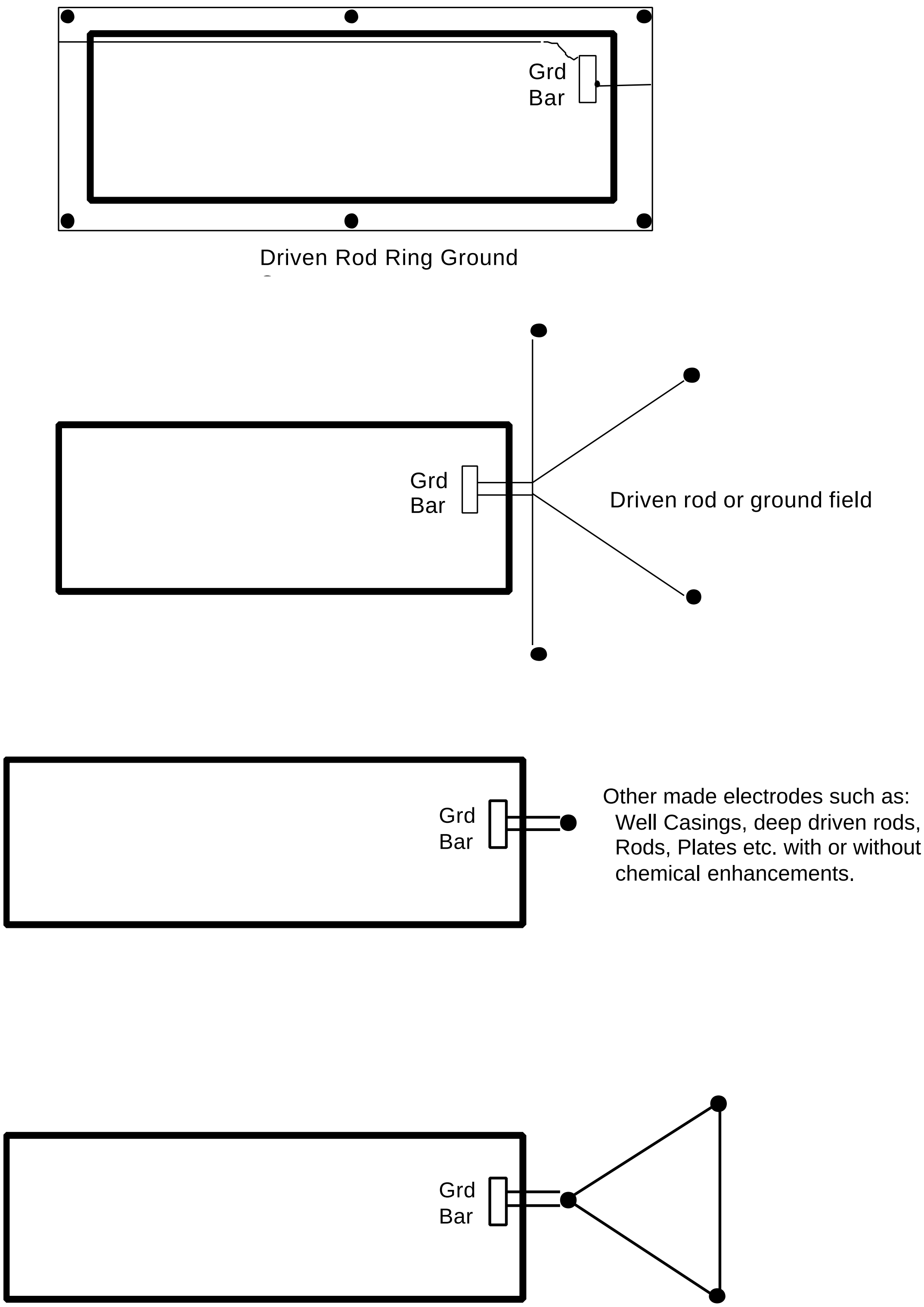


Figure 10-6: Examples of Grounding Schemes for Existing CEVs

10.2 Other Controlled Environment Equipment Enclosures (CEEs)

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.

Aboveground huts are often similar in size and structure to CEVs, CECs, UEs, and Radio sites. Grounding requirements from Section 10.1 or 7.21 may be used. Small portable buildings are often used as huts. A building raised above the ground on some kind of skid structure may not be at the same potential as earth. For these reasons, care should be taken in huts to bond and ground all metallic components (including metal skids, metal doorframes, metallic entrance conduits, etc.).

10.3 Above Ground Outdoor Type Cabinets

Above ground outdoor type cabinets shall be properly grounded for safety and equipment protection. A ground electrode shall be engineered and installed in accordance with Chapters 3 and 4, and Section 10.1.

A driven ground system shall be installed to establish a ground electrode for the cabinet. As mentioned in Section 10.1, the ideal is a ground electrode field that (when taken in parallel with any bond to the power company MGN) measures 5 ohms or less of impedance to earth (less ideal is the 25 ohms specified in the NEC). Typically, 4 ground rods should be installed for most electronic equipment enclosure (EEE) cabinet types (however, if less than 5 ohms are achieved with fewer rods, no more need to be added). (The minimum 4 rod rule should definitely be adhered to if the contractor is not measuring the impedance to earth after electrode installation with a megger.) The ground rods shall be exothermically welded to a #2 solid copper conductor in a ring configuration. The 5/8” dia. x 8' ground rods shall spaced at least 10 and no more than 15 feet apart (in some cases, 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 shall be placed at least 2 inches outside of any concrete pad on which the cabinet(s) sit. Oftentimes, more than one electronic equipment cabinet may be placed on a single pad. In these cases, the same ground electrode field should be used for both cabinets. Two #2 solid copper ground conductors shall be routed into the cabinet and connected at the designated ground bar. The two #2 solid conductors shall 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 shall be cleaned to a bright metal finish and a 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.).

(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 the cabinet is placed within a quarter mile of an electrical substation, contact the U S WEST Electrical Protection Engineer for special considerations concerning ground rise potential, high voltage protection, and grounding electrode fields.)

If the cabinet has a power plant, the battery return bar (usually the positive bar) shall be ground referenced to the cabinet ground bar with a #2 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 stranded copper conductor.

Cable sheaths, equipment units and battery plant framework shall be grounded as required with a minimum #6 stranded copper conductor to the cabinet ground bar.

The ACEG bar within the AC distribution panel should be grounded with a #2 AWG stranded insulated copper conductor connected to the cabinet ground bar (the No. 2 conductor is preferred, but a No. 6 AWG is also acceptable) as shown in Figures 10-8 and 10-9. (In some older cabinets, cabinet metal was used for this bonding — this is no longer an acceptable practice.

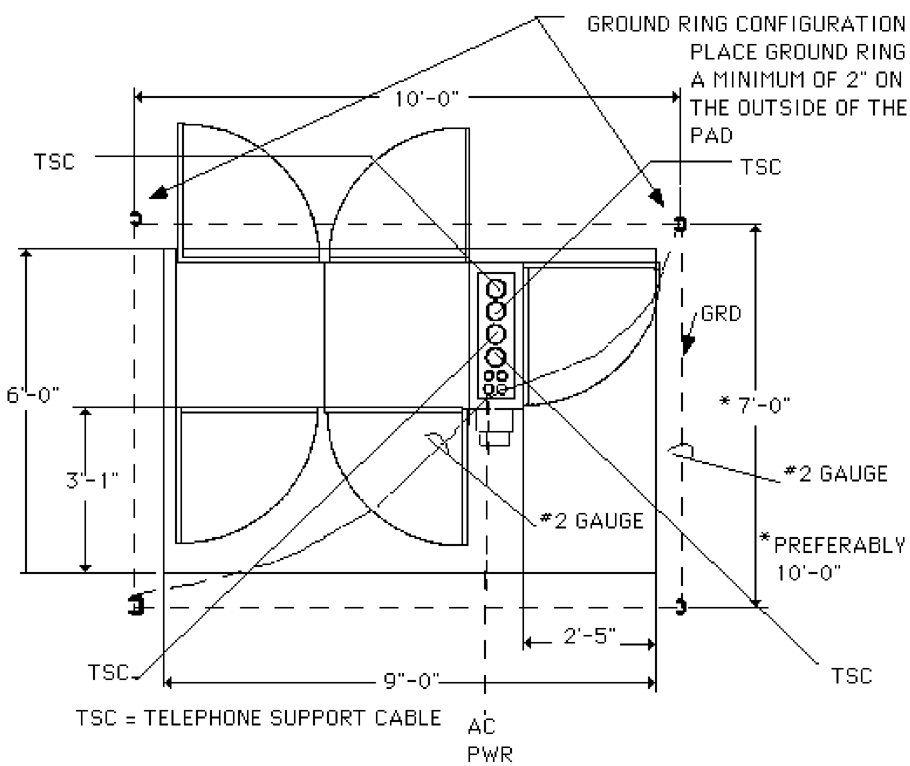


Figure 10-7: Typical DLC Cabinet Grounding

Any metallic objects (fences, metal posts, cable TV boxes, telephone cable closures, etc.) that have a ground potential and are located within 10 feet of the cabinet shall be bonded to the outside driven ground system.

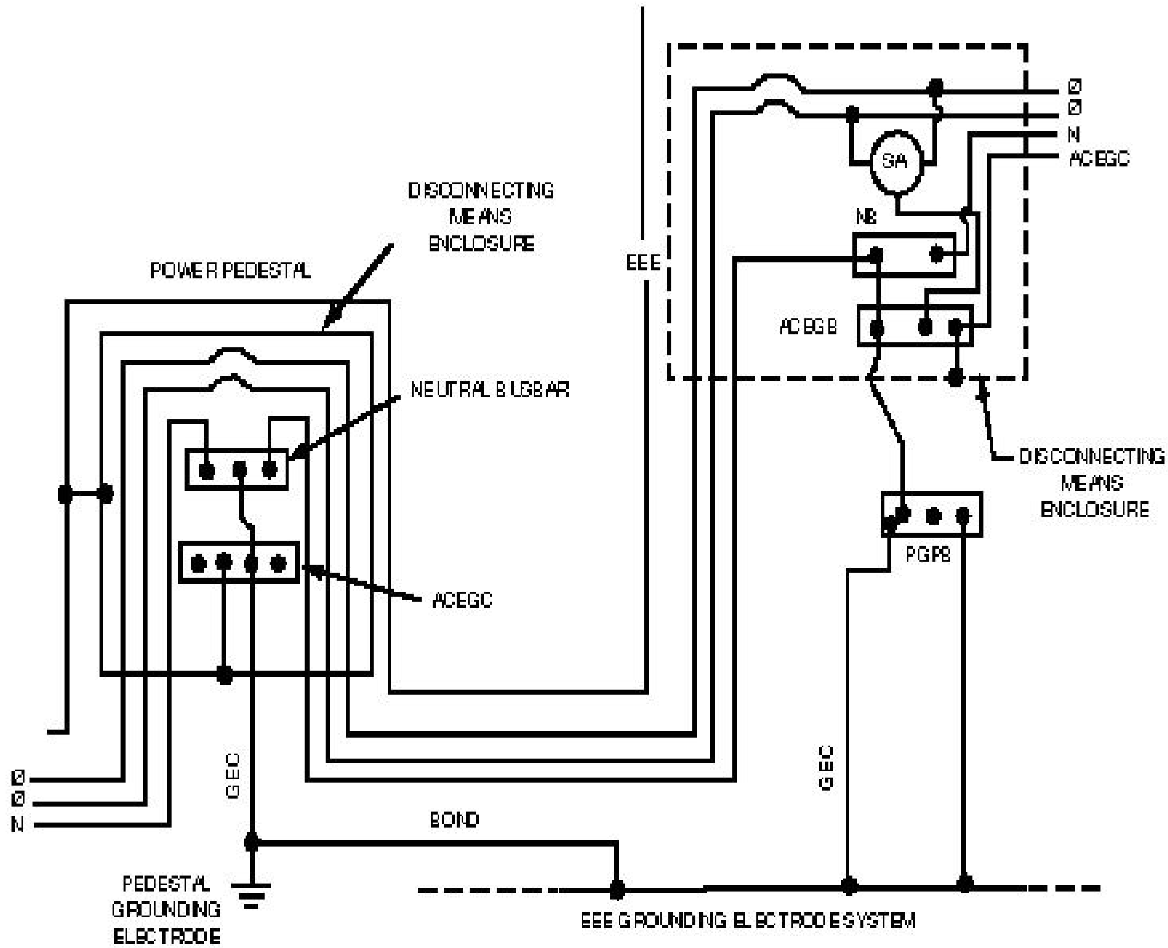
All connections on conductor to conductor shall be done with copper crimp type connectors (C or H taps). All connections to any metalwork shall be done with two hole copper crimp type connections. All contact surfaces shall be cleaned so that a bright metal to metal contact is made. All connections must be treated with a non-oxidizing compound to prevent corrosion.

Optical Network Units (ONUs) are a specialized type of cabinet typically serving 96 or fewer customers. For these smallest cabinets, although a ring ground (as described in the preceding paragraphs) and less than 25 ohm resistance to earth are strongly preferred, in some cases, this may not be practical. In these cases follow the ONU manufacturer's grounding guidelines (in the case of some small ONUs, this may mean only a single rod is required as the minimum). If the ONU is served by commercial AC, be sure to bond to the power company's MGN, similar to what is described in Section 10.4, and Chapter 4.

10.4 Grounding of the AC Neutral

There are two designs for grounding the neutral conductor of the AC service. The first design views the pedestal and the Electronic Equipment Enclosure (EEE) as two structures supplied from a common service, and the neutral conductor is grounded at the pedestal and at the EEE (EEEs include all of the aforementioned OSP enclosures: CEVs, CECs, UEs, huts, and above-ground cabinets). The second design is used when the pedestal and EEE are considered to be one structure. Generally they should be no more than about 5 feet apart (this also means that Figure 10-10 would apply when the power pedestal is integrated into or attached to the EEE structure), although some local Codes require that they be a minimum of 5 feet apart. Because these designs are not specifically described in the NEC, local rules should be consulted if power terminates on a pedestal. (See Figures 10-8 & 10-9.)

The power utility company will often drive their own ground rod right near the AC service entrance. It should be noted, that they are permitted to use the cabinet ground system set up as noted in the previous section. However, local codes and practices typically lead the power utility to drive their own rod. As shown in Figures 10-8 and 10-9, this rod should be bonded to the cabinet ground system with a minimum #6 AWG.



<u>Legend</u>:

ACEGB	AC Equipment Grounding BusBar
ACEGC	AC Equipment Grounding Conductor
NB	Neutral BusBar
PGPB	EEE Principal Ground Point BusBar
SA	Surge Arrestor
GEC	Grounding Electrode Conductor
N	Neutral Conductor
∅	Phase Conductor

Figure 10-8: Pedestal and EEE Treated as Separate Structures
(Power Neutral Grounded at Power Pedestal and EEE)

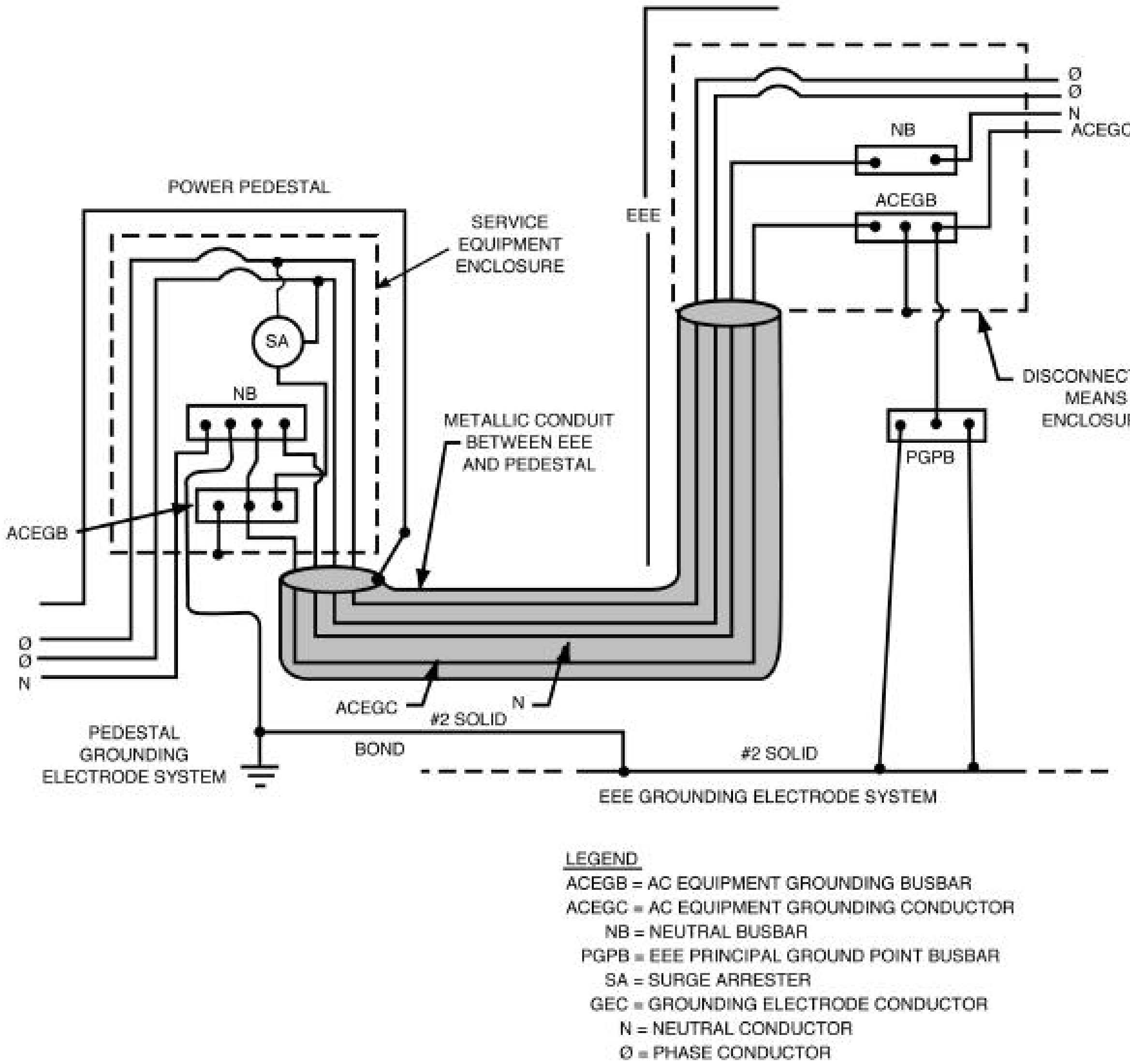


Figure 10-9: Pedestal and EEE Treated as one Structure
(Power Neutral Grounded Only at Power Pedestal)

10.5 Customer Premises Electronic Equipment Installation Grounding

Customer Premises grounding for U S WEST is covered in detail in U S WEST Technical Publication 77368, Chapter 6 and Section 7.8. Excerpts are provided in the following paragraphs.

There are essentially two types of Customer Premises installations from a grounding perspective, those that are relay-rack mounted (which are typically larger), and those mounted in one or more Customer Premises lockable cabinets (this is now the most common type of Customer Premises installation).

Because the customer owns the property in these types of installations, it is not always possible for U S WEST to mandate the placement of a good driven ground system. For this reason, the following ground electrodes are also acceptable for Customer Premises installations. They are listed in priority order.

- A Driven Ground System, as described in Section 3.2.
- Cold Water Pipe, as described in Section 3.2.7. It must be ensured that this piping is completely metallic (bond around plastic/PVC, water meters, and other non-metallic sections) all the way into the earth. (Checking with the city can also ensure that it is metallic for a considerable distance from the building.)
- Building Steel, as described in Section 3.2.7.
- The ACEG, if properly bonded to the power company's MGN at the HSP can serve as a ground source. If it is used as the ground source, the connection should be made as closely as possible to the HSP or nearest separately derived source.
- Absence of any of the above sources requires use of the AC Neutral. As with the ACEG, a connection to this ground source should be made as closely as possible to the HSP or nearest separately derived source. (Because this method holds the potential for rebonding the neutral to the cable sheath, it should only be used as a last source of ground reference when no other can be found.)

If a driven ground system can be used as the ground electrode source, it can be the only source. If it cannot be used, try to obtain at least two of the other sources listed above to connect to our U S WEST PGP (Principal Ground Point). It is preferable that the ground electrode field have an impedance to earth of less than 5 ohms, but if that is not possible, the impedance should not exceed the 25 ohm maximum specified in the NEC.

U S WEST requests that the customer extend the selected ground source(s) to the "telecommunications equipment room" with a cable sized according to the NEC (a minimum of #6 AWG) and terminate it on a ground bar that they provide (PGP). Typically, U S WEST will collect all of its grounds to a single collection point, and then cable that single collection point to the PGP with a #2 AWG minimum (a #6 AWG minimum is minimally acceptable for Customer Premises cabinets). Failing the presence of a customer-provided PGP bar, U S WEST should cable its single collection point to one or more of the ground sources listed above.

If a copper entrance facility is used, the Building Entrance Terminal should be located as closely as possible to the HSP (preferably within 20 feet according to NEC 800-11c) and grounded to one of the electrodes mentioned previously (the same electrode as that used for the PGP). If a fiber only entrance is used, and the fiber cable does not have metallic members, this requirement is not necessary. (Grounding and bonding of metallic cables that enter buildings is covered in NEC Articles 800-33 and 800-40).

U S WEST 's "ground collection bar" can be a separate ground bar, the customer-provided PGP, or the battery return bus of the power plant. If the power plant return bus bar is large enough to accommodate extra grounding connections, the use of an extra ground collection bar can be avoided. However, some Customer Premises installations are too large, and some power plant return bus bars too small to use the return bus as the ground collection bar. In this case, either the customer-provided PGP (if large enough) can be used, or a separate ground collection bar can be installed. Regardless of which bar is used as the ground collection bar, the following grounds should be connected to this "telecommunications equipment ground collection point":

- The Power Plant Return Bus Bar, unless used as the "collection bar" should be connected to the ground collection bus with a minimum #6 AWG conductor (use a minimum #2 AWG if the installation is a larger relay-rack type of installation).
- Equipment Cabinet rails, walls, and doors shall be electrically bonded; and then a connection shall be made from each cabinet to the ground collection point directly with a #6 AWG, or indirectly to a #2 AWG stringer run from the collection bar.
- Equipment Relay Racks should be connected to the collection point. If there are multiple relay racks and / or lineups, it may be wise to run a #2 AWG stringer above each lineup. A splice with a #6 AWG can be made to each relay rack frame from this stringer.)
- The shields of cables entering the space from the Outside Plant feeding U S WEST digital equipment should be bonded to a Splice Case ground point, which is in turn connected to the collection point with a #6 AWG. If there are metallic cables entering the space that do not feed U S WEST digital equipment, their sheath grounds should be tied to the customer's ground bar, as opposed to the U S WEST single-point collection bar.

  If the entrance is copper cable, each metallic pair in the cable must be protected, using a listed protector unit. The ground for the protector frame(s) should also be connected to the collection point, if they are in the same room. The NEC requires that the protector ground be bonded back to the building grounding electrode, so care must be exercised in equipment placement.

- The ACEG of the feeds to the Rectifiers should be extended to the collection point. (This is not necessary if the ACEG or AC Neutral is serving as the ground source.)
- The ACEGs of any Appliance/Convenience Outlets in the telecommunications equipment space may be **optionally** extended to the collection point. (As above, this is not necessary if the ACEG or AC Neutral is the ground source.)
- Any Other Metallic Bays, Cabinets, or Other Metal Objects in the telecommunications equipment area may be bonded directly to the collection point with #6 AWG, or connected to the collection point through “stringers” as described above. This is especially helpful in reducing ESD problems for cabinets that are used as storage for circuit packs.

Bonding metallic components of non-USWEST equipment located within 10 feet of U S WEST equipment needs to be brought to the attention of the Customer Premises’ controlling authority (landlord and/or owner). Un-bonded metallic frames may present a shock hazard to any person in the area. The Customer Premises’ controlling authority should be made aware of any such situations and asked to encourage all providers to bond their equipment to a customer-provided ground bar (see an earlier paragraph in this section).

10.5.1 Special Protection Requirements for Customer Premises Locations On or Near High Voltage Electric Power

Special electrical high voltage protection (sometimes requiring additional grounding) is required for communications facilities located on or near electric power generating stations or electric substations, or transmission lines. Guidelines are outlined in U S WEST Tech Pub 77321, ANSI/IEEE Std. 487-1992, and Bellcore BR 876-310-100. These documents describe under what circumstances the protection is necessary, and how to apply the protection (including grounding application).

CONTENTS

Chapter and Section **Page**

Figures

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 cabinets of sensitive electronic equipment. The protection afforded by the multi-point grounding system described herein should equal or exceed present requirements of various equipment suppliers. This section establishes a standard requirement that:

- Will allow sensitive electronic systems to be compatibly installed into a common ground plane and be served by a common power supply.
- Shall 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 effectively bonded together to create a common signal reference ground plane. This ground plane is insulated from incidental or deliberate connections with any other ground system, except for a single connection at a 'ground window'. The 'ground window' establishes a point of voltage neutrality between the signal reference ground plane and all other ground systems. The signal reference ground plane cannot be affected by current surges originating outside the plane because at least two connections are required for current to flow through the plane.

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). However, connection to other ground systems by this ground plane is not limited to a ‘ground window’, and requires that all conducting paths entering (and/or within 6’ of) the ground plane must be bonded to a signal reference ground plane herein referred to as the Signal Reference Grid (SRG)

11.4 Optimal Ground Point

The optimal connection point to ground for obtaining a stable ground reference should be equivalent to the CO Ground System. If the computer facility is not equipped with a CO Ground System, then one shall be provided.

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 fed from the CO Ground by a 750 kcmil, insulated, copper ground wire. Two hole, crimp type lugs should be used for all connections.

11.5 Signal Reference Grid (SRG)

The SRG system shall form a ground reference point 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 shall be connected to the CO Ground with a #2 AWG, copper, stranded, insulated wire using two hole compression lugs at the CO ground. The method of connection to the SRG shall be dependent on the type of SRG installed.

As a minimum, the SRG shall consist of a bolted stringer raised floor support structure. The bolted stringer to the pedestal head connection of this structure shall be installed and maintained with a resistance of less than .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 shall be composed of multiple runs of stranded, bare #2 AWG copper wire routed along each row of the raised floor pedestals in both directions under the raised floor, thus forming a grid. Each wire run shall be bonded at the intersecting point of each perpendicular wire run and the raised floor support pedestal (Fig. 11-3) by a mechanical connector that shall 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 shall 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 shall 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 shall 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) shall 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 U S WEST Facility Environmental Manager.

The connection between the cabinet and the SRG shall be made with a #6 AWG, flat braided copper strap and should be no longer than two feet. The braided SRG ground strap shall be attached with a two 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 shall be prepared to a bare, bright finish for connection of the ground strap by drilling and tapping two 1/4-20 holes and attaching the lug with two 1/4-20 x 3/4 inch bolts. An alternate method would be to drill two 5/16 inch holes and attach the lug with two 1/4-20 x 3/4 inch bolts, two 1/4-20 nuts and two internal tooth lockwashers (#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 two hole, crimp type lug to the bottom of the raised floor stringer, utilizing two 1/4 inch self-tapping screws.
- Connection to a square raised floor support pedestal may be accomplished by one of two methods:

- Drill two 1/4 inch holes through the pedestal (Fig. 11-4), attach a two hole, crimp type lug with two 1/4-20 x 1 1/2 inch long bolts, two 1/4 inch internal tooth lockwashers, and two 1/4-20 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 two hole lug and a 1/4 x 1 1/2 inch U -bolt (depending on the width of the pedestal). Attach the U-bolt and bar to the pedestal using two 1/4 inch internal tooth lockwashers and 1/4-20 nuts. Attach the two hole lug to the bar using two (2) 1/4-20 x 3/4 inch round head bolts, two (2) 1/4-20 nuts, and two (2) 1/4 internal tooth lockwashers. Two lugs may be attached at this point for two cabinet ground connections.

Attaching to a round pedestal may be accomplished by method above or by clamping the flat braid with a screw-type, stainless steel hose clamp.

Note: Torque all connections to 80 in-lbs. 1/4-20 Teflon lock nuts may be substituted for the ITLW and 1/4-20 nut. A compound that inhibits oxidation must be applied to all metallic contact surfaces.

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 shall be properly bonded to the SRG at the point of crossing or penetration. Metal equipment within 6 feet but not crossing shall 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 shall be attached to a metal channel with appropriate channel pipe straps. A #6 AWG flat braided strap with compression connectors shall attach the channel to the nearest raised floor pedestal as described in paragraph 11.6.

An alternate bonding method for individual electrical conduits or mechanical piping shall be a suitable pipe clamp and a #6 AWG flat braid with compression connectors at both ends attached to the nearest raised floor pedestal.

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 in US WEST as 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 U S WEST . 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 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.

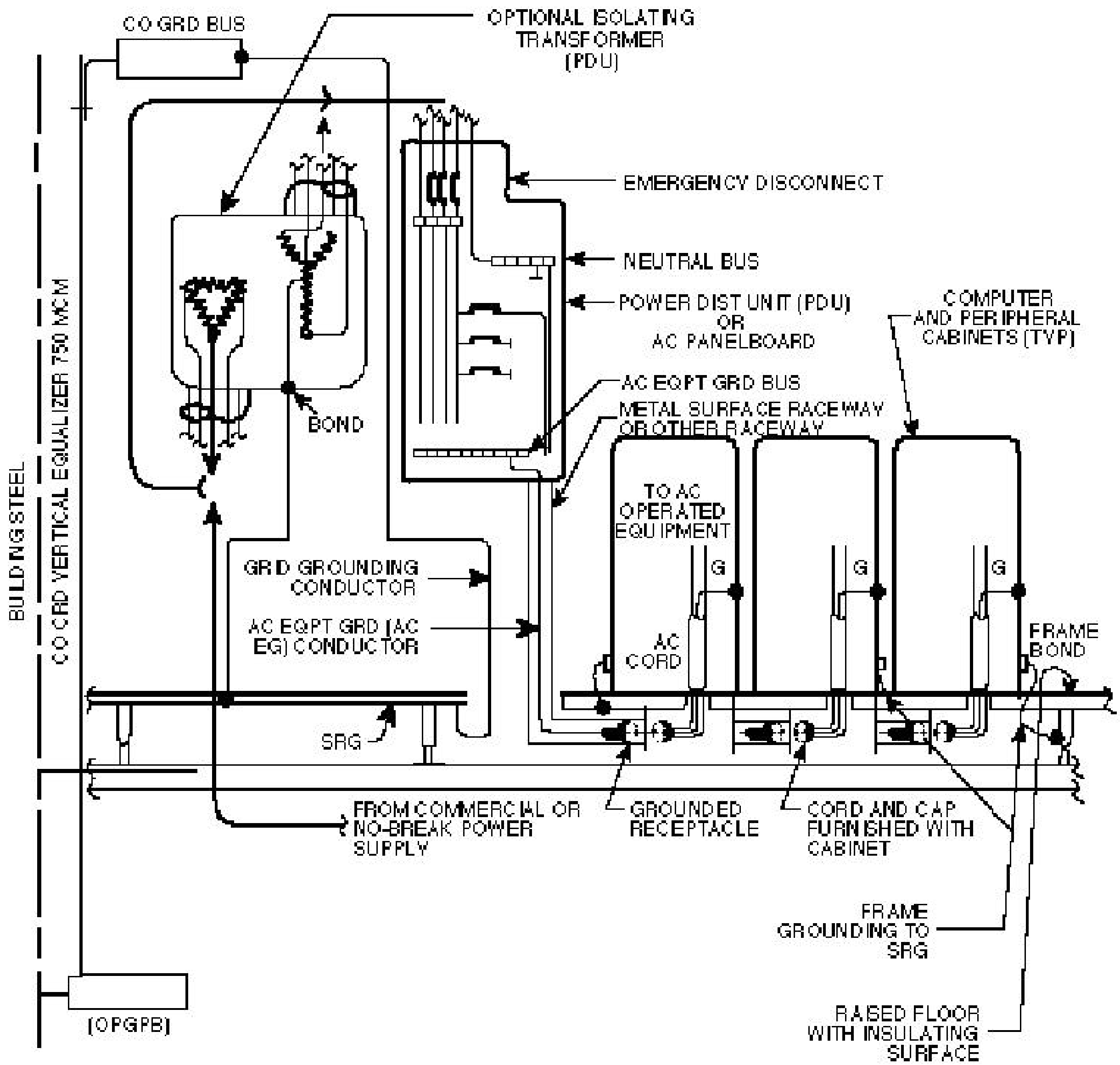


Figure 11-1: Typical Computer Room Grounding Arrangement

11-2 A Round Pedestal

11-2 B Square Pedestal

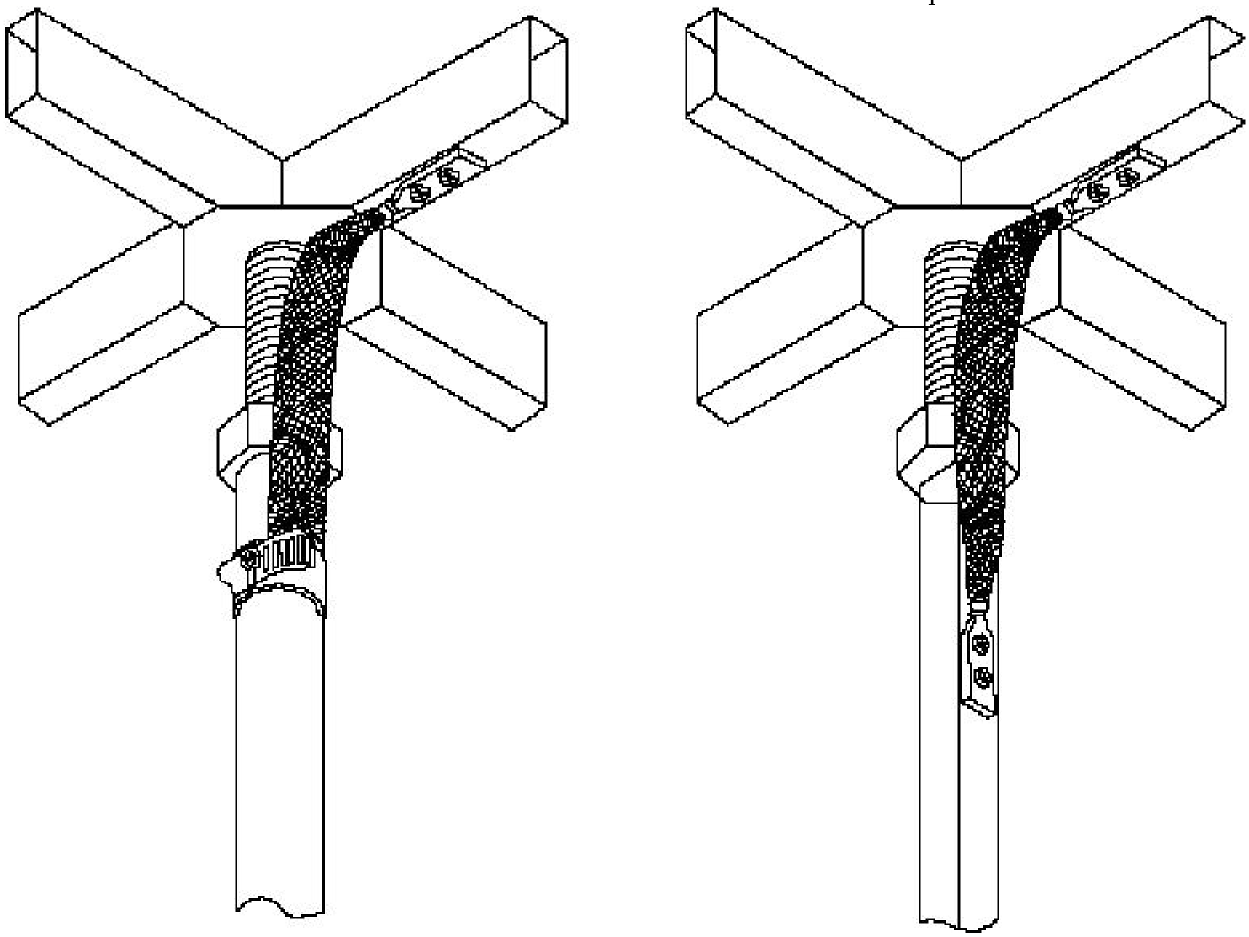


Figure 11-2: Bolted Stringer Raised Floor to Pedestal Connection

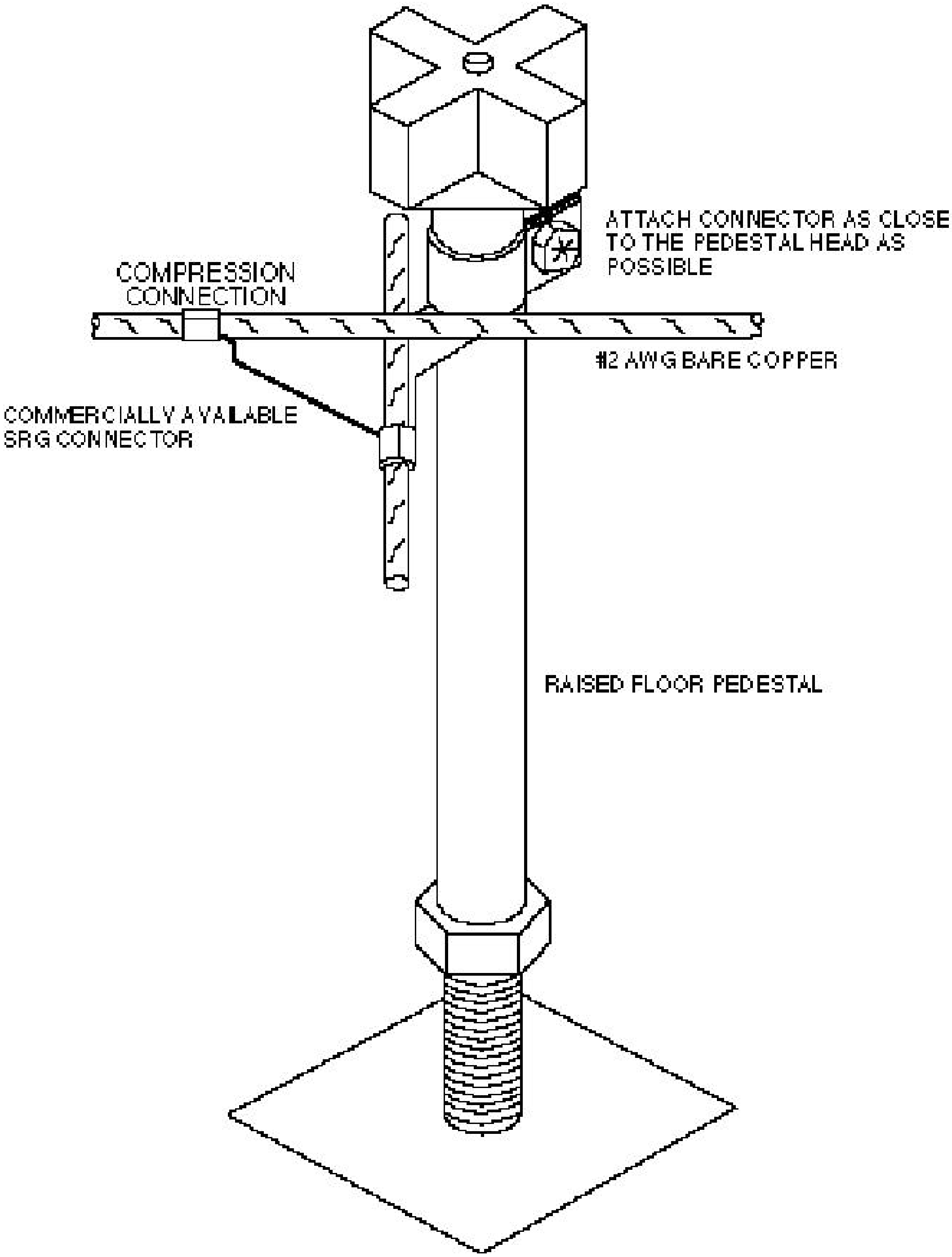


Figure 11-3: Supplemental Signal Reference Grid

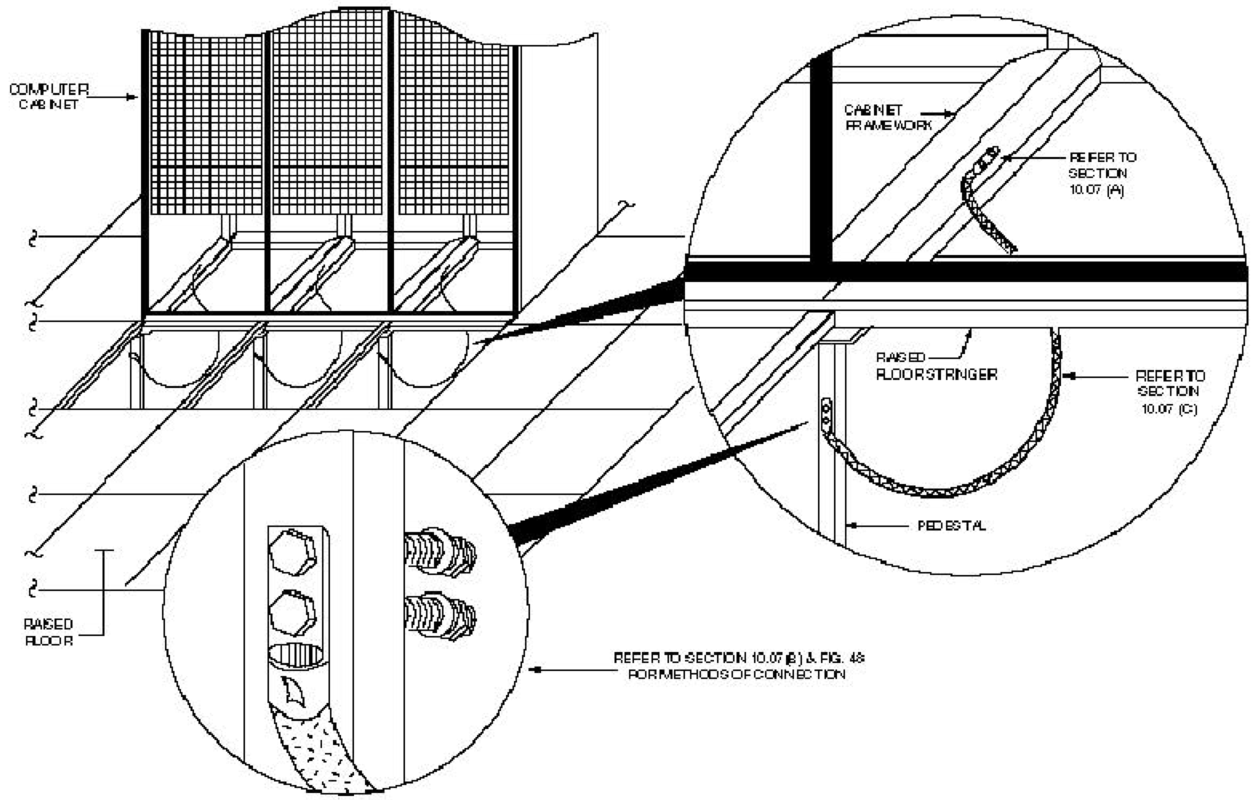


Figure 11-4: Typical Cabinet Grounding Arrangement

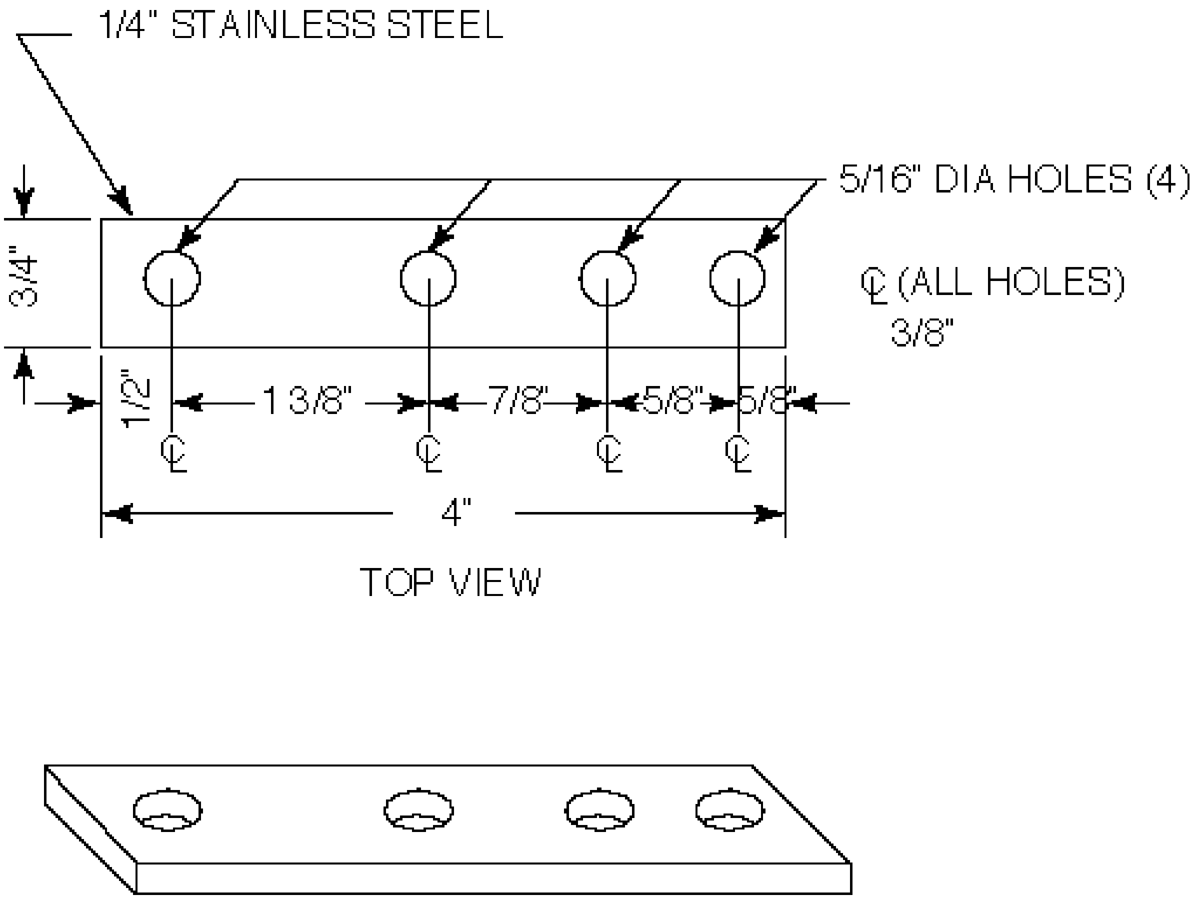
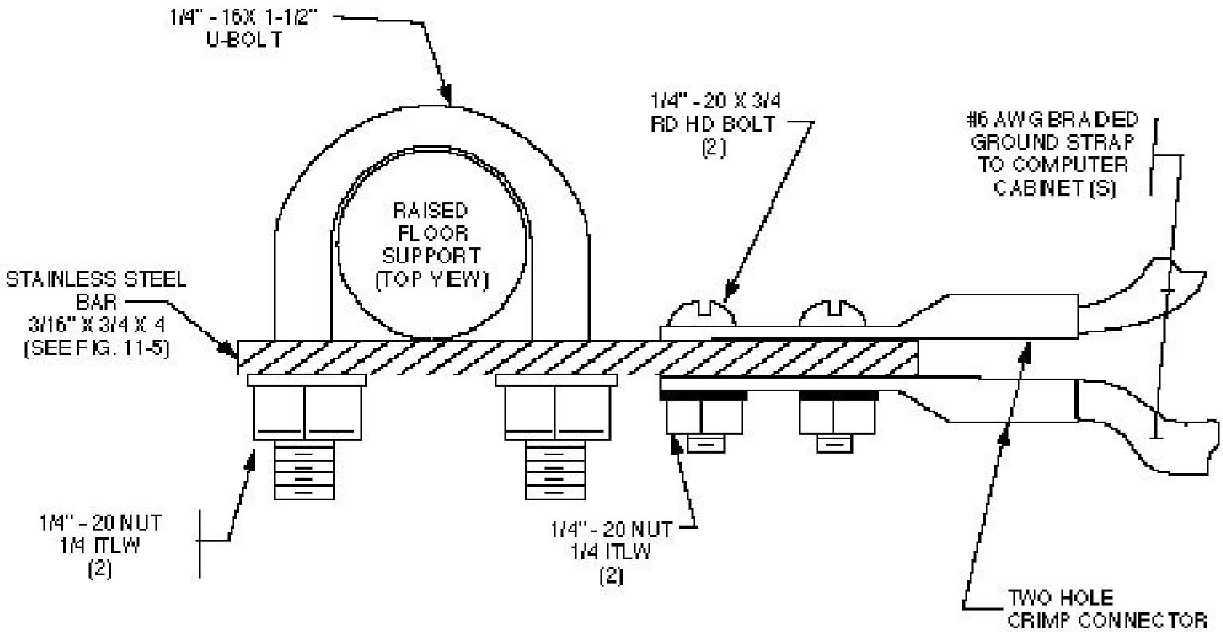


Figure 11-5: Computer Cabinet Grounding Bar



Notes:

1. A non -Oxidizing Agent Shall 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

AC	Alternating Current
ACEG or AC EG	Alternating Current Equipment Ground (green-wire ground)
ANSI	American National Standards Institute
AWG	American Wire Gauge
BCW	Bare Copper Wire
BDB	Battery Distribution Board / Bay (Primary Power Plant distribution)
BDFB	Battery Distribution Fuse Board
BFR	Bona Fide Request (special request process for Collocators)
BRI	Business Resources Incorporated (old terminology for the Real Estate Services department within U S WEST)
CDF	Combined Distribution Frame
CDO	Community Dial Office (small CO)
CEF	Cable Entrance Facility
CEV	Controlled Environmental Vault
CEC	Controlled Environmental Cabinet (half-buried 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
CO - GRD	Central Office Ground
COGB	Central Office Ground Bus / Bar (see also CO – GRD)
CORM	Clamp-On Resistance Meter
DC	Direct Current
DLC	Digital Loop Carrier
DMS	Digital Multiplex System (switching system made by Nortel)
EEE	Electronic Equipment Enclosure
ESD	Electrostatic Discharge

ESS	Electronic Switching System (see also SPCSS)
FOG	Foreign Object Ground
FRWK - GRD	Framework Ground
GEC	Ground Electrode Conductor
GPR	Ground Potential Rise
GPS	Global Positioning System
HSP	House Service Panel (Commercial AC Service Entrance)
HVAC	Heating, Ventilation, and Air-Conditioning
ICB	Integrated Collector Bar (DMS frame collector bar)
ICDF	InterConnection Distributing Frame (Collocator cross-connect bay[s] — see also SPOT)
IG	Isolated Ground (receptacles for computer rooms)
IGP / IGZ	Isolated Ground Zone / Plane
kcmil	the new designation for MCM
LRG	Logic Reference Ground (DMS Collector bar)
MCM	Thousand Circular Mills (old designation)
MDF	Main Distribution Frame
MGB	Main Ground Bus (in the Ground Window)
MGN	Multi-Grounded Neutral
MOV	Metal-Oxide Varistor (one type of TVSS device)
NEC	National Electrical Code
NESC	National Electrical Safety Code
NFPA	National Fire Protection Association
NRTL	National Recognized Testing Laboratory
OFC	Optical Fiber Cable
ONU	Optical Network Unit
OPGP or OPGPB	Office Principal Ground Point Bus (see also PGP)
OSHA	Occupational Safety and Health Act
OSP	Outside Plant
PBD	Power Board (Power Plant Distribution Bay — see also BDB)

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)
PGP or PGPB	Principal Ground Point Bus for non-CO applications
PIC	Plug-In Card / Circuit Pack
PVC	Polyvinyl Chloride (conduit / pipe)
RFI	Radio Frequency Interference
RGS	Ring Ground Systems
RHW	a type of approved manufactured cable (the insulation actually) for use in DC power and grounding circuits, typically with an insulation rating of 75 degrees C —the insulation is soft and rubber-like, but when ordered for U S WEST applications often comes with a cotton braid covering; and when the cable comes as RHW-LS, the insulation is rated for low smoke realease in a fire
RR - GRD	Relay Rack Ground
RSM	Remote Switch Modules
RSU	Remote Switch Units
RT	Remote Terminal
SME	Subject Matter Expert
SPCSS	Stored Program Control Switch System (see also ESS)
SPOT	Single Point of Termination (Collocator circuit cross-connect bay[s] — see also ICDF)
SRG	Signal Reference Grid
THHN and THWN	types of approved manufactured cable (the insulation actually) for use in AC circuits, with an insulation rating of 75 or 90 degrees C
TVSS	Transient Voltage Surge Suppression
UE	Universal Enclosure (half-buried vault)
UL	Underwriters Laboratory
XHHW	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 doesn’t need fiber wrapping at points of impingement with metal cable racking, etc.)

12.2 Glossary

ACEG(C) or AC EG

AC Equipment Ground Conductor, sometimes referred to as the green-wire ground.

Arrester

A protection device used on power lines to limit the line-to-ground surge voltage caused by lightning.

Bonding

The permanent joining of metallic parts to form an electrical conductive path which will assure electrical continuity and the capacity to conduct safely any current likely to be imposed.

Cable Entrance Facility (CEF)

A space at the central office where cables enter from the outside plant network. Electrical protection measures here protect the CO from the outside plant environment.

Carbon Blocks

A 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 TVSS devices use electronic components, like MOVs, or gas tube air gaps.)

Central Office Ground (CO GRD)

This 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)

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.

Earth Resistivity

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

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 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

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

Connected 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 system or circuit conductor that is intentionally grounded.

Example: The conductor usually referred to as the "grounded conductor" is the one identified as "the neutral" in AC circuits and "the return conductor" in DC circuits.

Grounding Conductor

A conductor used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or electrodes. Some examples of grounding conductors are as follows:

- 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 used to interconnect frames in transmission equipment.
- The grounding conductor used to interconnect the shield for telephone cables.

Grounding Electrode Conductor

The 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:

- The conductor that interconnects the insulated -48 volt return bus and the main ground bus in a digital SPCSS.
- In the AC entrance switch gear of a building, the conductor that interconnects the insulated neutral bus with the Office Principal Ground Point Bus (OPGPB) or the water pipe.
- In separately derived AC power sources such as step-down transformers, the conductor that interconnects the frame of the transformer to the nearest ground reference.

Ground Impedance

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

Sometimes referred to as a ground array. 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 to equalize potentials within the area covered.

Ground Potential Rise (GPR)

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 station protector, cable pairs may be subject to a ground potential rise.

Ground Window

A dimensional transition zone which is the interface between the building's integrated ground plane and a given isolated ground plane.

Heat Coil

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 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

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)

Voltage controlled currents induced in a telephone line by capacitive coupling from the electric field of a nearby power line.

Induction (Magnetic)

Currents induced in a telephone line by inductive coupling from the magnetic field of a nearby power line.

Insulating Joint

A splice in a cable sheath made so that continuity of the sheath, shield, metallic strength member and metallic moisture barriers is deliberately interrupted to prevent the flow of electrolytic currents (DC) that may cause corrosion.

Integrated Ground Plane

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

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. During external fault occurrences in the AC or DC power systems and when lightning current 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 Ground Bus (MGB)

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.

Multi-Grounded Neutral (MGN)

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

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 PGP(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 the AC entrance switchgear. Connect all main grounding conductors and grounding electrodes to the OPGPB. In the past, the principal ground point often was the main metallic water pipe in the building. Increased use of insulating couplings and nonmetallic water pipes in water systems now make water pipes, at worst, unreliable as grounding electrodes and, at best, supplementary 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
- Supplementary ground fields (as defined in Section 3.2.8)
- Structural steel ground grids
- Any combination of the above

Optical Fiber Cable

A communication cable containing optical fibers as the primary transmission medium. The cable may or may not contain metallic components. Strength members may also be non-metallic.

Protector

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

An enclosed channel designed expressly for holding wires, cables, or busbars, with additional functions as permitted in the NEC (see NEC 250-32 and the definitions in Section 100).

Radial Grounding

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.

Example: Figure 8-2 shows Simplified Examples of Serial and Radial Frame Grounding.

Reference Point 0

The point at which all grounds within a Central Office building are referenced to earth.

Separately Derived Power Supply

A power supply that has electrical isolation between its input and output current carrying members (see NEC Sections 250-5[d], 250-30, 100A; and Bellcore TR-NWT-000295).

Serial Grounding

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 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 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. The single point ground principle is used in the isolated ground planes of electronic analog and digital switching systems.

Single Point Ground (For 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 multi-grounded system.) Examples of single point grounded power supplies are:

- The 48 volt power source feeding isolated ground plane digital switching loads is grounded by a single connection from the insulated 48 volt return bus in the power plant 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 power supply is:
    - A -48 volt power source that feeds integrated ground plane electromechanical switching system loads. These loads are grounded at the power source (the -48 volt return bus in the power plant is not insulated) as well as at the loads where multiple connections to grounded frames are made along the length of the -48 volt return conductor.

Transient Voltage Surge Suppression (TVSS)

Transient Voltage Surge Suppression 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, TVSS devices 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. TVSS devices may use carbon filaments, gas tubes, MOVs or other solid state devices, or any combination of the above.

Vertical Equalizer

A low impedance conductor that interconnects buses on various floors of a building that require the same potential reference.

Vertical Riser

The main vertical grounding conductor used to obtain ground reference between the CO GRD BUS on each floor and the OPGPB in a building. The conductor shall 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.

CONTENTS

Chapter and Section **Page**

13. References

13.1 ANSI, IEEE and NFPA Documents

NFPA 70-1999 *National Electrical Code (NEC)*

ANSI/IEEE Std 81 *IEEE Guide for Measuring Earth Resistivity, Ground Impedance, and Earth Surface Potentials of a Ground System*, 1983 Issue

ANSI/IEEE 487 *IEEE Recommended Practice for the Protection of Wire-Line Communication Facilities Serving Electric Power Stations,* 1992 Issue

ANSI/NFPA 780 *Standard for the Installation of Lightning Protection Systems,* 1997 Edition

ANSI/EIA-222-D *Lightning Protection Code*

IEEE/ANSI C2 *National Electrical Safety Code*, 1997 Edition

13.2 Bellcore Documents

BR 802-010-100 *Use of a Clamp-On Resistance Meter,* Issue 1, December 1998

BR 876-310-100 *Electrical Protection of Communications Facilities Serving Power Stations,* Issue 3, July 1985

TR-NWT-000295 *Isolated Ground Planes: Definition And Application To Telephone Central Offices,* Issue 2, July 1992

13.3 Military Specifications

MIL-F-29046 [TD]

13.4 Other U S WEST Documents

PUB 77321 *Special High Voltage Protection,* Issue A, June 1998

PUB 77350 *Telecommunications Equipment Engineering, Installation And Removal Guidelines*, Issue G, April 1999

PUB 77368 *Customer Premises Environmental Specifications and Installation Guide,* Issue A, March 1998

PUB 77385 *Power Equipment and Engineering Standards,* Issue D, May 1999

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.

Ordering Information for Employees of U S WEST Inc.

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