

NOTICE

This is an interim release of the .pdf version of BSP 802-001-180MP.

This interim release is equipped with hyperlinks. These provide improved navigation within a document. Some basic information about using these hyperlinks was added to the page with the Abbreviated Table of Contents (2 pages from here).

This interim release also contains are some minor corrections:

1. The legend for Figure 5-1 was incorrect. It now reads:

- A Main AC Service Disconnect Panel
- B Neutral Bus
- C Grounding Electrode Conductor
- D PGP Bus Bar
- E #6 AWG Ground Ring
- F 5/8" x 8' Ground Rod

2. There were three incorrect references to figures in 5.5. They were:

- in 5.5.06 (1), the correct figure is 5-4
- in 5.5.06 (6), the correct figure is 5-5
- in 5.5.10 the correct figure is 5-6

3. A grammar error in the 2nd sentence 1.8.07, "... is not be met, ..." was corrected to read "... is not met, ...".

Grounding and Bonding Requirements
Telecommunications Equipment,
Power Systems,
Central Offices and Other Structures

List of Sub-sections

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Sub-section 1

Definitions, General Requirements, Material Requirements

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1.1 SCOPE

1.1.01 This Practice provides engineering, material, and installation requirements for protective grounding systems in structures containing network communications systems and other equipment.

1.1.02 This Sub-section contains information regarding the general applicability of the requirements in this Practice, definitions of terms used throughout this Practice, common material requirements and common installation requirements.

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1.2 GENERAL

1.2.01 The requirements in this Practice replace all associated grounding and bonding requirements in all previous Practices, Memorandums, Engineering Letters, Technical Publications, and other documents used by Nevada Bell, Pacific Bell and Southwestern Bell Telephone prior to the date of this Practice.

The list below contains the requirements documents that were most commonly used and now replaced by this Practice.

Note: The suffix "MP" on this Practice denotes that this is a merged practice. This suffix is now used in place of those (PT and SW) formerly used by the merged companies.

BSP 081-330-800SW	Cadweld Exothermic Ground Connections, Issue A, November, 1987
BSP 802-001-180	General Grounding Requirements in Central Offices, Radio Stations, and Other Structures
BSP 802-001-190	Equipment Ground Systems Material - General Equipment Requirements
BSP 802-001-191	Office Ground Electrodes - General Equipment Requirements and Engineering Information
BSP 802-001-192	Equipment Ground System, Central Offices - General Equipment Requirements and Engineering Information
BSP 802-001-193	Equipment Ground System, Central Offices - General Interface Requirements for DC Power Plants and Communication Systems
BSP 802-001-194	Equipment Ground System, Central Offices - General Interface Requirements, Manual Toll Relay Rack Ground System
BR 802-001-195	General Grounding Interface Requirements for Electronic Switching Systems and Power Plants
BSP 802-001-196	General Equipment Ground Requirements for Data Processing Computer System Installation
BSP 802-001-197	General Equipment Ground Requirements for Microwave Radio Main and Auxiliary Stations
BSP 802-001-198	General Equipment Ground Requirements for AC Service Distribution Systems in Communications Buildings
BSP 802-001-997SW	Protective Grounding Systems for Roof Mounted Antennas, Issue A, June, 1982
PBS-068-180PT	Grounding and Bonding Requirements - Telecommunications Equipment, Power Systems, Central Offices and Other Structures
TP 76300, Section H	Bonding and Grounding
TP 76400, Section 13	Bonding and Grounding
PBS-068-180PT	Grounding and Bonding Requirements, Telecommunications Equipment, Power Systems, Central Offices and Other Structures, Issue B, February 1995

1.2.02 Several documents listed above were the source of many of the requirements in this Practice. Several were also the source of grounding fundamentals used to develop requirements not originally contained in these documents.

1.2.03 This is the first issue of this Practice.

1.2.04 Requirements in this Practice will not cover every unique application that may be encountered. A grounding arrangement may be devised and used for a specific application based on design criteria provided in this Practice. This can be especially important when assessing the need for upgrades to an existing grounding arrangement.

1.2.05 Where applicable, the requirements in this Practice conform to or exceed the requirements in NFPA 70, the *National Electrical Code* (NEC). References to the NEC in this Practice are based on the 1996 edition.

1.3 DEFINITIONS

The following terms are used throughout this Practice. The terms marked with an asterisk (*) are consistent with the NEC and include the text from Article 100 of the Code. Several of the most common acronyms are included where appropriate.

Note: Table 1-1 is located at the end of this section on definitions. It contains a cross-reference between grounding and bonding terms used in this Practice and equivalent terms used by standards bodies, equipment vendors and others.

***Bonding**

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

Central Office Ground (CO GRD)

The grounding system within a structure, including the Office Principal Ground Point (OPGP), the Vertical Riser, horizontal equalizers, CO GRD bus bars on each floor, the connections to ac and dc power systems, and the connections to equipment and other objects. The CO GRD system is often referred to as a *tree* since, in multifloor applications, the vertical conductors resemble a trunk and the horizontal conductors resemble branches extending from the trunk. This system is designed to:

- (1) provide a fault current return path that permits effective operation of overcurrent protective devices
- (2) provide a low impedance reference to the building's principal ground point
- (3) allow an interchange of ground currents to effectively maintain equal potential in communication circuits

Central Office Ground Bus Bar

A bus bar that references the principal ground point through the Vertical Riser. At least one of these bus bars is provided on each floor to permit the grounding of frames and power supplies, as required.

Common Bonding Network (CBN)

A set of interconnected objects that has one or more connections to a ground reference. This network, created by a multitude of connections, helps to ensure that the objects are at essentially the same potential when fault current flows through them. Building steel, water pipes, vertical and horizontal equalizer conductors, metallic raceways, raised floor systems, equipment frames and other conductive objects form a common bonding network when bonded together by intentional and incidental connections.

This term is now used throughout this Practice in place of *integrated ground plane*.

DC System Grounding Conductor

The conductor used to connect one side of a dc power source to the site's grounding system

Example: In a -48 volt battery-type power plant serving central office equipment, the conductor between the positive (+) side of the plant and a point on the CO GRD system.

Driven Ground Electrode

For company locations, this means a driven ground rod. Other publications may use the term *made electrodes*, which includes plate, pipe, or other electrode designs that may not be approved for use at central offices and other company structures.

Equipment Ground (EG)

Deliberately engineered conductors in communication systems and ac and dc power distribution systems to provide electrical paths of sufficient capacity to permit protective devices (e.g. fuses, circuit breakers) to operate effectively and to equalize potential between equipment.

Framework Ground (FRWK GRD)

That portion of the equipment ground system that is furnished solely to provide ground continuity to frames, cabinets and metallic objects that do not receive a ground reference from another ground system. Relay Rack Ground (RR GRD) and alternating current equipment ground (ACEG) are the most common types of other ground systems.

***Ground (GRD, GND)**

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.

***Grounded**

Connected to the earth or to some conducting body that serves in place of the earth.

***Grounded Conductor**

A system or circuit conductor that is intentionally grounded.

Example: The conductor usually referred to as the *grounded conductor* is the *neutral* conductor in ac circuits and the *battery 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.

Example: The alternating current equipment ground (ACEG), also called the *green wire*, used to provide a fault current return path in ac power systems.

Example: The grounding conductors used to interconnect frames in transport equipment.

***Grounding Electrode Conductor (GEC)**

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.

Example: In the ac service entrance switchgear of a building, the conductor between the insulated neutral bus bar and the office principal ground point bus bar.

Grounding Electrode System

An arrangement of intentionally bonded objects that furnish reference to earth and consist of:

- (a) specifically designed metallic objects such as driven ground rods, well casings, or other approved electrodes
- (b) most buried metallic objects that enter any portion of a structure

Note: The Vertical Riser is considered to be an extension of the Grounding Electrode System

Ground Window (GW)

An imaginary, spherical area having a radius of 3 feet. This transition area contains the main ground bus (MGB), which is the physical interface between the building's common bonding network and isolated bonding network equipment. The Ground Window is the opening where grounding conductors serving isolated bonding network equipment see their last connection to the common bonding network.

Horizontal Equalizers

Conductors of relatively low impedance that interconnect:

- (a) Vertical Risers in a building that is of a size that requires more than one Vertical Riser
- (b) the CO GRD bus bar to equipment areas on the same floor
- (c) battery return bus bars in dc distribution systems for some electronic switching systems

Incidental Ground

An unplanned grounding connection. These ground paths exist within a building through contact between such items as structural steel, water piping, air ducts, conduits, superstructure, raceways, reinforcement rod, cable racks, and other conductive objects that are installed for purposes other than to provide ground paths.

Integrated Ground Plane (See Common Bonding Network)

Isolated Bonding Network (IBN)

A set of interconnected objects that is referenced to ground at a single point. This network is insulated from contact with any other conductive member not part of the same bonding network. With only one point of ground reference, the possibility that the equipment will be used as a conductive path for transient currents from exterior sources is greatly reduced.

This term is now used throughout this Practice in place of *isolated ground plane*.

Isolated Ground Plane (See Isolated Bonding Network)

Isolated Ground Zone (Same as Isolated Bonding Network)

Isolated Return Bar

This is a bus bar used when a power plant serves Isolated Bonding Network equipment but does not have its battery return bus bar insulated from the framework of the power plant. It consists of either a bus bar detail or a separate bus bar. When this is a bus bar detail, one end is mounted on an insulator and the other is bolted to the existing battery return bus bar. When it is a separate bus bar, both ends are mounted on insulators and at least one 750 kcmil conductor ties this isolated bar back to the battery return bus bar.

***Listed**

Equipment or materials included in a list published by an organization acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of listed equipment or materials, and whose listing states either that the equipment or material meets appropriate designated standards or has been tested and found suitable for use in a specified manner.

Main Ground Bus (MGB)

A bus bar located within the ground window that provides a physical means of connection between the CO GRD system and the isolated bonding network served by the ground window.

Office Principal Ground Point (OPGP)

A bus bar normally located near the ac entrance switchgear. It functions as:

- (a) the connection point for all main grounding conductors and earth electrodes
- (b) the point of origin for the Vertical Riser
- (c) if convenient, the CO GRD bus bar for the floor (typically the Basement) where it is located

***Premises Wiring (as applied to a System)**

That interior and exterior wiring, including power, lighting, control and signal circuit wiring together with all of its associated hardware, fittings, and wiring devices, both permanently and temporarily installed, which extends from the load end of the service drop or load end of the service lateral conductors, or source of a separately derived system to the outlet(s). Such wiring does not include wiring internal to appliances, fixtures, motors, controllers, motor control centers, and similar equipment.

***Raceway**

An enclosed channel designed expressly for holding wires, cables, or bus bars, with additional functions as permitted in the National Electrical Code (NEC).

Radial Grounding

A system is radially grounded when two or more sets of frames of the same system are grounded by a separate grounding conductor run between each set of frames and a common ground point.

Relay Rack Ground (RR GRD)

An early practice that used a bus bar at the top of a frame as both a battery return conductor and a means to ground the frame.

Ring Ground (for earth electrodes)

A buried conductor that forms a ring around a structure. The ring ground usually includes a series of driven ground rods bonded to the conductor.

Separately Derived Source

A power source that has no direct electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another system.

Note: This definition is similar to the NEC definition of *Separately Derived Systems*.

Example: A standby ac reserve arranged so that the neutral is switched.

Example: Power supplies with isolation between input and output such as most delta-wye transformers and some inverters and converters.

Serial Grounding

A system is serially grounded when a set of frames in the system is connected in series from its associated ground point. This term is sometimes used to describe an unacceptable practice that is also called *daisy chaining*. It exists when an equipment unit's grounding conductor is connected to the metalwork of another unit instead of an acceptable grounding conductor, such as a lineup's grounding conductor.

Single Point Ground

A method used to ground a circuit at only one physical point.

Solidly Grounded

A method of grounding either a power supply or a frame that uses a grounding conductor connection in which no additional impedance has been intentionally connected in series with the grounding path.

Stored Program Control Systems (SPCS)

Switching and other systems used in the communication network that are operated under control of internally stored instructions which a processor can execute. These systems are also referred to as *electronic*.

Vertical Riser (VR)

This conductor, also called the Vertical Equalizer, extends ground reference from the OPGP to one or more CO GRD bus bars.

Note: The portion of this conductor that is routed horizontally between the OPGP and the first connection to a CO GRD bus bar is also called the vertical riser.

Term Used in this Practice	Equivalent Terms
Battery Return (BR)	0 Volt Reference, -48 V Return, Battery Ground, DC Return, Power Return
Central Office Ground (CO GRD)	Building Grounding System, Central Office Protection, COG
CO Ground Bar	COG, COGB, FGW, Floor Ground Bar
Common Bonding Network (CBN)	Integrated Ground Plane, Integrated Ground System, Integrated Ground Zone
Ground	Earth
Grounding Conductor	Earthing Conductor, Protective Conductor
Grounding Electrode System	Earthing Network
Ground Window	SPC Window
Isolated Bonding Network (IBN)	Isolated Ground Plane, Isolated Ground System, Isolated Ground Zone
Logic Ground	Logic Return, Signal Ground
Main Ground Bus (MGB)	Single Point Ground, Single Point Connection (SPC)
Office Principal Ground Point (OPGP)	Building Principal Ground, Facility Ground, Master Ground Bar, Main Earthing Terminal, OPGPB, PGP Bus, Principal Ground Point, Reference Point 0, Zero Potential Reference Point
Vertical Equalizer	CO Ground Riser, Equipment Ground Riser, Vertical Riser

Table 1-1
Cross Reference of Grounding and Bonding Terms

1.4 GROUND RODS

1.4.01 Ground rods shall be either solid stainless steel or copper clad steel. Stainless steel rods shall be of A.I.S.I grade 302 or 304 alloy. Copper clad rods shall be manufactured by a process that applies molten copper to a steel core. Steel rods, bare or galvanized, or rods covered with copper or stainless steel tubing, or hollow core pipes of any type shall not be used as driven ground rods.

1.4.02 The minimum diameter for ground rods is 5/8", the minimum length is 8 feet. These dimensions equal or exceed the requirements in the NEC, section 250-83.

1.4.03 Copper clad rods or stainless steel rods may be used indiscriminately where corrosion of buried objects is not a significant factor.

1.5 CONDUCTORS

1.5.01 Except where allowed per standard drawings, grounding conductors shall not be used to carry normal load currents.

Note: The Relay Rack Ground system uses a single conductor for both battery return and framework ground. Installation of this system has been discontinued, but remnants of these systems still exist. Requirements are in Sub-section 3.

A. Exterior Buried Conductors

1.5.02 All direct-buried conductors shall be a minimum #2 AWG uninsulated solid tinned or untinned copper, using soft (annealed) or semi-hard drawn commercial grade copper. They shall not be:

- (a) insulated
- (b) direct-buried stranded copper conductors
- (c) placed in conduit
- (d) aluminum conductors of any type

NOTE: Items (a) and (b) are acceptable for existing locations if installed prior to 1993 provided all other requirements for the earth electrode system are met. Items (a) and (b) are always acceptable for use in cathodic protection systems.

B. Equipment Grounding Conductors

1.5.03 Conductors used in an equipment grounding system, including CO GRD system extensions to frames, cabinets and other units, shall be of the same cable type(s) approved for power system conductors. Grounding conductors, whether stranded or solid, shall be tinned copper. Aluminum conductors shall not be used.

1.5.04 A conductor used for a vertical equalizer may be type THW or other if its insulation is rated UL 94V-0 or UL 94V-1.

1.5.05 Other types of equipment grounding conductors may be used if they are in accordance with system specifications for equipment approved for use.

C. Alternating Current Equipment Ground (ACEG) Conductor

1.5.06 Conductors that are part of the ACEG system shall be copper, and should be insulated. Insulation shall be the same as that of phase conductors and shall have an insulation temperature rating at least equal to that of the phase conductors. When armored cable is used, the ACEG conductor shall be a separate conductor, and shall not be the sheath continuity strand.

1.5.07 Insulation for the ACEG conductor shall be green or green with one or more yellow stripes, or the conductor shall be uninsulated (bare). For ACEG conductors larger than #6 AWG, insulation of some other color may be used if the insulation is painted or otherwise colored green, or is removed at every point of access along its entire length.

1.5.08 Connectors furnished as part of electrical equipment may be used to terminate ACEG conductors. Otherwise, connectors specified in 1.6 shall be used.

D. Grounding Conductors Within Equipment Frames, Cabinets & Enclosures

1.5.09 A grounding conductor located within an equipment bay shall be a copper bus bar, ribbon, or a solid or stranded copper conductor. It may be insulated or uninsulated and while a tinned surface is preferred, it may be unplated.

1.5.10 A bay's framework should not be used in place of a dedicated grounding conductor to extend CO ground reference to any point within the bay. Except for early vintage equipment, the frame or cabinet metalwork should not be in contact with any current-carrying conductor.

E. Grounding Conductor Color

1.5.11 There are two categories of grounding conductors used in this Practice that must or may use green insulation; those associated with ac power systems and certain radio system grounding conductors.

1.5.12 Insulation on grounding conductors used in ac power systems shall either be green or green with one or more yellow stripes. The most common of these are:

- (a) equipment grounding conductors run with feeder and branch circuit conductors
- (b) grounding electrode conductors from house service panels and the sources of separately derived systems
- (c) main and equipment bonding conductors

Note: When these conductors are larger than #6 AWG, they may be identified with a suitable means of green marking (tape, paint, etc.).

1.5.13 With two exceptions, the insulation of CO GRD conductors shall be gray. The first exception is when an equipment vendor uses a color code on conductors considered within their equipment system (their "black box"). The other exception is for conductors that are part of the interior ring ground system at a radio site or a radio room in some other structure, which may be green.

1.6 CONNECTORS & CONDUIT BONDING DEVICES

A. Thermal Welding

- 1.6.01 The primary method of thermal welding described in this Sub-section is exothermic welding. Any equivalent method of molecular welding similarly utilizing brass or copper to form the bond may also be used.
- 1.6.02 Two brand names: *Cadweld* and *Thermoweld* are often used in place of the generic term *exothermic weld*. The generic term is used throughout this Practice.
- 1.6.03 Exothermic welds should be used for all buried connections and for connections to building steel. Where practical, exothermic welds should also be used for above ground terminations on the exterior of the building.
- 1.6.04 Within buildings, exothermic welding may be used at water pipes, connection of the CO GRD riser to CO GRD bus bars and bonds to building steel. Other applications may also be practical, such as connection to the peripheral ground ring in microwave stations and elsewhere.

Note: In occupied areas within a building, the use of exothermic welds should be restricted to those methods that use "smokeless" or "low smoke emitting" processes, such as the EXOLON[®] process from Erico Products, Inc.

- 1.6.05 Exothermic welding shall not be used for connections to thin wall pipe or tubing (.035 inch wall or less).

B. Clamp Type Pipe Connectors and Conduit Bonding Devices

- 1.6.06 For terminations on pipes, grounding clamps should be used when it is not practical to use exothermic welds or threaded type grounding hubs or bushings. When used, clamps, hubs, bushings or other bonding devices shall be listed for their intended use by a nationally recognized testing laboratory (NRTL). For clamps, the heavy duty type using bronze saddles are preferred.

Note: The bonding conductor for a conduit containing a single grounding conductor may also be attached to the conduit by drilling the conduit and using a crimp type connector fastened to the conduit.

C. Crimp Type Bolted Tongue Connectors

- 1.6.07 Crimp (compression) type bolted tongue connectors shall be used to terminate stranded grounding conductors. The connectors shall be tin plated copper, may be either short barrel or long barrel, and shall be listed for their intended use by an NRTL.

Note: Tin plated aluminum connectors installed prior to the date of this Practice or connectors that are part of an approved product are acceptable and need not be replaced.

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1.6.08 Crimp type connectors used on solid conductors must be listed by an NRTL for use on solid conductors, and must be crimped with the dies specified by the manufacturer of the connector.

1.6.09 Two hole bolted tongue connectors shall be used except where single hole connectors are specified in the standard equipment drawing. If a single hole connector is specified, and the surface is not prepared by cleaning and the application of an anti-oxidant compound, the securing hardware shall include an external tooth type lockwasher (starwasher) placed between the connector and the surface to which the connector is secured.

D. Pressure Type (Mechanical) Connectors

1.6.10 Some grounding conductor termination points preclude the use of exothermic welds or crimp type connectors. This may be due to physical constraints or because the mechanical connector or terminal is a component of a listed or Company-approved product, such as the ACEG bus in an ac distribution panel. At these locations, pressure type (mechanical) connectors or terminals may be used to terminate grounding conductors. All connectors and terminals shall be listed or recognized for their intended use by an NRTL.

E. Parallel Cable Connectors

1.6.11 Crimp type parallel connectors (C-taps or H-taps) shall be used to join one (or more) branch conductors to a main conductor.

1.6.12 While an in-line type crimp connector is preferred, a crimp type parallel connector may also be used to splice grounding conductors. Connectors shall be listed for their intended use by an NRTL.

1.6.13 Pressure type (mechanical) parallel connectors may be used where crimp type parallel connectors cannot be used due to physical constraints. These connectors shall be listed for their intended use by an NRTL.

F. Miscellaneous Commercial Connectors

1.6.14 A variety of pressure type connectors are commercially available. Where exothermic welds or crimp connectors cannot be used due to physical constraints, and the design of the commercial connectors make them desirable for a specific application, they may be used for grounding connections.

G. Solder Type Connectors

1.6.15 Connection methods that depend entirely on solder shall not be used for grounding or bonding connections.

Note: A bare, solid #6 AWG tinned copper conductor has been used for many years as a bay ground lead. Although discontinued and replaced by the stranded bay ground lead (PBSD-ED-6501), many are still in use. Grounding conductors are wrapped around the #6 AWG before they are soldered to it. Therefore, this method does not rely entirely on solder, and is acceptable.

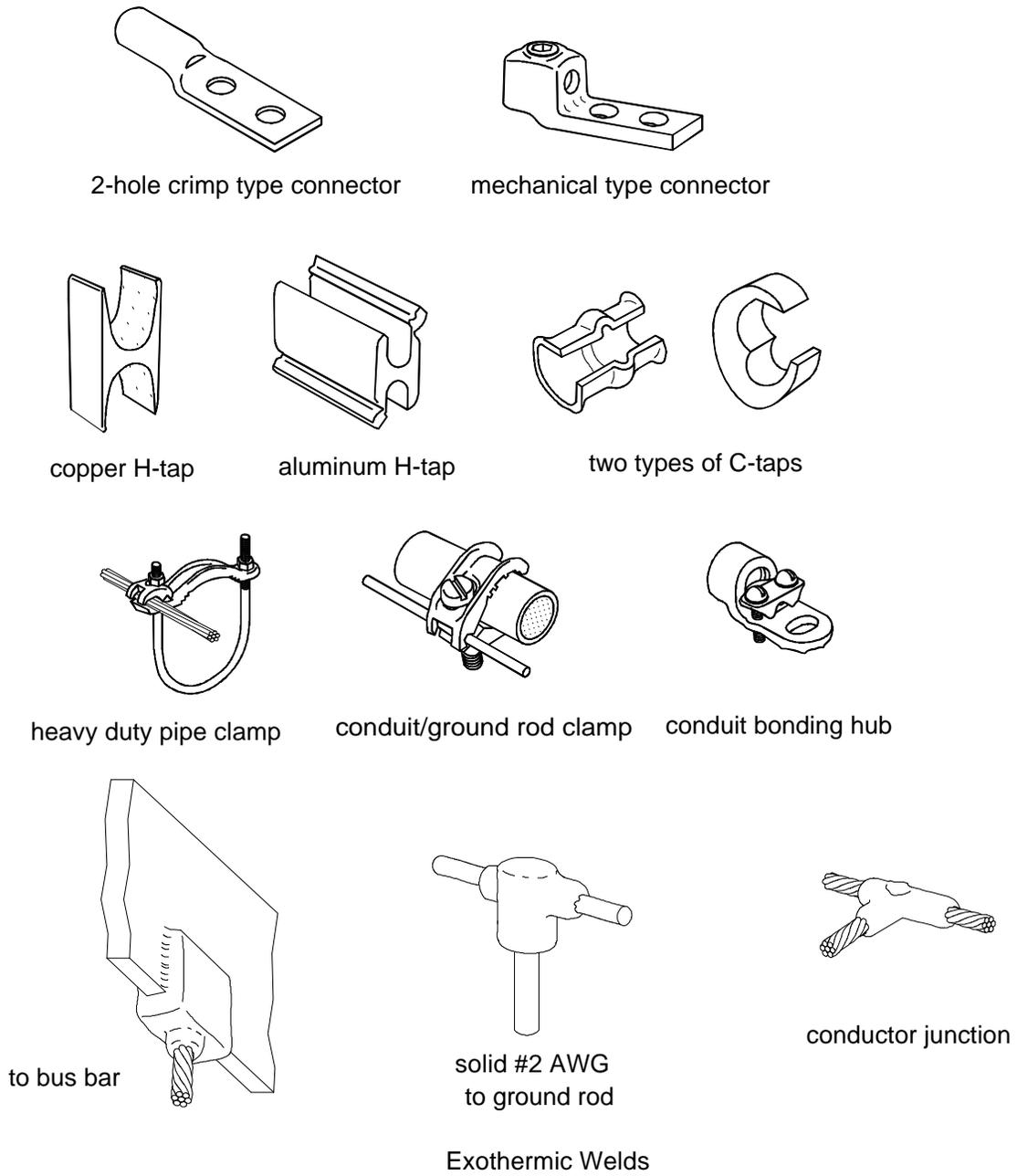


Figure 1-1
Typical Material and Methods Used to Terminate Conductors

1.7 Bus Bars

- 1.7.01 Bus bars shall be copper. Ground bars furnished as part of a listed assembly or an assembly that has been approved for use may be used without regard to material.
- 1.7.02 Bus bars shall be sized per this Practice. When bus bars specified in standard drawings are different in size from those in this Practice, the dimensions specified in the standard drawing shall be used.

1.8 INSTALLATION REQUIREMENTS

- 1.8.01 All CO GRD system conductors shall be routed on and secured to:
- (a) a cable rack or cable bracket containing only grounding conductors
 - (b) the side or bottom of ironwork details or cable rack containing other cable types
 - (c) the surface of ceilings, columns, or permanent walls
- Note 1: Grounding conductors may be placed on the same cable brackets used to support other cables if the grounding conductors are secured to the surface of the bracket opposite that used to secure the other cables.
- Note 2: Some equipment manufacturers allow grounding conductors routed within their equipment systems to be routed with other conductors, typically dc power conductors. When a system is approved for use, the routing requirements of the equipment vendor may apply.
- 1.8.02 When grounding conductors are routed on the side or bottom of cable racks or other ironwork, or the surface of ceilings, columns or walls, they shall be secured at an interval of approximately 12 inches. When cable brackets are used for support, they shall be placed at an interval of approximately 18 inches.
- Note: See 2.5 in Sub-section 2 for support of vertical equalizer conductors.
- 1.8.03 The exterior surface of conduits or raceways containing ac power conductors shall not be used to support CO GRD system conductors.
- 1.8.04 Unless expressly required by local code, CO GRD conductors shall not be run in metallic conduit. If a CO GRD system conductor is placed in metallic conduit or raceway, it shall be bonded to the conduit or raceway at each end with a minimum #6 AWG conductor. While non-metallic sleeves are preferred when a CO GRD conductor penetrates a floor, metal sleeves may be used if they are bonded to the conductor at each end.
- 1.8.05 When metal clamps are used to support or secure CO GRD conductors, they should not completely encircle the conductor. The metallic continuity should be interrupted by non-metallic hardware, a cable tie or sewing twine.

1.8.06 The phrase *completely encircle* applies to ferrous metal clamps, conduits and raceways. Openings formed by interconnected cable racks, auxiliary framing, threaded rods or similar material do not require bonds if the length of the encircling arrangement or object is less than three times its diameter. This means that bonds are not required between CO GRD conductors and:

- (a) a metal cable hole cover or combing when a CO GRD conductor is routed through a cable hole instead of a floor sleeve
- (b) a cable rack when a conductor on the rack passes through the opening formed by the cable rack's stringers and straps
- (c) sheet metal studs when a CO GRD conductor penetrates a wall

1.8.07 Bends in CO GRD system conductors should be made with a minimum radius of one foot. If the one foot radius objective is not met, a smaller radius is acceptable based on the following conditions:

- (a) For the #2 AWG peripheral conductor at a radio site, the minimum bend radius shall be 6 inches.
- (b) For all other conductors, the minimum bend radius shall not be less than 5 times the finished diameter of the cable. Table 1-2 provides the minimum bending radius, rounded up to the nearest inch for the most common grounding conductor sizes, based on the approximate diameter for rubber-covered wire (type RH, RHH, RHW).

Grounding Conductor Size	Minimum Bending Radius (inches)
6 AWG	2
4 AWG	3
2 AWG	3
1/0 AWG	4
4/0 AWG	4
750 kcmil	7

Table 1-2

Minimum Bending Radius for Grounding Conductors

1.8.08 Except for hatch plate bonding conductors described in Sub-section 6 of this Practice, the direction of a grounding conductor's bend (e.g. towards CO GRD) is not restricted. The direction of the bend should be made for ease of installation and to maintain an acceptable bending radius.

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1.8.09 Unplated metallic surfaces shall be prepared to a bare, bright finish before joining. A corrosion preventive compound such as NO-OX-ID "A" shall be applied to the unplated surface.

1.8.10 Bolts, nuts, screws, threaded pressure devices, raceway fittings and every ground system connecting or securing device shall be free from corrosion, properly assembled, correctly tightened and accessible for inspection.

1.8.11 At OPGP, CO GRD and MGB bus bars, the end of every CO GRD system conductor whose far end termination is not readily apparent shall be equipped with a destination tag identifying the termination point of the opposite end of the conductor. These tags (145C or equivalent) are also allowed to be placed at other points in the CO GRD system.

1.8.12 Certain CO GRD system conductors shall be equipped with a brass tag with the phrase: **DO NOT DISCONNECT** stenciled on it or stamped into it. The letters shall be 3/16" minimum. The following conductors shall always be equipped with this tag:

- (a) conductors from earth electrodes
- (b) grounding conductors at a water pipe
- (c) grounding electrode conductors from a house service panel or other source of a separately derived system
- (d) horizontal equalizer connections at an OPGP or CO GRD bus bar
- (e) vertical equalizer connections at an OPGP or CO GRD bus bar
- (f) both ends of a dc power plant system grounding conductor
- (g) both ends of a grounding conductor between a protector frame and an OPGP or CO GRD bus bar
- (h) the conductor serving a cable entrance facility

Note: The other side of a DO NOT DISCONNECT tag may be used as a destination tag.

1.8.13 If an installation requirement in another Sub-section of this Practice conflicts with the preceding installation requirements, the requirement in the Sub-section shall apply.

1.9 REFERENCE MATERIAL

A. Acronyms

ABC	Area Bus Center
ac	Alternating Current
ACEG	Alternating Current Equipment Ground
AG/EEE	Above Ground Electronic Equipment Enclosure
AWG	American Wire Gauge
BDB	Battery Distribution Board
BDCBB	Battery Distribution Circuit Breaker Board
BDFB	Battery Distribution Fuse Board
BG/EEE	Below Ground Electronic Equipment Enclosure
BSP	Bell System/Service Practice
CBN	Common Bonding Network
CDF	Combined Distributing Frame
CEF	Cable Entrance Facility
CO	Central Office
CO GRD	Central Office Ground
CRF	Cable Rearrangement Facility
dc	Direct Current
EEE	Electronic Equipment Enclosure
EG	Equipment Ground
EMT	Electrical Metallic Tubing
EQPT	Equipment
GEC	Grounding Electrode Conductor
GRD	Ground
HSP	House Service Panel
IBN	Isolated Bonding Network
IDF	Intermediate Distributing Frame
IMC	Intermediate Metal Conduit
kcmil	1,000 Circular Mils
KO	Knock Out
LPCDF	Low Profile Combined Distributing Frame
MCM	1,000 Circular Mils (old term; see kcmil)
MDF	Main Distributing Frame
MGB	Main Ground Bus
MTCE	Maintenance
NEC	National Electrical Code
NFPA	National Fire Protection Association
NRTL	Nationally Recognized Testing Laboratory
OPGP	Office Principal Ground Point

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PBD Power Board
PBS Pacific Bell Standards
PBSD Pacific Bell Standard Drawing
PCF Power Control and Fuse Distribution
PD Power Distribution
PDC Power Distribution and Control
PDU Power Distribution Unit
PGP Principal Ground Point
PRTD Power Ringing and Tone Distributing

RR GRD Relay Rack Ground

SBGL Stranded Bay Ground Lead
SLC Subscriber Loop Carrier
SPCS Stored Program Controlled System

UL Underwriters Laboratories

VR Vertical Riser

B. Other Documents

The documents listed below contain a wide variety of information on the subject of grounding. The first group, labeled *Public Domain Documents*, should be readily available to anyone. The second group *Operating Company Documents*, contains documents that may not be available to non-employees because of proprietary information agreements.

Public Domain Documents

ANSI/IEEE Std 142-1991 IEEE Recommended Practice for Grounding of Industrial and Commercial Power Systems

FIPS PUB 94 Federal Information Processing Standards - Guideline on Electrical Power for Automated Data Processing Installations

The IAEI Soares Book on Grounding (International Association of Electrical Inspectors)

NFPA 70 National Electrical Code
NFPA 75 Standard for Protection of Electronic Computer/Data Processing Equipment
NFPA 780 Lightning Protection Code

Section 802 Rural Electrification Administration (REA) Electrical Protection Grounding Fundamentals

TR-NWT-000295 Isolated Ground Planes - Definition and Application to Telephone Central Offices (Bellcore)

TR-NWT-001089 Electromagnetic Compatibility and Electrical Safety Generic Criteria for Network Telecommunication Equipment (Bellcore)

Operating Company Documents

Grounding and Protection Practices

PBS-005-300PT	Electrostatic Discharge Control
BSP 760-150-155	Building Planning for Operations Support Systems
BSP 760-400-510	Building Electrical Systems Grounding
BSP 790-100-660	AC Power for Telecommunication Equipment
BSP 876-000-000	Index, Electrical Protection and Bonding
BSP 876-100-100	Principles of Electrical Protection - Engineering Considerations
BSP 876-101-130	Electrical Protection Grounding
BSP 876-200-100	Electrical Protection - Central Offices
BSP 876-210-100	Electrical Protection of Radio Stations
BSP 876-300-100	Electrical Protection at the Customer Premises
BSP 876-700-100	Measurements of Ground
BSP 876-701-100	Earth Resistivity Measurements

Northern Telecom Inc. Practices

NTP 297-1001-156	DMS-100 Family Power Distribution and Grounding Guide
NTP 297-2271-156	TOPS-04 Power and Grounding Guide
NTP 297-2291-156	TOPS-MPX Power and Grounding Guide

Equipment Drawings

ED-1A200-11	No. 1 ESS Power Feeders and Grounding Methods
ED-1B053-10	TSPS Power Feeders and Grounding Methods
ED-2H109-10	No. 2 & 2B ESS Typical Grounding Arrangements
ED-3C014-51	Method of Grounding Unequal Flange Duct Type Frames
ED-3H150-10	3ESS Grounding Methods and Requirements
ED-30781-10	SXS Power Feeders and Grounding Methods
ED-4A081-10	4ESS Switching Equipment Central Office Grounding
ED-5D022-11	5ESS Switching Equipment Grounding Methods
ED-6C005-70	COSMIC I and II Grounding
ED-6C145-30	COSMIC Framework Grounding, AC Distribution, Lighting
ED-62545-11	Grounding Duct Type Bays Not Equipped With Ground Bars
ED-65358-01	Relay Rack Framework Grounding -PBX and SXS Systems
ED-68918-12	No. 4A Toll ETS
ED-71146-01	TTY SWBDs, TLG Test Boards, TLG Service Boards
ED-90026-01	MDF & CDF Ground Bus Bar Connections
ED-90093-01	Misc Frames & Racks
ED-90276-01	Protector Frame
ED-90484-01	Relay Rack
ED-91210-51	Relay Rack-Angel Type
ED-92465-01	Relay Rack Framework
ED-92971-70	Framework Ground for Bulb Angle or Channel Relay Racks
ED-95176-70	Fuse Bay-Combination Panel
ED-97729-10	Protective Grounding Systems for Central Office Equipment
ED-97915-01	Guidelines, Computer System Raised Floor Systems
PBSD-ED-6501	Stranded Bay Ground Lead

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Grounding Systems Schematic Drawings

SD-66197-01 PBX Systems
SD-80850-01 J Carrier
SD-80852-01 K Carrier
SD-81094-02 TD-2 Radio
SD-81366-01 TJ Radio
SD-81384-01 TH Radio
SD-81782-01 TH Radio
SD-81805-01 TD-3 and TH-3 Radio
SD-98144-01 TL Radio
ES-223264 Operating & Terminal Room-Desks & Cabinets
ES-223291 Toll SWBDs & Toll Test Boards

Power Distribution Systems Schematic Drawings

SD-68610-01 Electronic Translator System
SD-70676-01 AC & DC, TTY SWBDs
SD-80426-01 Toll SWBD No. 3, 3B, 3C Toll Tandem SWBD No. 3 (A&M)
SD-80539-01 Teletypewriter SWBD No. 1
SD-80586-01 3A Teletype SWBDs
SD-80720-02 350A, 355A, SXS No. 1, 700 Type PBX
SD-80728-01 SXS No. 1
SD-80783-01 Toll Switching No. 4
SD-80909-01 Crossbar No. 1, Crossbar Tandem
SD-81063-02 No. 5 Crossbar
SD-81111-01 TD Radio
SD-81116-01 Toll Switching System No. A4A
SD-81142-01 Toll Switching System No. 3CL
SD-81189-01 Inter Toll Trunk Concentrating System
SD-81197-01 Toll Switching System No. 4A & 4M
SD-81228-01 Broadband Carrier System
SD-81460-01 E and V Repeaters
SD-81770-01 O, N1, N2, N3 Carrier System
SD-81767-01 TD-3 and TH-3 Radio (A&M)
SD-81950-01 TD-3 and TH-3 Radio-Long Haul
SD-81977-01 TD-3 and TH-3 Radio-Medium Haul
SD-1A148-01 No. 1 ESS, Typical
SD-1A213-01 No. 1 and No. 2 ESS AC Distribution
SD-1B043-01 TSPS
SD-2H083-01 No. 2 ESS and AIS DC Distribution
SD-2H084-01 No. 2 ESS DC Distribution

C. Conductor Information

Size	Area Cir. Mils	Area in. ²	Ohms/kft.
14 AWG	4110	0.0032	3.1400
12 AWG	6530	0.0051	1.9800
10 AWG	10380	0.0082	1.2400
8 AWG	16510	0.0130	0.7780
6 AWG	26240	0.0206	0.4910
4 AWG	41740	0.0328	0.3080
3 AWG	52620	0.0413	0.2450
2 AWG	66360	0.0521	0.1940
1 AWG	83690	0.0657	0.1540
1/0 AWG	105600	0.0829	0.1220
2/0 AWG	133100	0.1045	0.0967
3/0 AWG	167800	0.1318	0.0766
4/0 AWG	211600	0.1662	0.0608
250 AWG	250000	0.1964	0.0515
300 AWG	300000	0.2356	0.0429
350 kcmil	350000	0.2749	0.0367
400 kcmil	400000	0.3142	0.0321
500 kcmil	500000	0.3927	0.0258
600 kcmil	600000	0.4712	0.0214
750 kcmil	750000	0.5891	0.0171

**Table 1-3
Properties of Stranded Copper Conductors**

Note: DC Resistance is for bare conductors at 75 degrees C

Conduit Size	Wall Area, in. ²		DC Resistance per kft.		
	EMT	*Rigid	EMT	Rigid Steel	Rigid Alum.
1/2"	0.084	0.254	.9700	.3200	.0800
3/4"	0.127	0.337	.6400	.2420	.0605
1"	0.188	0.500	.4500	.1540	.0385
1 1/2"	0.322	0.790	.2530	.1030	.0258
2"	0.409	1.080	.1990	.0790	.0198
2 1/2"	1.236	1.710	.0659	.0476	.0119
3"	1.518	2.250	.0536	.0352	.0088
4"	2.256	3.180	.0362	.0239	.0060

Table 1-4

Properties of Steel and Aluminum Conduit

* Rigid steel and aluminum conduit have equivalent cross-sectional areas

Sub-section 2

Office Ground Electrodes, Vertical and Horizontal Equalizers, AC Service and Distribution System

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2.1 SCOPE

2.1.01 This Sub-section provides requirements for earth electrode systems for structures leased or owned by the Company. Also provided are requirements for the Central Office Ground (CO GRD) system and the grounding of ac service and distribution systems. The requirements supplement information in the 876- series Protection Practices, the 760- series Electrical System Practices and the requirements in the National Electrical Code (NEC).

Note: Sub-section 5 provides requirements for earth electrode systems and ac service grounding for electronic equipment enclosures (EEEs) as well as other requirements specific to such installations. Sub-section 6 contains additional requirements for earth electrodes and bonds to building components for radio sites and structures.

2.2 EARTH ELECTRODES

A. Public and Private Water Systems

2.2.01 In accordance with NEC Article 250-81, a metallic underground water piping system, either private or public, shall always be used as a grounding electrode where such a system is available.

2.2.02 To qualify as an earth electrode, the water pipe must be an electrically continuous piping system. The NEC requires that the buried portion of the system shall be not less than 10 feet. For Company applications, it is preferred that the buried piping is electrically continuous for at least 40 feet.

2.2.03 When a water meter is located in the structure, the water pipe on the street side of the meter is used as the point of connection if allowed by the water utility. If a connection on the street side is not possible, and if allowed by the water utility, the pipe on the building side of the meter may be used when a bond is provided around the meter.

2.2.04 If allowed, the bond around a water meter shall be the same size as the grounding electrode conductor. See Table 2-2.

2.2.05 When an internal metallic water pipe system exists, the water pipe must be bonded to the office principal ground point (OPGP) bus bar whether or not the water pipe is used as an earth electrode.

2.2.06 Per the NEC, a supplemental earth electrode is always required in addition to the metallic water pipe system. When a main water pipe is non-metallic, the supplemental earth electrode may serve as the grounding electrode system.

Note: Earth electrode systems installed per in 2.2 C. satisfy the requirements in the NEC.

B. Water Well Metallic Casing

2.2.07 Where public water systems do not exist and a water supply is required within a structure, a drilled well with metallic casing and electrically continuous piping may be provided. The well may be located on the property outside the structure or beneath the structure. While the NEC states that 10 feet of combined pipe and casing exposed to earth is an adequate electrode, a well casing that penetrates to a depth of at least 40 feet is preferred.

2.2.08 In special circumstances, it may be economical to install well casing and pipe as a supplementary ground system rather than a driven ground system. This may apply in areas where gravel or other earth conditions make effective grounding by means of driven rods impractical or where a driven rod system at an existing structure is economically unfeasible.

2.2.09 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 purposes only, unless special cost considerations are a factor.

C. Driven Ground Electrodes

2.2.10 A driven ground rod system may consist of from two to any number of rods. The preferred arrangement is one that forms a ring around the structure. This design helps equalize potential in the area of the structure.

2.2.11 The construction methods used in a building determines the recommended design for driven ground rod systems. The basic types of building construction used are described below and appear in Table 2-1:

- (a) building with electrical continuity through vertical and horizontal structural steel
- (b) building with electrical continuity through vertical column steel only
- (c) building without electrical continuity through vertical column steel

Note: Continuity may consist of steel sections riveted, bolted or welded to form vertical and horizontal paths or it may consist of welded or wirewrapped reinforcing bars.

2.2.12 The components of driven ground systems and their recommended application to the basic types of building construction are shown in Table 2-1 and Figures 2-1 and 2-2. In Table 2-1, an "X" in a column means that the associated component is always required to meet the minimum recommended configuration for a given construction method. An "O" means that use of the component is optional.

Driven Ground System Component	Construction Method			Note
	(a)	(b)	(c)	
#2 AWG buried perimeter ring ground	X	X	X	1
#2 AWG buried between rows of columns	X	X	O	2
#2 AWG buried bond to all perimeter columns	X	X		
#2 AWG buried bond to all interior columns	X	X		
#2 AWG grid bonded to top of all columns		X		3
5/8" x 8' ground rod at every perimeter column	X	X		
5/8" x 8' ground rod at every interior column	O	O		
5/8" x 8' ground rod at approx. 15-ft. interval			X	

Table 2-1

Driven Ground System Components Used in Various Types of Building Construction

Note 1: For buildings with basements, the perimeter ring should be placed within the outer walls below the concrete slab. For buildings without basements, the ring should be placed outside the perimeter of the outer walls.

Note 2: This conductor is placed between rows of columns (in one direction only) and is connected to opposite sides of the perimeter ground ring

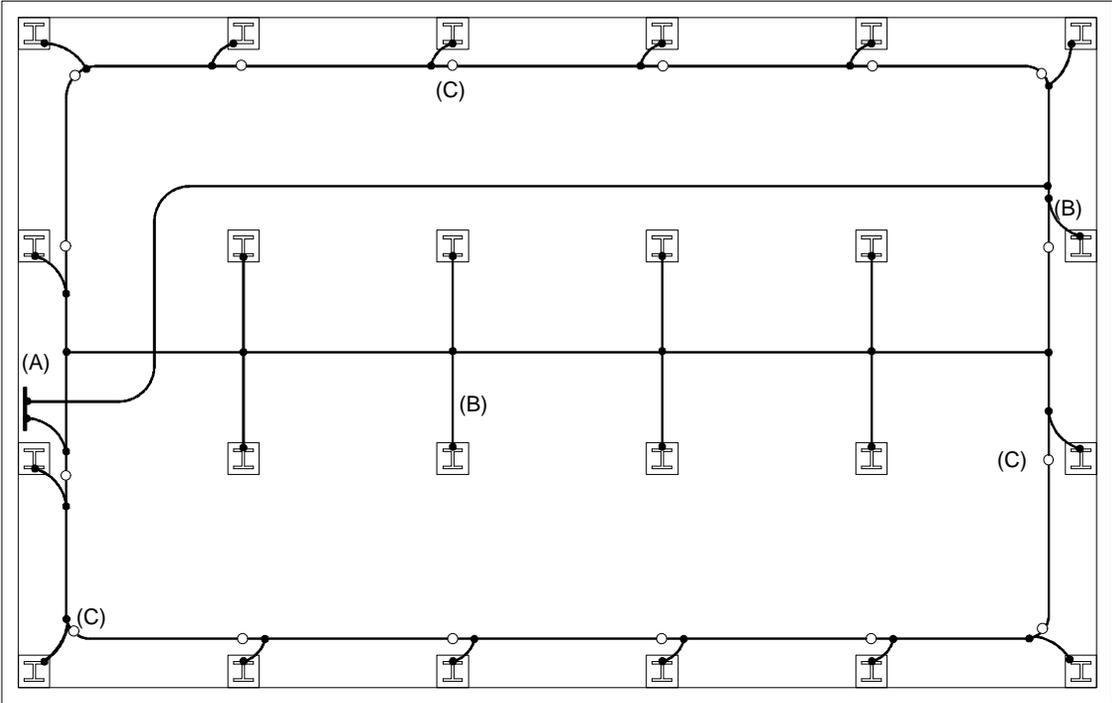
Note 3: This grid should be installed so that all columns are interconnected

2.2.13 Metallic flashing on parapets, and metallic objects mounted on the roof shall be bonded to structural steel when continuity to ground exists through the steel.

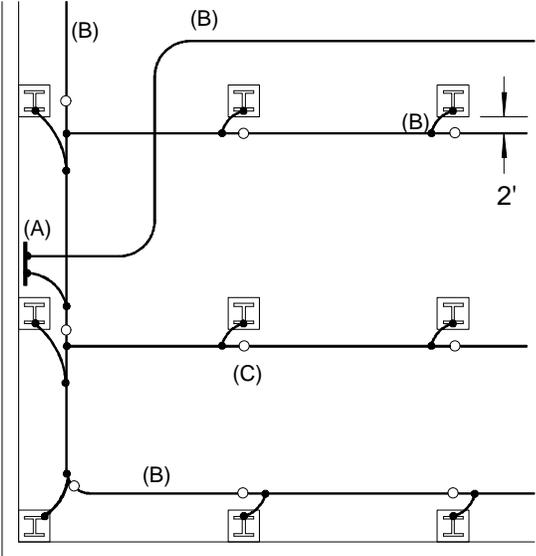
2.2.14 The main (interconnecting) conductor of a driven ground system shall be solid copper, sized at #2 AWG minimum. Tinned wire is preferred. The conductor shall be placed at a depth of at least 18 inches below grade and approximately 24 inches from the exterior wall.

2.2.15 The ring formed by the main conductor shall be connected to the OPGP with at least two conductors. The preferred design uses conductors connected to opposite sides of the ring. This design is feasible for new structures only, because the conductor from the far side of the ring must be routed under or within the concrete foundation of the structure.

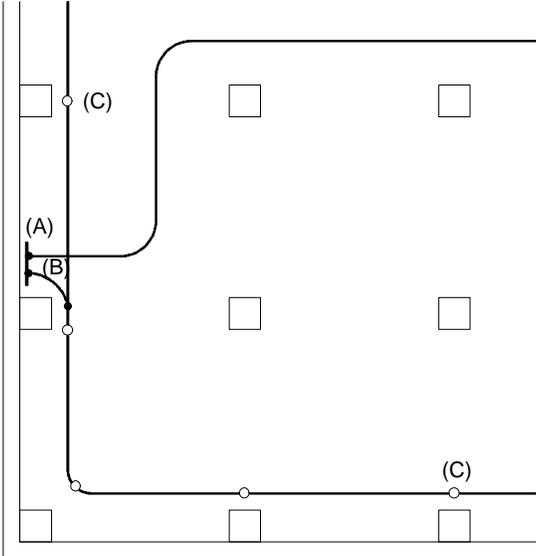
2.2.16 It is permissible for the two conductors terminated to the OPGP to be the ends of the ring around the structure. This design is used when a driven ground system is added to an existing structure.



Building Plan A - Supplementary ground field for building with structural steel columns or concrete columns using welded or wire-wrapped reinforcing bars



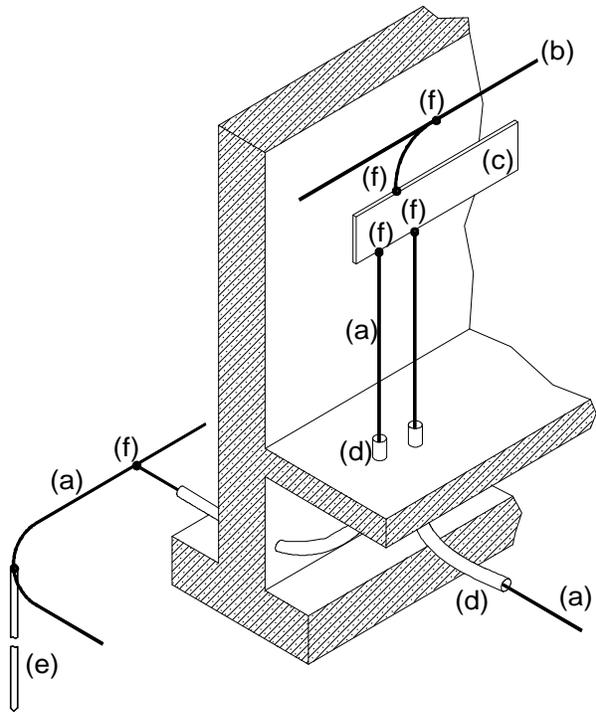
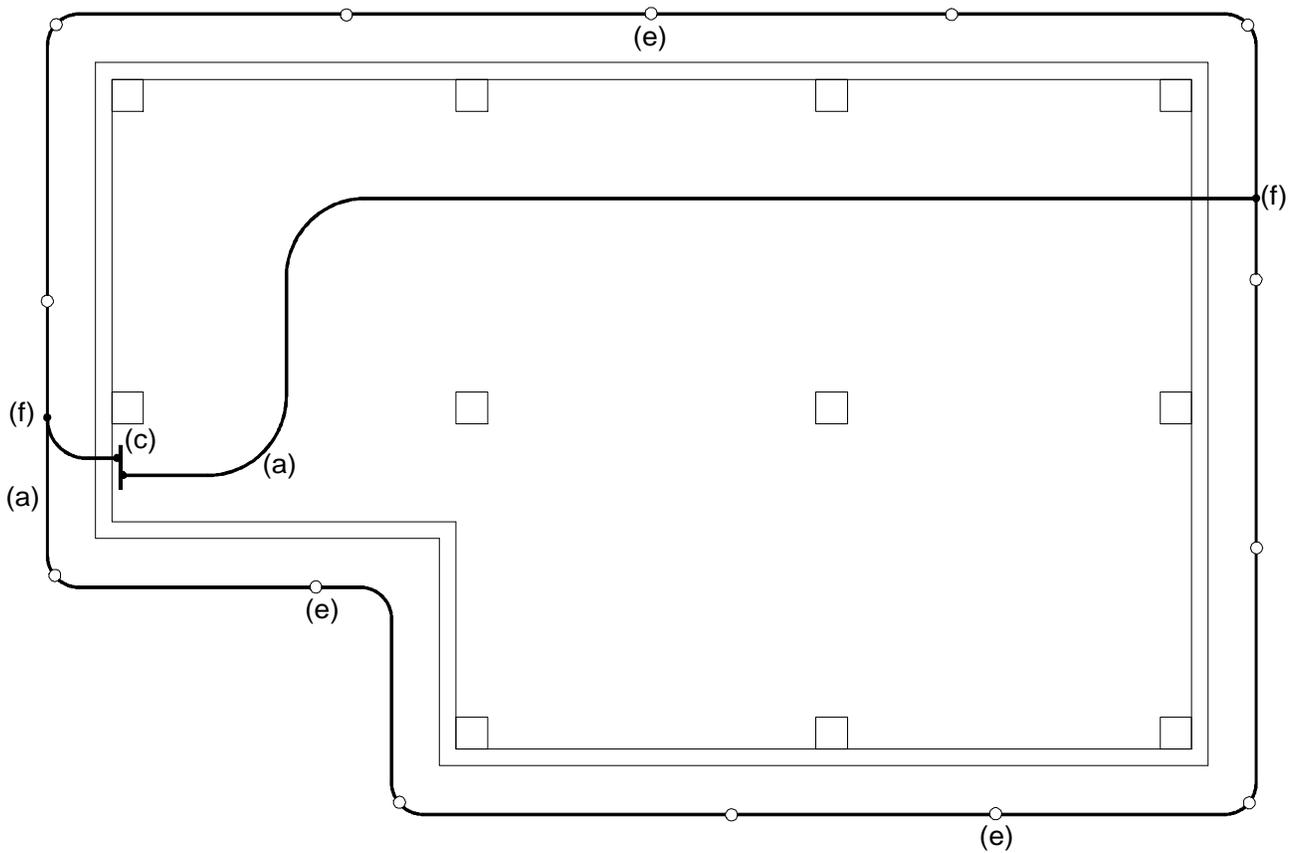
Building Plan B - Same as Plan A except that ground rods are located at every column



Building Plan C - Same as Plan A except that columns lack reliable electrical continuity and are not bonded to the supplementary field

- (A) OPGP Bus Bar
- (B) #2 AWG Bare Tinned Copper Wire
- (C) 5/8" x 8' Ground Rod
- Exothermic Weld to Ground Rod
- Exothermic Weld to #2 AWG, Bus Bar or Building Steel

Figure 2-1
Methods of Establishing Supplementary Ground Fields - Buildings with Basements



- (a) #2 AWG solid tinned copper wire
- (b) Grounding Electrode Conductor run between the main house service panel and the main cold water pipe; sized per Table 2-2
- (c) OPGP bus bar
- (d) PVC conduit
- (e) 5/8" x 8' ground rod
- (f) exothermic weld connection

Figure 2-2
Typical Driven Ground System for Buildings Without Basements

2.2.17 Some sites, including buildings other than central offices, were equipped with a supplemental driven ground rod system consisting of 4 to 6 ground rods arranged in a straight line. These systems do not require rearrangement unless warranted by a change in conditions at the site, such as the addition of a radio antenna tower on the roof of the building or a building addition that would disturb the driven ground rod system.

2.2.18 The preferable separation between driven ground rods is twice their length. In no case shall the separation between rods be less than their length.

2.2.19 Rods shall be driven to the depth of the ring conductor. A ground rod driving shield is recommended to prevent damage to the top of the rod.

Note : Inspection boxes with removable covers may be placed at ground rod locations. This not only facilitates inspection, but allows access to the driven ground rod system if it must be rearranged.

2.2.20 All connections to ground rods and all buried connections to the #2 AWG conductor shall be made using an exothermic weld.

Note: Some earth electrode systems were installed using mechanical connectors. A decision to replace these connectors with exothermic welds should be made on a site basis.

2.2.21 Where ground rods cannot be driven vertically to the desired depth below grade, they may be driven at an angle away from or parallel to the exterior wall. When driven parallel to the wall, the angle shall not exceed 45 degrees.

D. Other Electrodes

2.2.22 Certain earth electrodes recognized by the NEC are either not recommended or are prohibited for Company structures.

2.2.23 Normally, a concrete encased electrode (sometimes referred to as a *Ufer ground*) is not recommended. However, if the site's geological conditions preclude the use of a driven ground rod system, a concrete encased electrode may be used. It shall:

- (a) be a continuous minimum #2 AWG solid copper conductor
- (b) be placed in the footing around the perimeter of the structure
- (c) have both ends of the #2 AWG loop connected to the OPGP using exothermic welds
- (d) be placed in a footing that is in direct contact with the earth with no moisture barriers interrupting the contact

2.2.24 If a concrete encased electrode system is available at any site, such as a leased building, it must be bonded to the structure's earth electrode system.

2.2.25 A second option for an earth electrode system when ground rods cannot be driven is a counterpoise system. The horizontal counterpoise system consists of minimum #2 AWG bare copper conductors, with rods if they can be driven, buried at a depth of at least 18 inches below grade, radiating from the ring ground system from a minimum of four corners of the structure.

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2.2.26 The counterpoise conductors shall be run in a straight line, to the edge of owned property or for a maximum length of 125 feet, whichever is the lesser. They shall not be less than 25 feet long.

2.2.27 Gas service pipe, tanks, pipes (other than water pipes or well pipes) or plate electrodes are prohibited.

E. Interbonding of Earth Electrodes

2.2.28 Each ground rod of a driven ground system and every other intentional driven ground rod or buried object in the vicinity of a structure that may act as an unintentional electrode shall be bonded together to limit potential difference between them.

2.2.29 An optimum separation of intentional earth electrodes is from 10 to 15 feet, or from 1.5 to 2 times their length, whichever is greater. Proximity of any type of electrode at less than 6 feet to any other is not desirable and it is recommended that such occurrences be avoided where practicable.

2.2.30 When a driven ground system is installed around a structure equipped with lightning protection, the lightning protection system's down conductors shall be connected to the driven ground system rather than to separate lightning protection system ground rods.

2.3 DRIVEN GROUND SYSTEM FOR RADIO SITES

2.3.01 The general requirements for a driven ground system at a radio site are the same as those for a central office. Additional requirements appear in 6.3 of this Practice. They apply to radio sites as well as central offices that contain switching and radio equipment.

2.4 CENTRAL OFFICE GROUND SYSTEM

2.4.01 The Central Office Ground system provides:

- (a) grounding of communication systems equipment units
- (b) earth potential reference for ac and dc power systems and communications circuits
- (c) lightning and 60 Hz current discharge paths for communication system entrance cable protectors
- (d) current paths for equalization of dc voltages

2.4.02 The CO GRD system includes conductors that extend from:

- (a) the OPGP to CO GRD bus bars located on each floor of a building
- (b) CO GRD bus bars on each floor to the battery return systems of dc power plants, other principal dc distribution components and if present, other vertical risers
- (c) CO GRD bus bars to equipment frames, cabinets and other metallic objects on equipment floors, and are referred to as framework or equipment ground, and by other names derived from the served equipment or the function of the conductor

2.4.03 A CO GRD system shall be provided in every new Central Office building and equipment area in other structures.

A. Office Principal Ground Point (OPGP)

2.4.04 The office principal ground point serves as a central connecting point for grounding conductors from within the structure and from earth electrodes. The most common conductors terminated at the OPGP are:

- (a) the ac service Grounding Electrode Conductor
- (b) a bond to the Cable Entrance Facility
- (c) a bond to the water pipe system in the structure
- (d) bonds to structural steel
- (e) bonds to supplementary ground fields
- (f) a CO GRD system vertical riser
- (g) a bond to the earth electrode system in an adjacent structure
- (h) bonds to equipment requiring an earth ground reference
- (i) bonds to unintentional earth electrodes

2.4.05 New structures or those undergoing significant reconstruction should employ a design that places OPGP, the main ac service equipment and the cable entrance facility as close together as practicable. In new structures and existing structures where an OPGP is being added or relocated, a location should be chosen that will remain accessible.

2.4.06 The former practice of locating the OPGP directly on the main water pipe is no longer recommended. This applies to both central offices and commercial buildings.

Note: While the main water pipe is not recommended as a location for the OPGP, it is still a requirement to provide a bond from the metallic water pipe to the OPGP. See 2.7.08 and Figure 2-3 for a discussion of routing and connecting this conductor.

2.4.07 The size of the OPGP bus bar shall accommodate the initial conductors plus a 50 percent growth factor, and in no case shall it be smaller than the minimum size for a CO GRD bus bar: 1/4" x 4" x 16". In small structures such as CDOs, the OPGP may also serve as the only bus bar in the structure.

2.4.08 The OPGP bus bar should be mounted horizontally. If warranted by local conditions, the initial OPGP bus bar or extensions to it may be mounted vertically.

Note: Extensions of bus bars may be made by mechanical means; an exothermic weld is not required.

2.4.09 Where practicable, the OPGP bus bar should be mounted on studs welded to structural steel. If such an arrangement would place the OPGP in a less centralized or less accessible location, the bus bar's location can be altered provided a minimum #2 AWG conductor is used to bond the OPGP to structural steel.

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2.4.10 If the OPGP is not bonded to structural steel, insulators providing at least 2" of separation shall be placed between the OPGP and its mounting surface. These insulators may also be used if the mounting studs are not used as a means to bond the OPGP to building structural steel. In any case, the 2" separation is required to provide working access between the bus bar and the mounting surface.

2.4.11 When the OPGP lies in the path of the grounding electrode conductor between the House Service Panel (HSP) neutral bus bar and the water pipe or other primary earth electrode, the conductors from these points should be connected to the OPGP using exothermic welds. This satisfies the NEC requirement for an unspliced grounding electrode conductor, and has the added advantage of transforming the OPGP bus bar into a part of the grounding electrode conductor.

Note: This method, as well as an alternative method to bond a grounding electrode conductor to the OPGP is shown in Figure 2-3. In the alternative arrangement, the grounding electrode conductor passes near the OPGP and a bond of equal size is placed between the OPGP bus bar and the grounding electrode conductor. Terminations must be made with crimp type connectors, exothermic welds, or a combination of methods.

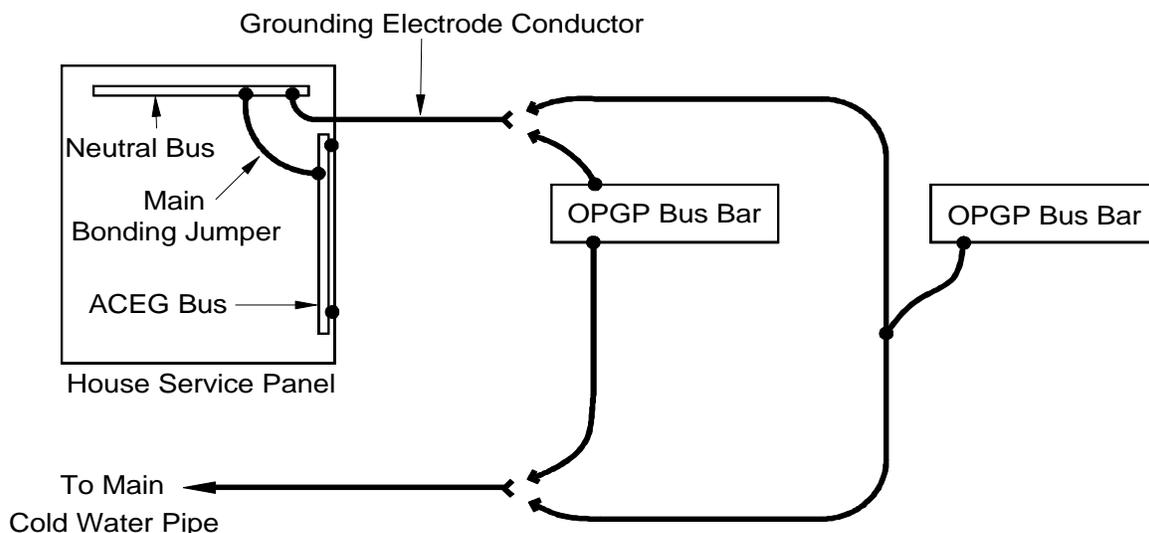


Figure 2-3
Two Methods for Bonding a Grounding Electrode Conductor to the OPGP

2.4.12 At the OPGP, an exothermic weld is the preferred method for terminating the two #2 AWG solid conductors from the driven ground system. Where local conditions prevent the use of an exothermic weld, a crimp type two hole connector is an acceptable alternative, but only when the connector is listed for use on a solid conductor and the crimp tool die set used is one specified by the connector manufacturer.

2.4.13 If a building addition is abutted to an existing structure and is provided with a new and separate ac service, a separate OPGP may be established. A bond shall be provided between the two principal ground points using a conductor sized as follows:

- (a) for buildings with less than 4 floors (including a basement), the conductor shall be the same size as the largest grounding electrode conductor provided for either the existing building or the building addition.
- (b) for buildings with 4 or more floors, the conductor shall be a 750 kcmil

2.4.14 When a common communication installation is housed in two closely adjacent structures (i.e., separated by an alley) having individual earth electrodes, the OPGPs shall be bonded together. The bond shall be the same as described for abutted buildings above.

2.4.15 Metal pipes and other buried objects having entry to the structure may act as unintentional earth electrodes. These electrodes shall be made common with the intentional electrode(s) using a minimum #2 AWG bond between their entry point and the OPGP. A single #2 AWG conductor may be branched to bond two or more of these objects.

B. Interbonding

2.4.16 Interbonding should be included in the building ground system design for any new structure without regard to its intended use. It should also be added to central office buildings when any significant renovation is performed on the building ground system or a main house service panel or during a major building construction project.

2.4.17 At minimum, interbonding must always include three general elements within a structure. These are the utility power service entrance, the communication cable entrance and the earth electrode entrance. The points of connection for the interbonding conductors are shown in Figure 2-4 and are described as follows:

- (a) a point at or near the communication cable's entrance into the structure - the cable entrance facility (CEF)
- (b) a point on the neutral bus bar in the HSP for the conductor to the OPGP (grounding electrode conductor)
- (c) a point on the HSP's equipment ground bus bar close to the connection of the main bonding jumper from the neutral bus bar for the conductor to the CEF
- (d) a point of access to the structure's primary earth electrode, most often the OPGP

Interbonding exists when these points are connected together with conductors so that a loop is formed with any one element connected to at least two others.

2.4.18 In structures with more than one OPGP, HSP and/or CEF, bonds shall be placed between any one of these points and at least two other points in the interbonding system.

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2.4.19 In structures other than central offices, a copper bus bar must be provided in the CEF area. It must be:

- (1) a minimum size of 2" wide, 12" long and 1/4" thick
- (2) equipped with a permanent label: **CABLE ENTRANCE GROUND BAR**
- (3) mounted on insulators that provide at least 2" of clearance from its mounting surface
- (4) located at a convenient point to serve the cable shield bonding conductors, and if required, protector unit grounding conductors.

2.4.20 In a central office building, the conductor from the HSP to the CEF must terminate in the CEF using either a crimp type parallel tap to the #1/0 AWG conductor originating at the OPGP, or a two hole crimp type connector on the same bus bar used to terminate the #1/0 AWG conductor originating at the OPGP.

2.4.21 On the OPGP, the preferred connection point for the conductors from the HSP and the CEF is nearest the point of connection of the conductors from the driven ground system, building structural steel or the main water pipe.

2.4.22 In the HSP, it is essential that the conductor from the CEF is connected to the ac equipment ground (ACEG) bus bar as close as possible to the point of connection of the main bonding jumper from the neutral bus bar. Terminating this cable on a neutral bus bar is **prohibited**.

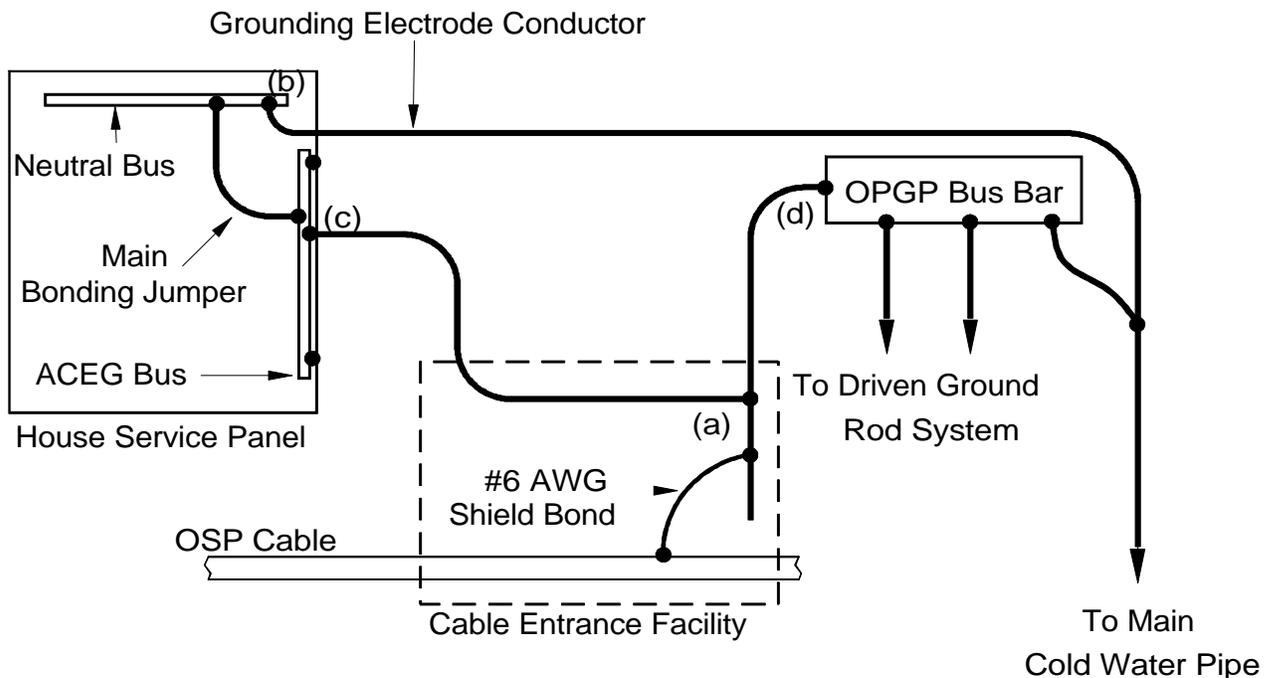


Figure 2-4
Typical Interbonding Arrangement

(see 2.4.17 for legend)

C. Design Parameters - Vertical Riser System

2.4.23 In a single story building, a vertical riser is the conductor between the OPGP and a CO GRD bus bar. In multifloor buildings it also bonds the CO GRD bus bars together. It provides a low impedance path to the earth electrode system via its connection to the OPGP. Equipment that requires a connection to the earth electrode system for proper operation and/or protection can use the connection to a floor's CO GRD bus bar because it is considered an appearance of the grounding electrode. Also, the vertical riser serves as a current path for battery return current interchange between circuits on different floors and as a low impedance fault current path.

2.4.24 The location of a vertical riser shall be such that the maximum conductor length between a CO GRD bus bar and the furthest grounded equipment unit does not exceed 200 feet. This means that the equipment served may not be located outside the perimeter of a square (200' x 200') superimposed on a circle with a 100' radius, centered at the location of the CO GRD bus bar. This is shown in 2-5 below.

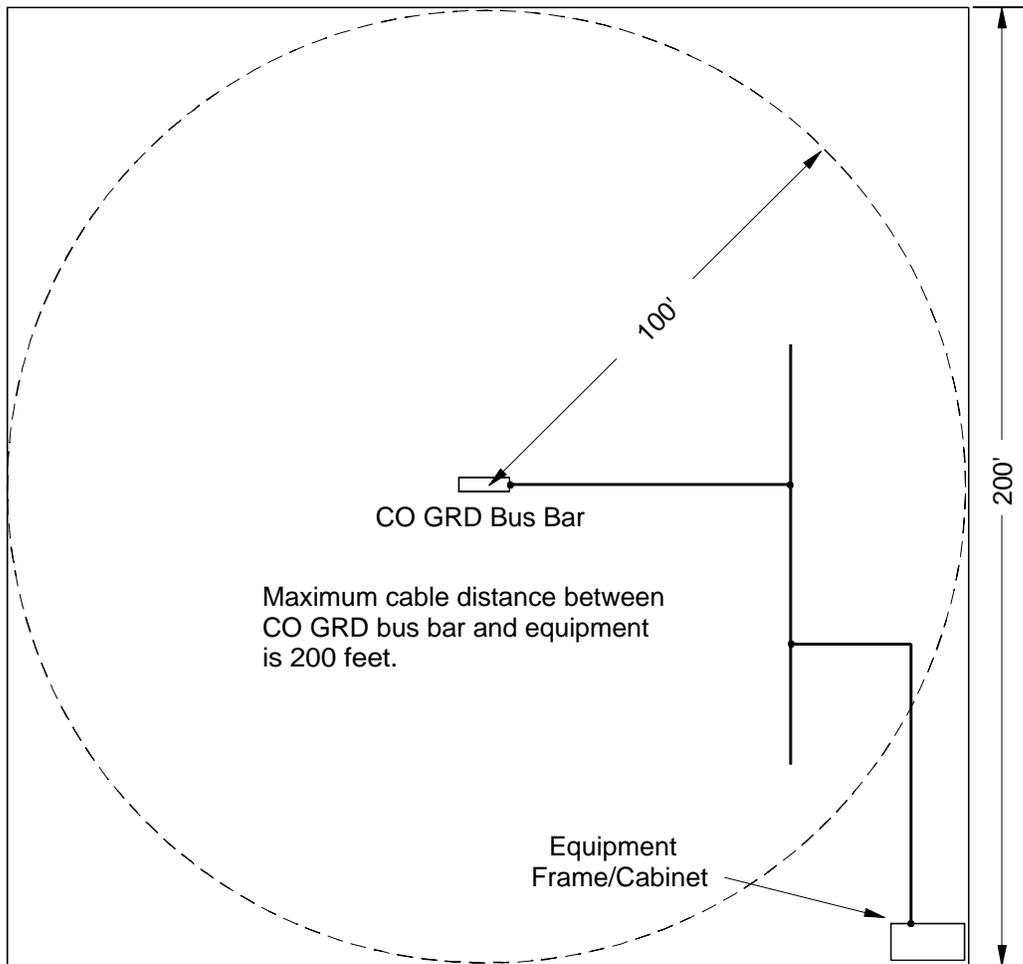


Figure 2-5
Maximum Floor Area Served by a Vertical Riser

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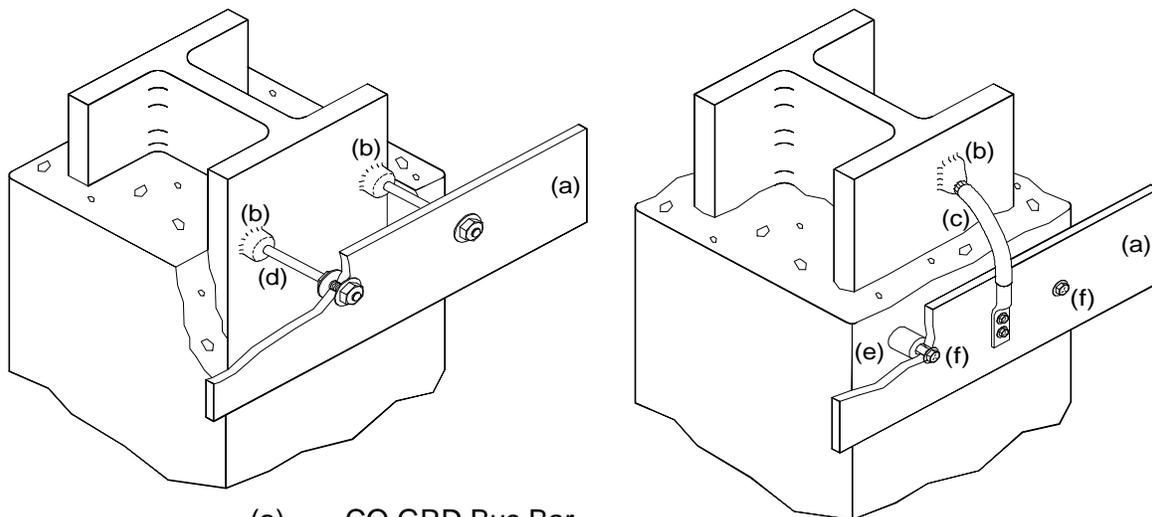
2.4.25 The vertical riser shall be located so that the horizontal portion of the run to the OPGP is as short as practical.

2.4.26 A vertical riser shall consist of a continuous 750 kcmil copper conductor or it may be a steel building column. When a 750 kcmil conductor is used, the vertical run shall be as straight as practicable, preferably with only minor bends to avoid obstructions such as floor beams.

Note: In the past, a #4/0 conductor was used in small single story structures as a vertical riser. The continued use of such arrangements should be evaluated on a site basis.

2.4.27 Splices in a 750 kcmil vertical riser shall be made using either an exothermic weld or an in-line crimp type connector. A 750 kcmil vertical riser conductor may also be extended using a crimp type parallel connector tapped onto an existing vertical riser conductor.

2.4.28 Certain types of building columns may be used as a vertical riser. Other types cannot be used for this purpose but require bonding to floor CO GRD bus bars. When column steel consists of structural steel sections, and all section butt ends of the column are bridged with a weld, a welded steel plate or an exothermically welded or brazed 750 kcmil copper bond, the column may be used as a CO GRD system vertical riser. Bonds between CO GRD bus bars and column steel shall be made using a 750 kcmil copper conductor, two 3/4" studs welded to the steel column or an equivalent means (see Figure 2-6).



- (a) CO GRD Bus Bar
- (b) Welded Connection
- (c) 750 kcmil Bonding Conductor
- (d) 3/4" Stud (e/w nuts, washers, lockwasher)
- (e) 2" Spacer (to allow access)
- (f) Standard Masonry Anchor Assembly (1/2" or 5/8")

Figure 2-6
Bonding CO GRD Bus Bar to Building Steel

- 2.4.29 When structural steel of a column is not welded or bonded, it may not be used as a vertical riser. However, an equalizing bond shall be provided between the column steel in closest proximity to each bus bar. The bond shall be made using one of the methods used when the column steel is used as a CO GRD vertical riser, except that when a conductor is used, it need be no larger than #3/0 AWG.
- 2.4.30 When columns are reinforced concrete and reinforcing bars are not welded or wire wrapped, it is assumed that continuity to earth does not exist. For this reason, column reinforcing bars not known to be electrically continuous to earth shall not be bonded to the CO GRD bus bars.
- 2.4.31 When a vertical steel column is used as the CO GRD conductor, that column must be connected to the OPGP with a 750 kcmil copper conductor. This conductor should be as short as practicable, and shall be exothermically welded or brazed directly to the column steel, or connected to a ground bar arranged similar to that described in 2.4.28.
- 2.4.32 A vertical riser may serve a horizontal CO GRD system which does not exceed 200 conductor feet from a CO GRD bus to the furthest equipment frame, as explained above. When this distance will be exceeded, a second vertical riser with associated CO GRD bus bars and horizontal equalizers is required.
- 2.4.33 When multiple vertical risers are required, they shall be located within 200 feet of each other so that horizontal equalizers can serve a contiguous floor area.
- 2.4.34 Multiple vertical risers shall be bonded together at the lowest floor and at every third floor with a 750 kcmil conductor. For example, bonds would be made in the basement, at the third, sixth, ninth, etc., floors.
- 2.4.35 The second vertical riser shall terminate at the OPGP except when the horizontal portion of the first vertical riser extends from the OPGP in the direction of the second vertical riser. In this case, the second vertical riser may terminate at a CO GRD bus bar served by the first equalizer or tapped to the equalizer conductor on the floor containing the OPGP if the resultant run length from the OPGP to the vertical portion of the second equalizer is not greater than 120 percent of a direct run between the two points.
- 2.4.36 An exothermic weld or crimp type parallel connector shall be used when Vertical Risers are joined to share a common 750 kcmil path to the OPGP.
- 2.4.37 When multiple vertical risers are installed in a building, they shall be designated as **CO GRD #1**, **CO GRD #2**, etc.
- 2.4.38 Multistory buildings that are separated by an alleyway or permanent building wall require one or more separate Vertical Risers in each building. The risers shall be designated **CO GRD #1** , **CO GRD # 2** , etc., when ac or dc supplies of either building provide power to equipment in the other building. The equalizers shall terminate on the OPGP of their respective building, and a bond shall be provided between the two OPGPs sized as indicated in Table 2-2 of this Sub-section.

2.4.39 Acceptable methods for bonding a 750 kcmil vertical riser to the CO GRD bus bar are shown in Figure 2-7 and described below:

- (1) A 750 kcmil conductor is exothermically welded to the edge(s) of the bus bar. On the bottom floor of a building, the conductor from the OPGP and the one to the next floor's CO GRD bus bar may both be welded to the top (or sides) of the bus bar.
- (2) A short length of 750 kcmil is exothermically welded to the bus bar. The other end is tapped, using a crimp type H-tap, to the vertical riser. This method allows the weld to the bus bar to be made at some other location (e.g., outside).
- (3) Same as arrangement (2), but both connections are made with exothermic welds.
- (4) A "flag" type connector is crimped to the vertical riser and bolted to the bus bar.
- (5) Same as arrangement (2), but both connections are crimp type.

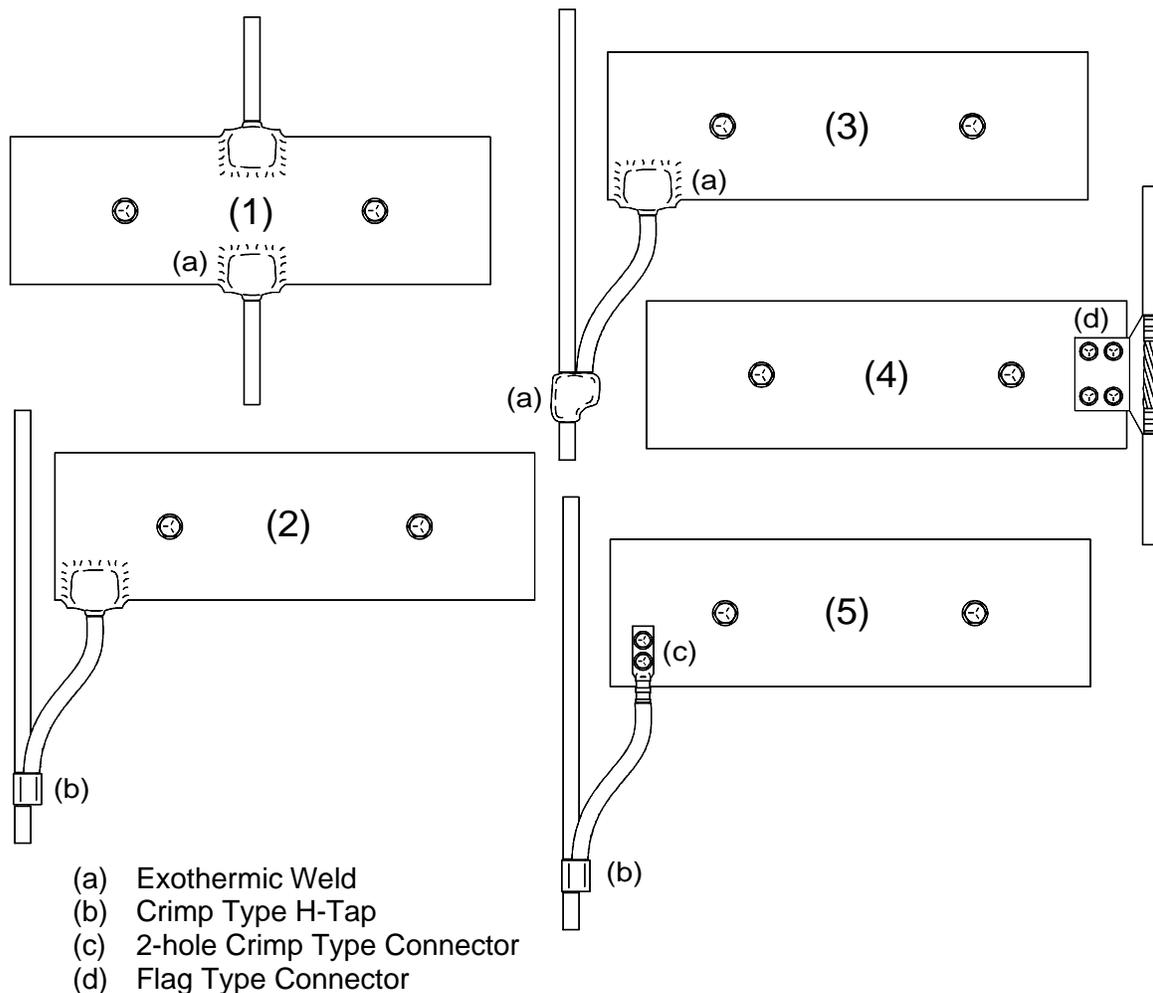


Figure 2-7
Methods of Connecting 750 kcmil Vertical Riser to CO GRD Bus Bar

D. Design Parameters - Horizontal Equalizer System

2.4.40 In the past, the recommended practice was to extend a separate 750 kcmil horizontal equalizer from a floor's CO GRD bus bar into each quarter section of the floor area. While this is still acceptable, the size of the building, and the amount and type of equipment to be served by the CO GRD system should be evaluated to determine the need for this arrangement. Often, a single 750 kcmil conductor routed along a main aisle is an alternative that will provide an acceptable arrangement and will satisfy any foreseeable needs.

Note: The 750 kcmil conductor between an MGB or a power plant's battery return bus and CO GRD is considered a part of the horizontal equalizer system. Any conductor normally connected to a horizontal equalizer may terminate on this conductor.

2.4.41 A minimum #2 AWG conductor may be used between the CO GRD bus bar and an area containing a group of bays or miscellaneous units, or with more than one lineup of equipment. Separate #6 AWG conductors may then be branched from this conductor to serve an equipment lineup or individual equipment units. The #2 AWG conductor may originate at an OPGP or CO GRD bus bar, or from a horizontal equalizer.

2.4.42 When a BDFB is located in an area not served by a 750 kcmil horizontal equalizer, the BDFB's #1/0 AWG framework ground conductor may serve in place of the #2 AWG described above. If a BDFB has a 750 kcmil conductor between its return bus and a CO GRD bus bar, this is considered to be a horizontal equalizer, and may be used as such.

2.4.43 All new extensions of, or branches from a horizontal equalizer conductor shall be made with crimp type parallel connectors.

E. CO Ground Bus Bars

2.4.44 At least one CO GRD bus bar is required on every floor of a structure with a CO GRD system. The bus bar shall be located on the column that serves as the Vertical Riser, or on a column or wall when a vertical riser is a separate conductor.

2.4.45 The preferred location for the bus bars on equipment floors is the approximate center of the equipment area. Where a CO GRD bus bar cannot be centrally located, it should be located as near as practicable to the protector frames or other distributing frames equipped with protectors.

2.4.46 The CO GRD bus bar in a building's basement need not be in vertical alignment with other floor CO GRD bus bars. It should be located at a point along the CO GRD vertical riser run in the basement, and in a position that affords the shortest practical run length of the bond between the vertical riser and the predominant power plant, if one exists.

2.4.47 The bus bar should be located approximately 12"-18" below the lowest layer of ironwork. This location will allow access to the bus bar, help maintain an acceptable conductor bending radius, and furnish an adequate span of support for conductors.

2.4.48 The bond between a vertical riser and a CO GRD bus bar shall be as short as practicable, and in no case shall be more than 20 feet.

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2.4.49 In single floor buildings, more than one CO GRD bus bar may be provided. The additional bus bars may be connected directly to the OPGP or to the vertical riser serving another bus bar. If the direct route to the OPGP results in a run length 25% less than the run via another bus bar, the direct route should be used.

F. Designation of OPGP & CO Ground Bus Bars

2.4.50 All CO GRD bus bars on all floors and all OPGP bus bars shall be designated. The designations may be stamped on the bus bar or engraved in or stamped on a separate designation plate. The plate must be securely fastened to either the bus bar or to the surface of the wall or column adjacent to the bus bar.

2.4.51 The preferred size for the characters used in the designation is 3/4" and in no case shall the characters be smaller than 1/2".

2.4.52 The terms used in designations for floor CO GRD bus bars are to be either "CO GRD", "C.O. GRD.", "C.O. Ground" or "Central Office Ground". For OPGP bus bars, the terms used in the designations are to be either "OPGP", "O.P.G.P." or "Office Principal Ground Point". Terms such as "Telco Ground" or "Telephone Ground" shall not be used.

G. Office Drawings

2.4.53 The appropriate T-XXXX-XX-650 office drawing shall be used to record the following information:

- (a) the location of CO GRD, MGB, OPGP and other bus bars used primarily for terminating grounding conductors
- (b) a cross reference table containing cable sizes, connector identifiers and any other piece parts associated with terminating CO GRD system conductors
- (c) the approximate route of all CO GRD conductors (other than ACEG conductors) up to their point of connection to equipment frames, cabinets or other enclosures
- (d) where appropriate, figures showing the connection sequence of conductors
- (e) any figures or notes required by engineering or installation to describe grounding arrangements unique to the area covered by a drawing

Note: Some sites may use combination office drawings containing floor plans, cable rack plans, grounding schematics, etc., and a separate -650 drawing is not issued.

2.5 ROUTING AND SUPPORT OF EQUALIZER CONDUCTORS

2.5.01 All vertical and horizontal equalizer conductors should be routed so that U shaped configurations are avoided. Where such turns are unavoidable, they shall be made with the greatest possible radius.

2.5.02 Vertical and Horizontal Equalizers shall be run exposed so as to afford visual inspection of the entire system and to provide access for adding connectors.

2.5.03 Cable supports and sleeves provided for routing of horizontal and vertical equalizer conductors shall not be used for routing of any type of cable or conductor other than grounding conductors.

Note: Horizontal equalizer conductors may be placed on the same cable brackets used to support other cables if secured to the opposite surface of the brackets.

2.5.04 Horizontal runs should be supported along the exterior of cable rack stringers or from framing bars by means of clips or similar devices that do not form a closed metallic ring around the conductor. Short runs through walls should be supported within 2" PVC plastic or other approved non-metallic conduit.

2.5.05 Vertical risers shall be run through floors in core-drilled holes or in 2" PVC plastic or other non-metallic conduit. If a cable hole is adjacent to the column supporting the vertical riser, it may be used in place of non-metallic conduit as long as a separation is maintained between the vertical riser and other conductors routed through the cable hole.

2.5.06 Vertical risers shall be secured to columns and walls using supports located approximately 2 feet from the floor, the ceiling, each side of any intervening bus bar, and at an interval of 2 feet (or less) between these points.

Note: The requirement (for power cable) to provide a minimum of 20 feet of conductor supported on horizontal cable rack every third floor shall not be applied.

2.5.06 The vertical conductor may be supported by cable brackets or similar details fastened to Unistrut or other material that is anchored to a wall or column. An auxiliary support shall be provided on every other floor consisting of either wedge plugs in the top of sleeves or cable support grips suspended from J-bolts secured by anchors in the ceiling.

2.5.07 Several methods of supporting grounding conductors, including vertical and horizontal equalizers, and typical material are shown in ED-97729-11. This drawing can be obtained by employees from any Information Management Center or Engineering Library. The use of support methods similar to those shown in this drawing are acceptable.

2.6 BUILDING ENGINEERING

2.6.01 The exact location of vertical risers shall be determined by Building Engineering based on the requirements described in preceding paragraphs.

2.6.02 For buildings with structural steel, the preferred method is to use the welded structural steel as the vertical riser.

2.6.03 When it is intended that structural steel columns be used as vertical risers, instructions for bonding of the structural steel sections, as described in preceding paragraphs, shall be included in building specifications.

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2.6.04 When bonding of floor CO GRD bus bars to building steel is required the Building Engineer shall arrange for the addition of the two 3/4" studs or the 750 kcmil conductor to building steel prior to pouring of concrete.

2.6.05 The installation of sleeves in floors and requirements associated with building construction should be included in construction specifications. When sleeves are placed at columns, care should be exercised to offset them from the column to miss horizontal beams while not interfering with clear equipment aisle space.

2.6.06 Where more than one vertical riser system is required in a building and bonding is required between them, suitably located sleeves through intervening walls that will result in shortest practical run lengths shall be provided.

2.7 AC SYSTEM GROUNDING

2.7.01 The AC service distribution system used in a Central Office is usually a single or three-phase 120/208 or 277/480 volt grounded system. The grounding of these systems includes two sub-systems: the ac service grounding system, covered in 2.7 A. - C., and the ac equipment grounding system, covered in 2.8 A. - H..

A. Grounding Electrode Conductor (GEC)

2.7.02 A grounding electrode conductor (GEC) bonds the neutral of an ac power system to an acceptable earth electrode system. The preferred point of connection of the GEC to an earth electrode system is at an OPGP or CO GRD bus bar.

Note: For the end of the GEC terminated in the main house service panel the preferred location for the connection is the neutral bus bar.

2.7.03 Figure 2-3 shows the two preferred methods for connecting the main ac service GEC to an OPGP bus bar and, in turn, to the main cold water pipe. Of the two methods, the one using exothermic welds is most preferred.

2.7.04 If a GEC connects to an earth electrode system that does not terminate on the OPGP, a bond equal in size to the GEC is required between the separate earth electrode system and the OPGP. If it provides a shorter path, the conductor from the separate electrode system may terminate at a point on the earth electrode system serving the OPGP.

2.7.05 The neutral conductor of an ac system shall not be connected to a grounded object on the load side of the system's main disconnect device.

2.7.06 The GEC shall be sized per NEC section 250-94 except that conductors smaller than #2 AWG shall not be used for services, and conductors smaller than #6 AWG shall not be used for the source of a separately derived ac power system in any Company structure. See Table 2-2.

Size of Largest Service Entrance Conductor or Equivalent Area for Parallel Conductors		Size of Grounding Electrode Conductor
Copper	Aluminum or Copper-Clad Aluminum	Copper
Up to 1/0 AWG	Up to 3/0 AWG	6 AWG
Over 1/0 thru 3/0 AWG	Over 3/0 AWG thru 250 kcmil	4 AWG
Over 3/0 AWG thru 350 kcmil	Over 250 thru 500 kcmil	2 AWG
Over 350 thru 600 kcmil	Over 500 thru 900 kcmil	1/0 AWG
Over 600 thru 1100 kcmil	Over 900 thru 1750 kcmil	2/0 AWG
Over 1100 kcmil	Over 1750 kcmil	3/0 AWG

**Table 2-2
Grounding Electrode Conductor Sizing**

2.7.07 The GEC may be a bare or insulated, stranded or solid copper conductor.

2.7.08 The GEC should be run in the open, or in non-metallic raceway. When required to be in metallic raceway, the raceway must be bonded to the conductor at both ends. If a conductor is used for this bond, it shall be no smaller than the GEC.

Note: The GEC and associated bonds are often installed by an electrical contractor as directed by Company specifications.

B. Main Bonding Jumper

2.7.09 A main bonding jumper shall be used to connect the grounded conductor of the system (the neutral) to the equipment grounding conductor and service equipment enclosure.

2.7.10 The main bonding jumper shall not be smaller than the sizes given in Table 2-2 above, except that sizes smaller than #2 AWG shall not be used for main house service panels in Company structures. Where the service entrance phase conductors are larger than 1100 kcmil copper or 1750 kcmil aluminum, the bonding jumper shall have an area not less than 12 1/2 percent of the area of the largest phase conductor.

C. Grounding of Separately Derived AC Systems

Note: A separately derived ac power system is a power source that has no direct electrical connection, including a solidly connected grounded circuit conductor, to supply conductors originating in another system. Typical sources are isolation transformers, some inverters and some engine-alternators.

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- 2.7.11 A GEC is required between the neutral of the source of a separately derived ac power system and an earth ground reference.
- 2.7.12 In offices equipped with a CO GRD system, the preferred point of connection for a GEC is to the OPGP, a floor CO GRD bus bar, or building steel. In structures without a CO GRD system or building steel, the GEC must be connected to an approved earth electrode.
- 2.7.13 Grounding electrode conductors and main bonding jumpers for separately derived ac systems shall be installed per the requirements in 2.7 A. and 2.7 B. above, based on the size of the derived phase conductors.

2.8 AC EQUIPMENT GROUNDING

A. Feeder and Branch Circuit Equipment Grounding System

- 2.8.01 A separate ACEG conductor shall be provided in all conduits, raceways and other distribution systems containing ac circuit conductors.
- 2.8.02 A separate ACEG conductor shall be provided in all additions, rearrangements or extensions of service, feeder and branch circuit raceways. This includes distribution systems serving both communication equipment and building service equipment.
- 2.8.03 An additional insulated ACEG conductor is required for all circuits feeding isolated ground type outlets. This conductor must remain insulated from contact with any other ground reference between the circuit load(s) and its source (HSP, isolation transformer, dc-ac inverter, etc.).
- Note: See 4.10 D., *Special Note on Isolated Ground Type Receptacles*, for a discussion of the application of these receptacles.
- 2.8.04 A separate bonding jumper is required between a receptacle and its enclosure with the following exceptions:
- (a) the receptacle is an isolated ground type
 - (b) the enclosure is surface mounted and direct metal-to-metal contact exists between it and the receptacle's mounting yoke
 - (c) the receptacle is cover-mounted and the enclosure and cover combination are listed as providing satisfactory ground continuity between the enclosure and the receptacle
- 2.8.05 Except for ACEG conductors serving isolated ground type receptacles, all ACEG conductors shall be bonded to metal enclosures to provide continuity independent of that provided by the raceway. A single bond may be used between multiple ACEG conductors and an enclosure.

2.8.06 An ACEG conductor shall be connected to an enclosure by one of the following means:

- (a) a ground bus bar
- (b) a terminal strip
- (c) a grounding bushing
- (d) a grounding clip
- (e) a screw fastener
- (f) the arrangements described in 2.8.04 (b) and (c)

Note 1: Grounding clips are normally used only at junction boxes and receptacle enclosures.

Note 2: A screw fastener (machine screw, nut, bolt or stud) must be used for no other purpose than to terminate ACEG conductors.

2.8.07 ACEG conductors shall never be connected to an ac neutral at any point downstream from the point where the source of the system receives its ground reference.

2.8.08 The inclusion of an ACEG conductor in a raceway shall not be counted in determining the ampacity of conductors in accordance with Note 8 associated with Tables 310-12 and 310-14 of Article 310 of the NEC.

2.8.09 The ACEG conductor shall be included in calculations of allowable percentage of conduit fill defined in Chapter 9, Table 1 of the NEC.

2.8.10 At minimum, all ACEG conductors and bonds between them and metallic enclosures shall be sized per Table 2-3 below, which is from Table 250-95 of the NEC.

Note: When phase conductors are increased in size to compensate for voltage drop, the size of associated ACEG conductor(s) shall be increased proportionately.

2.8.11 Where conductors are run in parallel in multiple raceways, ACEG conductors shall be run in parallel. Each parallel ACEG conductor shall be sized on the basis of the ampere rating of the overcurrent device protecting the circuit conductors in the raceway in accordance with Table 2-3.

2.8.12 Insulated ACEG conductors shall be colored green or green with one or more yellow stripes. Conductors larger than #6 AWG may be identified by marking the exposed insulation with green tape or paint at each end and at every point where the conductor is accessible.

2.8.13 When multiple ac circuits share a common raceway, only one ACEG conductor is required for the raceway. Its size shall be based on the largest overcurrent device serving circuits in the raceway.

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Not Exceeding (Amperes)	Minimum Size of Copper Equipment Grounding Conductor
15	14 AWG
20	12 AWG
30	10 AWG
40	10 AWG
60	10 AWG
100	8 AWG
200	6 AWG
300	4 AWG
400	3 AWG
500	2 AWG
600	1 AWG
800	1/0 AWG
1000	2/0 AWG
1200	3/0 AWG
1600	4/0 AWG
2000	250 kcmil
2500	350 kcmil
3000	400 kcmil
4000	500 kcmil
5000	700 kcmil
6000	800 kcmil

Table 2-3

**Minimum Size of Equipment Grounding Conductor
 for Grounding Raceway and Equipment**

2.8.14 The ACEG conductor in a circuit serving equipment in a frame, cabinet or other metallic enclosure that also contains dc-powered equipment may not be used in place of the required bond between the enclosure and the CO GRD system.

2.8.15 While ACEG conductors are considered part of (and bonded to) the CO GRD system, no other CO GRD conductor may serve in place of an ACEG conductor. Bonds between the CO GRD system and ac power distribution system components shall not be used in place of any ACEG conductor.

B. Extending ACEG Conductors

2.8.16 Since ac distribution systems are of different ages, it is likely that a system not originally equipped with a separate ACEG conductor will be encountered. It is often not feasible to place an ACEG conductor in the existing upstream feeder conduit or raceway. However, the conduit or raceway may be able to serve as the ACEG conductor. The point from which an ACEG conductor is extended will usually be an enclosure such as:

- (a) a distribution panel
- (b) a pull box
- (c) a junction box
- (d) a receptacle box
- (e) a lighting fixture

2.8.17 Before any ac distribution system is extended or rearranged from a point in a distribution system not equipped with a separate ACEG conductor, the integrity of the ACEG system upstream from the enclosure must be verified. This is done by determining whether an acceptable type of conduit or raceway has been used and by verifying the tightness of the fitting(s) used to fasten the conduit or raceway to the enclosure

2.8.18 For existing distribution systems not equipped with a separate ACEG conductor, the only types of conduit or raceway allowed to serve as an ACEG conductor are:

- (a) electrical metallic tubing (EMT)
- (b) intermediate metal conduit (IMC)
- (c) rigid metal conduit
- (d) metal raceways listed for grounding

Note: If none of the above are present in the upstream feed to the enclosure, no circuit shall be extended from the enclosure until corrective action has been performed.

2.8.19 The ACEG conductors being added shall be terminated to the enclosure by one of the means in 2.8.06 above.

2.8.20 If more than two ACEG conductors are being added (typically at a distribution panel), it is preferable to add a ground bus to the panel. This bus may be bonded to the panel using its mounting screws provided the paint is removed from the mounting surface of the panel and an antioxidant compound is applied to the bare metal.

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C. AC Power Distribution Cabinets

- 2.8.21 Every ac power distribution cabinet requires an ACEG conductor in the conduit or raceway containing the feeder conductors serving the cabinet.
- 2.8.22 ACEG conductors shall terminate on the interior of the cabinet enclosure on a bus bar bonded to the cabinet enclosure or one of the methods in 2.8.06 (b) thru (e).
- 2.8.23 Except for cabinets containing the service disconnecting means, the neutral bar must be insulated from the enclosure and the equipment ground bar.
- 2.8.24 The ACEG conductor provided with feeder conductors provides an acceptable extension of the CO GRD system to an ac distribution cabinet and ac powered equipment **only** when the ac system's source receives its ground reference on the same or adjacent floor to that on which the cabinet is located. Otherwise, the cabinet shall be bonded to the floor CO GRD system using a minimum #6 AWG conductor.

D. AC Busduct System

- 2.8.25 AC busduct components shall maintain equipment ground continuity throughout the busduct system. Feeder tap boxes and plug-in units are considered to be adequately bonded through mechanical interconnection to busduct sections.
- 2.8.26 The ACEG conductor(s) associated with busduct feeder and distribution circuits shall be furnished in accordance with requirements above.

E. Engine-Alternator Sets

- 2.8.27 Engine-alternator and inverter derived ac supplies provided in case of commercial power failure are normally controlled through automatic or manual switching so that the phase conductors of the standby supply are never joined to the commercial supply. The neutral conductor of the standby supply is normally directly connected to the neutral of the commercial secondary service. The grounding electrode conductor (GEC) of the secondary service system serves as a ground reference for both the standby and commercial systems and such systems do not require a separate GEC. However, in some cases the use of ground fault protection will mandate that the neutral be switched.

Exception: When an engine-alternator set is located in a separate building that has its own earth electrode system, the standby system's neutral shall also be connected to that earth electrode system.

Note: If the transfer switch does switch the neutral, then the engine-alternator or inverter is considered the source of a separately derived system and must be equipped with a GEC and a main bonding jumper.

- 2.8.28 An ACEG conductor is always required in the conduit(s) or raceway(s) containing phase leads from the alternator, and shall be furnished in accordance with the requirements above.

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

2.8.30 The neutral of the alternator shall not be bonded to the ACEG conductor or engine-alternator frame when it is located in the same building as the main ac service panel. The neutral shall be bonded to the ACEG conductor only when the set is located in a separate building equipped with its own earth electrode, or if the neutral is switched.

F. Grounding of AC Tap Boxes

2.8.31 Every ac tap box shall be equipped with an ACEG bus bar. This bus bar shall be bonded to the metalwork of the tap box by its mounting hardware or by a separate bonding conductor.

2.8.32 A separate ACEG conductor shall be furnished in the raceway serving the tap box. The ACEG conductor shall be installed per the requirements in 2.8 A. of this Sub-section, except that the size of the ACEG conductor shall be based on the rating or setting of the overcurrent protective device installed in the circuit between the tap box and the system it serves.

2.8.33 If the transfer switch for a site's engine-alternator switches the neutral conductor, the neutral bus bar of the tap box shall be equipped with a GEC and a main bonding jumper per the requirements in 2.7 A. and 2.7 B. above.

G. Cord Connected AC Operated Equipment

2.8.34 Parallel polarized U ground slot receptacles are standard for frame base appliance outlet and other miscellaneous ac branch circuit applications serving cord connected equipment. Such equipment, whether portable or permanently mounted, shall be equipped with a three conductor cord and a three conductor grounding attachment plug. Two conductors of the cord shall serve as circuit members. The third conductor shall serve as a grounding member, connected at the plug to the U blade, and to the equipment structural metal, so that ground continuity is established from the receptacle to the equipment structure.

2.8.35 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 be bonded to the metal outlet box or other enclosure mounting the receptacle as well as the EG (green) terminal screw of the receptacle.

2.8.36 If ground continuity is not provided to the U ground slot via the receptacle mounting members, a bonding jumper is required.

2.8.37 Certain equipment still in use may be equipped with 2-pole ungrounded plugs and 2-conductor cords. Unless protected by an approved system of double insulation, such units are potentially hazardous. Such cord and plugs shall be replaced with 3-conductor cords and 2-pole, 3-conductor grounded plugs.

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2.8.38 Where units suitably arranged for grounding are used in offices with 2-pole ungrounded receptacles, the plug shall be equipped with a ground conductor type adaptor to ensure that grounding facility is available.

2.8.39 Frame mounted ac operated equipment now in service served with 2-conductor cord and ungrounded plugs need not be modified for a grounded system where it can be ascertained that these permanently mounted units have continuity through the frame to the raceway enclosing the branch circuit conductors

2.8.40 Generally, all new ac operated portable or permanently mounted equipment units utilizing cord and plug for ac supply shall be supplied with 3-conductor cords and 2-pole, 3-conductor grounded plugs 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.

H. Job Drawings, Architectural

2.8.41 AC distribution system circuit requirements for specific job installations shall be recorded on drawings prepared by the building architect and/or the communication systems equipment engineer.

2.8.42 An ACEG system shall be provided, as specified in this Sub-section, in the portion of the ac distribution system controlled by architectural drawings. The ACEG conductors shall be shown on the plans in a similar manner to that of phase and neutral conductors. Methods of termination and other information necessary for proper installation shall be provided.

2.8.43 For the purpose of establishing a standard identification of ACEG conductors shown on circuit schematic, wiring diagram and job circuit drawing, it is recommended that lead identification at points where an ACEG lead is referenced to other circuit figures or other drawings shall use letter designation, as follows: ACEG.

Sub-section 3

Power Plants and Equipment, Transport and Miscellaneous Equipment

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3.1 SCOPE

3.1.01 This Sub-section covers requirements and information about connections between a central office ground system and:

- power equipment
- transport equipment
- miscellaneous equipment frames and units
- cable entrance facilities
- protector and distributing frames
- power systems serving the above and other types of equipment

3.2 GENERAL

3.2.01 This Sub-section provides requirements for equipment that is normally installed in a common bonding network environment. It includes requirements for power plant equipment and power distribution systems that serve both common bonding network and isolated bonding network equipment.

3.2.02 Where requirements are specified in communication system equipment circuit drawings or specifications, they shall have precedence over the general requirements of this Sub-section. Where grounding requirements are not furnished in system specifications or where they have not been updated to the requirements outlined in this Sub-section, a ground system of equal requirements covered in this Sub-section shall be provided.

Note: Equipment specifications devised prior to the introduction of the CO GRD system may not include grounding requirements that make use of horizontal and vertical equalizers.

A. An Overview of Power and Grounding Systems

Network equipment and the power and grounding systems that serve them are often a mixture of designs from different eras. Modern equipment may be served by older power and grounding systems and vice versa.

It was once standard practice to connect battery return conductors (also called ground or discharge ground) to bus bars that were in electrical contact with equipment framework. This provided a means to ground the equipment frames by extending the CO GRD system only to critical points in the battery return network. These points were primarily horizontal equalizer connections to the return bus bars of BDFBs, equalizing centers and similar points in distribution systems. The conductors between these points and equipment frames functioned as both a battery return (**grounded**) and framework ground (**grounding**) conductor.

This arrangement also causes dc current (battery return current) flow throughout the huge parallel network formed by the many metallic paths that are part of bonding and grounding networks. The increasing use of more sensitive components often requires designs that separate framework ground from battery return within the equipment. While this separation of battery return and framework ground has been a design requirement for some time, equipment (especially power distribution equipment) designed prior to this prohibition is still in use. Today, there is much less dc current flow on grounding systems in central offices. In the future, there may be none or very little current flow. This will always depend on the design of the power distribution and grounding systems within any given structure.

Another common practice was to place general purpose power plants of different voltages reasonably close together. One plant was chosen as the predominant plant. This was most often the 48-volt plant, since it was generally the one with the greatest ampere capacity.

Some BDFBs served by different plants have fuse panels dedicated to different voltages, but the BDFB is equipped with a single, common battery return bus bar. A battery return conductor calculated to serve as a combined battery return path for all voltages present in the BDFB is provided between the BDFB and the predominant power plant. One or more conductors calculated for voltage drop are provided between the battery return bus bars of the predominant plant and other plants. The bonds serve to complete the battery return path (to the batteries), and to provide ground reference to the other power plant(s).

Some of the arrangements described above are no longer acceptable. While a common battery return bus bar may still be used in a BDFB, the battery conductors from all power plants serving the BDFB and the distribution circuits from the BDFB should be equipped with paired battery return conductors. Also, the bond between two power plants' battery return bus bars should be augmented by a separate conductor to a CO GRD or OPGP bus bar from the battery return bus bar of each plant.

These issues are presented as a reminder that they often must be considered during power and ground system additions, removals and rearrangements.

3.3 DC POWER SYSTEMS

- 3.3.01 DC power plants have been categorized as general purpose plants, special voltage plants, converter plants and in the past, dedicated plants.
- (a) General Purpose Plants are used to provide 24-volt, 48-volt, and 130-volt power to switching, transport, radio and miscellaneous equipment. Individual plants are provided for each voltage and polarity required.
 - (b) Special Voltage plants provide a voltage (i.e., 140 volts) that is suitable for feeding converters, but not normally suitable for direct connection to communication equipment.
 - (c) Converter plants change dc power from one voltage to another, most often from 48 volts to 130 volts.
 - (d) Dedicated plants were used for radio systems and for electronic switches that had specific restrictions against sharing a power plant with other types of equipment.

A. Battery and Converter Plants, DC-DC Converters

3.3.02 The return side of every dc power source shall be referenced to the site's grounding system with a dc system grounding conductor. This applies to all battery plants, converter plants and all converters mounted in equipment frames, cabinets or other enclosures, whether or not the dc source serves loads located in the same enclosure.

Note: Where two or more plants use a combined battery return arrangement, each plant should have a separate bond from its battery return to the CO GRD system.

3.3.03 For battery type plants, the default size for the system grounding conductor shall be 750 kcmil. Using Table 3-1, a smaller conductor may be allowed. Its minimum size shall be based on the maximum plant capacity specified by the manufacturer.

Note: If a battery plant has been assembled from discrete components (batteries, rectifiers, fuse panels, etc.) and has no maximum capacity value, the system grounding conductor shall be based on the combined output rating of all installed rectifiers.

Maximum Plant Capacity (Amperes)	Minimum Size of System Grounding Conductor
up to 100	6 AWG
101 - 500	2 AWG
501 - 1199	4/0 AWG
1200 or more	750 kcmil

Table 3-1
Battery Plant System Grounding Conductor Sizing

3.3.04 When approved for use, power plants and equipment with imbedded power arrangements may use conductor sizes other than those shown in Table 3-1. For such installations, the conductor should be the minimum size specified by the manufacturer of the equipment.

3.3.05 The dc system grounding conductor may be placed directly between a power plant's battery return bus bar and a CO GRD or OPGP bus bar or a point on a 750 kcmil horizontal equalizer. It may also be connected to the CO GRD system by a connection to a Main Ground Bus (MGB) in a ground window.

Note: The conductor between a power plant's battery return bus bar and a CO GRD or OPGP bus bar is considered a part of the horizontal equalizer system. Conductors normally permitted to connect to a horizontal equalizer may terminate on this conductor.

3.3.06 The minimum size of the system grounding conductor for dc-dc converters shall be that shown in Table 3-2, based on the output fault current rating of the converter. The fault current rating shall be the rating of the output overcurrent protective device or the current limit inception value if no protective device is furnished.

Overcurrent Device Rating or Current Limit Inception Not Exceeding (Amperes)	Minimum Size of System Grounding Conductor (AWG)
15	14
20	12
30	10
40	10
60	10
100	8
200	6
300	4
500	2
600	1/0

**Table 3-2
System Grounding Conductor Sizing for DC-DC Converters**

3.3.07 For converter plants consisting of two or more converters with outputs connected in parallel, the size of the system grounding conductor shall be based on the combined fault current available from a fully equipped converter plant as specified by the manufacturer.

Note: When the output of multiple converters embedded in equipment share a common distribution path via backplane layers, conductors or bus bars, the system grounding conductor shall be sized on the combined maximum available fault current.

3.3.08 Some equipment designs use dc-dc converters whose output is referenced to ground via the converter's input battery return conductor. When this arrangement is used, the converter's input battery return conductor shall be no smaller than that required per 3.3.06, 3.3.07 and Table 3-2.

B. 140-Volt Power Plant and Distribution System

3.3.09 The 140-volt plant and distribution system is a special voltage plant that primarily serves converters and converter plants for #4ESS. The converters supply voltages required by the #4ESS equipment. The ground systems of the input and output sides of the converters are isolated from each other.

3.3.10 Single point grounding of the isolated bonding network portion of the 140-volt distribution system is via a minimum #1/0 AWG conductor, and is connected to the 140-volt system from a CO GRD bus on the distribution system's midpoint floor level.

3.3.11 The midpoint floor level is determined on the basis of building floors encompassed in a single 140-volt distribution system. The system may only serve equipment on five floors above and below the midpoint floor on which a bond to the CO GRD bus bar is made.

C. Power System Equipment Grounding

3.3.12 All frames, cabinets and other components of a power plant must be equipped with a minimum #6 AWG bond to the CO GRD system. This includes frames in a power board lineup, rectifier bays, metal battery stands, etc. A typical power area grounding arrangement is shown in Figure 3-1 on Page 3-8.

3.3.13 Framework grounding conductors for power plant frames, cabinets and other equipment shall be branched from a main power plant framework grounding conductor. The main conductor shall be #2 AWG minimum, and shall be connected, in order of preference, to the nearest:

- (a) power plant system grounding conductor
- (b) MGB, when it is part of the plant's battery return bus bar
- (c) CO GRD horizontal equalizer
- (d) CO GRD or OPGP bus bar

3.3.14 For bays containing rectifiers, the minimum size for a framework ground conductor shall be #6 AWG. Table 3-3 shall be used to determine the size of the framework ground conductor based on the size of the output rating of the largest rectifier in the framework.

Rectifier Output Rating (Amperes)	Framework Ground Conductor Size
up to 100	6 AWG
200	4 AWG
400	2 AWG

**Table 3-3
Rectifier Framework Ground Conductor Sizing**

3.3.15 The framework grounding conductor for any dc-to-ac inverter shall be a minimum #6 AWG. Table 3-4 shall be used to determine the minimum size for the framework grounding conductor based on the rating or setting of the dc input circuit's overcurrent protective device. This requirement applies to all stand-alone inverters and to all bay-mounted inverters. This framework grounding conductor is required in addition to the ACEG conductor for the ac input and/or output circuits. If the inverter is the source of a separately derived system, this conductor is also required in addition to the Grounding Electrode Conductor.

Rating/Setting of DC Input Protective Device (Amperes)	Framework Ground Conductor Size (AWG)
up to 100	6
200	4
400	2

**Table 3-4
Inverter Framework Grounding Conductor Sizing**

D. Engine Alternator Equipment

3.3.16 All equipment and metallic objects in an engine room located within a structure must be bonded to the CO GRD system. The minimum arrangement is the same used for grounding equipment in a power room - a minimum #2 AWG main conductor shall be extended from the CO GRD system and routed throughout the engine room(s) to allow minimum #6 AWG branch conductors to be added for equipment and metallic objects.

3.3.17 A small equipment unit that is exclusively ac-powered (tank monitor, etc.) is considered effectively bonded to the CO GRD system via its ACEG conductor.

3.3.18 An engine alternator located in a separate, stand-alone enclosure outside a central office building or other structure may use the ACEG conductor(s) furnished in feeder conduits between the enclosure and the main structure as the bond to the CO GRD system.

3.3.19 Equipment and metallic objects in a remotely located engine alternator enclosure must be bonded together. The preferred method is to use separate bonding conductors, but units may also be considered bonded together if joined by welds, rivets, or other adequate mechanical means.

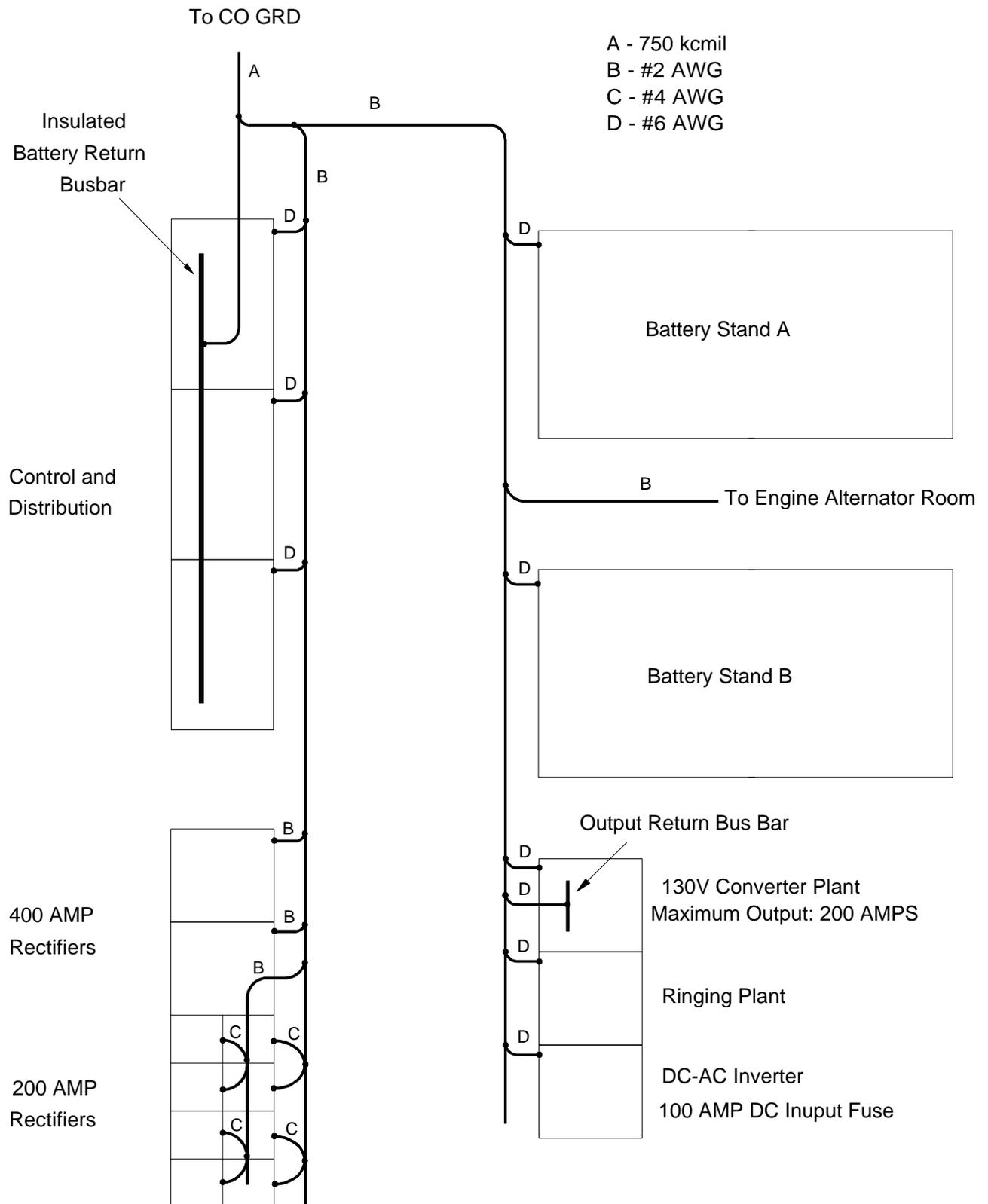


Figure 3-1
Typical Power Area Grounding Arrangement

3.4 POWER DISTRIBUTION SYSTEMS

3.4.01 A variety of equipment and conductor configurations have been used to ground and to distribute dc power to communication systems. As mentioned earlier in this Sub-section, specific grounding requirements for equipment no longer used are in the 802-001-XXX Practices. While some of these equipment systems may no longer exist, all or part of their original grounding and/or power distribution systems may still be in use. All are described below, but only (a) through (d) should be part of new or growth jobs.

- (a) Distribution by means of paired battery and return conductors from power plant distribution bays to power distribution frames (PD, PDC, PCFD, etc.) within electronic switching equipment. From the distribution frames, paired conductors extend to equipment bays. Refer to Sub-section 4 of this Practice for a discussion of typical distribution systems and grounding arrangements.
- (b) Distribution by means of paired battery and battery return conductors from a 140-volt dc power plant (415 type) to area bus centers (ABC) on each equipment floor. Circuits using paired conductors are extended to bulk converter plants and to converters on equipment bays. The 140-volt distribution system is part of an isolated bonding network and contact with the common bonding network is restricted to a single point.
- (c) Distribution by means of paired battery and return conductors from power plants to battery distributing fuse boards (BDFB), by paired conductors to individual equipment bays or lineups, and to centrally located fuse boards.
- (d) Direct distribution by means of paired battery and battery return from power plants to fuse panels in individual equipment bays.
- (e) Distribution by means of paired battery and returns from power plants to centrally located fuse boards. Distribution from fuse boards to load units may be by means of paired battery and returns or by means of individual battery conductors and a common battery return conductor between frame mounted bus bars and the fuse board battery return bus bar.
- (f) Distribution by means of paired battery and battery return conductors from power plants to equalizing centers, then by equalizer conductors along the main aisle of an equipment block. Battery and return conductors are tapped and extended to each frame line in the equipment block. The battery conductor is routed through a 100-ampere fuse at the head of the lineup, extended along the lineup and tapped to feeders connected to fuse panels in equipment bays.
- (g) Distribution by means of paired battery and return conductors from power plants to battery distribution circuit breaker boards (BDCBB). Branch circuits were extended from BDCBBs via paired conductors to radio and other equipment bays. This system was standard for TD-3 and TH-3 Microwave Radio stations.

A. Battery Distributing Fuse Board (BDFB)

3.4.02 BDFBs are used to distribute one or more dc voltages to network equipment. The battery return bus bars on early BDFBs were in electrical contact with the framework of the BDFB. All new BDFBs should have the bus bar insulated from the framework.

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3.4.03 If a BDFB is more than one floor from the floor on which its serving power plant's dc system grounding conductor is connected to the CO GRD system, the BDFB's battery return bus bar shall be connected to the CO GRD system on the floor on which the BDFB is located. The conductor shall be sized at 750 kcmil, and may be connected directly to a CO GRD bus bar or to a 750 kcmil CO GRD horizontal equalizer. Figure 3-2 on the next page shows a single plant serving several floors of both common and isolated bonding network equipment.

Note : Plants with insulated battery return bus bars may be intentionally referenced to ground on a floor other than that containing the power plant. This is preferred if it avoids placing bonds between BDFB battery return bus bars and CO GRD.

3.4.04 The framework ground conductor for BDFBs shall be a minimum #1/0 AWG conductor, and shall be connected directly to a CO GRD bus bar or tapped to a horizontal equalizer of equal or greater size.

3.4.05 When a #1/0 AWG conductor is added between the BDFB framework and a CO GRD bus bar, it may serve other BDFBs as well as other equipment lineups. If more than one BDFB is in a lineup, a single #1/0 AWG conductor may serve every BDFB in the lineup. Where applicable, this conductor may also serve in place of the #6 AWG lineup grounding conductor.

B. Fuse Boards (F BD)

3.4.06 Fuse boards were used in older network equipment systems as an intermediate distribution point. They served units mounted in relay rack bays in the vicinity of the fuse board and were fed either from BDFBs or directly from a power plant. While rare, some are still in use, and the grounding requirements for them have been retained in this Sub-section.

3.4.07 With the exception of F BDs furnished in toll systems, F BDs equipped with battery return buses in electrical contact with the frame need not be bonded to the CO GRD system when the predominant power supply is furnished from a BDFB or a power plant on the same floor, and the length of the battery return conductor from the BDFB is 50 feet or less.

3.4.08 When the F BD receives its predominant supply from a power plant on another floor, or the battery return conductor from the BDFB is longer than 50 feet, a bond between the F BD battery return bus and a point on the CO GRD system is required. It shall be a #4/0 AWG conductor when only one fuse bay is served by the bond. When more than one fuse bay in a floor segment requires bonding with a conductor, a single 350 kcmil bond, run in the most direct manner between F BDs, shall be used to bond them together and to the nearest acceptable junction point to CO GRD.

3.4.09 Miscellaneous fuse boards that are not equipped with a frame ground bus bar or occupy less than a full bay or other frames that contain a fuse panel, and power ringing and tone distribution (PRTD) frames are considered to be adequately grounded through conductive paths inherent in the assembly of the system. These types of power distributing equipment do not require bonding as described previously for the purpose of providing current paths between battery return conductors.

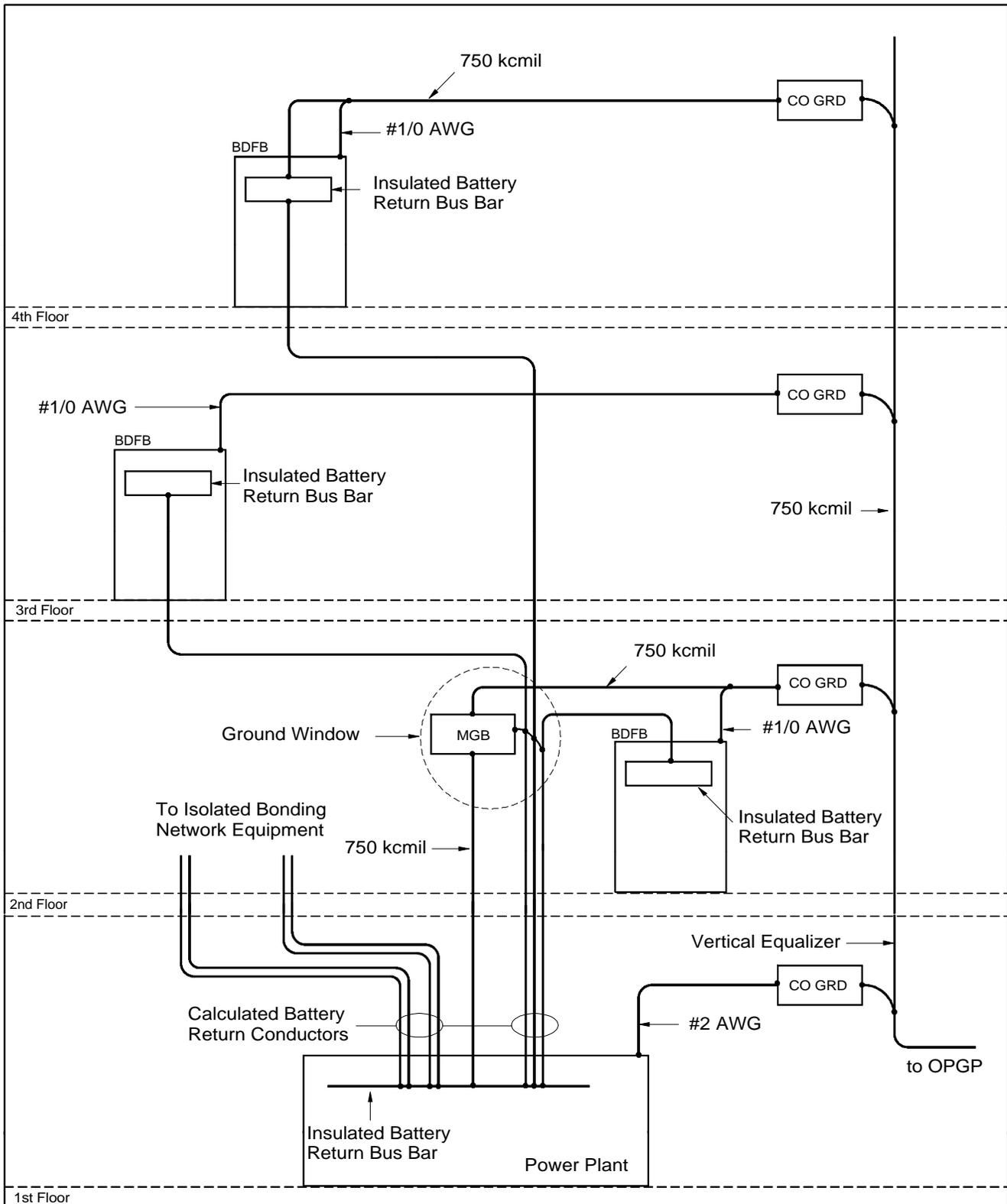


Figure 3-2
Power Plant Serving Both Common & Isolated Bonding Network Equipment
Also shows BDFB Framework and Battery Return Bus Bar Grounding

3.5 COMMUNICATION SYSTEMS & MISCELLANEOUS EQUIPMENT

A. Specific System Requirements

3.5.01 Where specific grounding requirements are included in the specifications of approved equipment, they shall have precedence over the general requirements of this Sub-section. Where specific grounding requirements are not furnished in system specifications or have not been updated to the requirements contained in this Sub-section, a ground system meeting the requirements of this Sub-section shall be provided.

B. Transport Systems and Equipment

3.5.02 Transport systems consist of network transmission elements that link local and toll voice and data switching elements. Transport equipment also provides links between network and Inter-Exchange Carriers and other customers. Today, nearly all transport equipment, whether in a company-owned structure or on customer premises, is located in an area that is part of the common bonding network. These areas contain an assortment of equipment, often in a variety of frames, cabinets, and other enclosures. Any given transport area may contain several generations of technology from a wide assortment of vendors.

Note: While some radio equipment is, by its function, classified as transport equipment, it is covered in Sub-section 6 of this Practice.

3.5.03 There are three requirements that apply to transport and other equipment deployed in the network, regardless of its size, technology, or manufacturer:

- (1) The equipment enclosure must be equipped with a separate bond to the CO GRD system that is capable of safely conducting any fault current likely to be present at the enclosure.
- (2) Every bond to the CO GRD system, both from and within equipment enclosures, must consist of electrical conducting paths that are intentionally designed and provided for the purpose. Unit or enclosure metalwork shall not be used in place of a conductor as part of the path to the CO GRD system.
- (3) The bond from the equipment to the CO GRD system should not be used to conduct normal load current.

C. Miscellaneous Frames, Racks, Cabinets and Units

3.5.04 Every metallic frame, cabinet or other unit in an equipment area shall be bonded to the CO GRD system with a separate conductor. This does not include minor units mounted where they are not normally contacted by personnel (e.g., wall mounted clocks).

Note 1: An enclosure containing only ac-powered equipment is considered effectively bonded to the CO GRD system via the ACEG conductor in the circuit serving the equipment provided the requirements of 2.8.24 have been met. Where such an enclosure may eventually contain dc-powered equipment (e.g., a miscellaneous relay rack), a separate bonding conductor shall be provided.

Note 2: Grounding of metallic circuit pack storage cabinets is covered in PBS-005-300PT, and in SW 010-700-901, both of which are titled *Electrostatic Discharge Control*.

3.5.05 Some early vintage equipment frames and cabinets were equipped with a combination battery return/framework ground conductor, which usually included a bus bar bolted to the top of the frame. This arrangement, called relay rack ground, does not require a separate bond between the framework and the CO GRD system when the requirements given in 3.4.07 and 3.4.08 (for Fuse Boards) have been met.

3.5.06 All equipment units mounted in frames, cabinets or other enclosures should be provided with one or more of the following:

- (a) thread-turning or self-tapping type mounting screws that provide adequate contact between the unit's chassis and the metalwork of the frame or cabinet
- (b) at least one mounting screw equipped with an external tooth type lockwasher (starwasher)
- (c) a chassis grounding conductor termination point

3.5.07 When a unit in a frame, cabinet or other enclosure requires a separate grounding conductor from the unit, it shall be sized per Table 3-2 and connected to one or more of the following:

- (a) a crimp type parallel tap to a grounding conductor of equivalent or larger size within the enclosure
- (b) the same point of connection on the enclosure's metalwork as the framework grounding conductor if of equivalent or larger size
- (c) a grounding terminal (wire-wrap, solder, etc.) within the frame or cabinet
- (d) a crimp type parallel tap to a grounding conductor of equivalent or larger size outside the enclosure

D. Duct Type Framework

3.5.08 Duct type framework is commonly used to mount equipment in transport and other common systems. A pipe (often referred to as a *water pipe*) may be used as a means of support between the framework and the auxiliary framing. This pipe may also be used as the lineup grounding conductor.

Note: The pipe shall not be used as a battery return conductor.

3.5.09 Where more than one pipe section is used in a lineup, the sections shall be bonded together with a #6 AWG conductor.

3.5.10 A frame or cabinet may be bonded to CO GRD via a connection to the pipe using a minimum #6 AWG conductor and 2-hole crimp type connectors. Methods and material such as that shown in drawing ED-3C014-51, Method of Grounding Equal and Unequal Flange Duct Bays, are acceptable.

3.5.11 Early duct type frame designs did not use the #6 AWG conductor from the pipe to the frame. Instead, a set screw through the frame top angle was used to maintain contact with the pipe. This method is not reliable, and if encountered, these bays shall be connected to the CO GRD system using material such as that shown in drawing ED-3C014-51.

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3.5.12 All terminals shall be fastened to the pipe and frame with thread forming screws, such as *Taptite* screws or equivalent. These screws roll their own thread in the metal to form a secure connection. When adding the bond to early vintage framework, the installer may need to drill holes in the pipe and the framework.

3.5.13 Frames that do not use a pipe type support at the top of the frame require a separate conductor from the CO GRD system. It shall be routed along the lineup, usually at the top of the frames, preferably along a cable rack.

Note: When a lineup is served by more than one type of lineup conductor (bus bar, water pipe, separate conductor, etc.) all sections of lineup conductor shall be joined together with a minimum #6 AWG conductor.

3.5.14 The minimum size for a lineup conductor serving one or more frames, cabinets or other enclosures shall be #6 AWG. When a conductor extends CO GRD to more than one lineup, the conductor extending CO GRD shall be minimum #2 AWG.

3.5.15 When a #1/0 AWG conductor serves a BDFB framework in a lineup, it may serve in place of the #6 AWG or pipe type lineup grounding conductor.

E. Other Systems

3.5.16 The preceding descriptions of CO GRD requirements cover the majority of configurations used in power, transport and miscellaneous equipment systems. Other systems and equipment units not mentioned may also require connection to the CO GRD system. This may be accomplished by comparing the physical arrangements to that of the systems described above, and devising comparable arrangements.

F. Bay Ground Lead

3.5.17 A bay ground lead extends CO GRD into frames, cabinets and other enclosures to allow termination of grounding conductors from units and cable shields. The bay ground lead may be a solid or stranded conductor, bus bar, or other conductive path specifically designed as a grounding conductor.

3.5.18 A bay ground lead may not depend on any portion of the enclosure metalwork for a path to CO GRD. It must be connected to the framework ground conductor. This connection should be made using a crimp type connector tapped to the framework grounding conductor. Though less preferable, this connection may also be made using the same hardware that secures the connector used to terminate the framework grounding conductor.

3.5.19 The bay ground lead shall not be used to conduct load (battery return) current.

3.5.20 A stranded bay ground lead (SBGL) is shown on the next page and is ordered per drawing PBS-D-ED-6501. It permits termination of #26 through #6 AWG conductors by means such as crimp connectors, wire wrapping, or wrapping and soldering. It is the preferred method to extend CO GRD into equipment frames, cabinets and other enclosures.

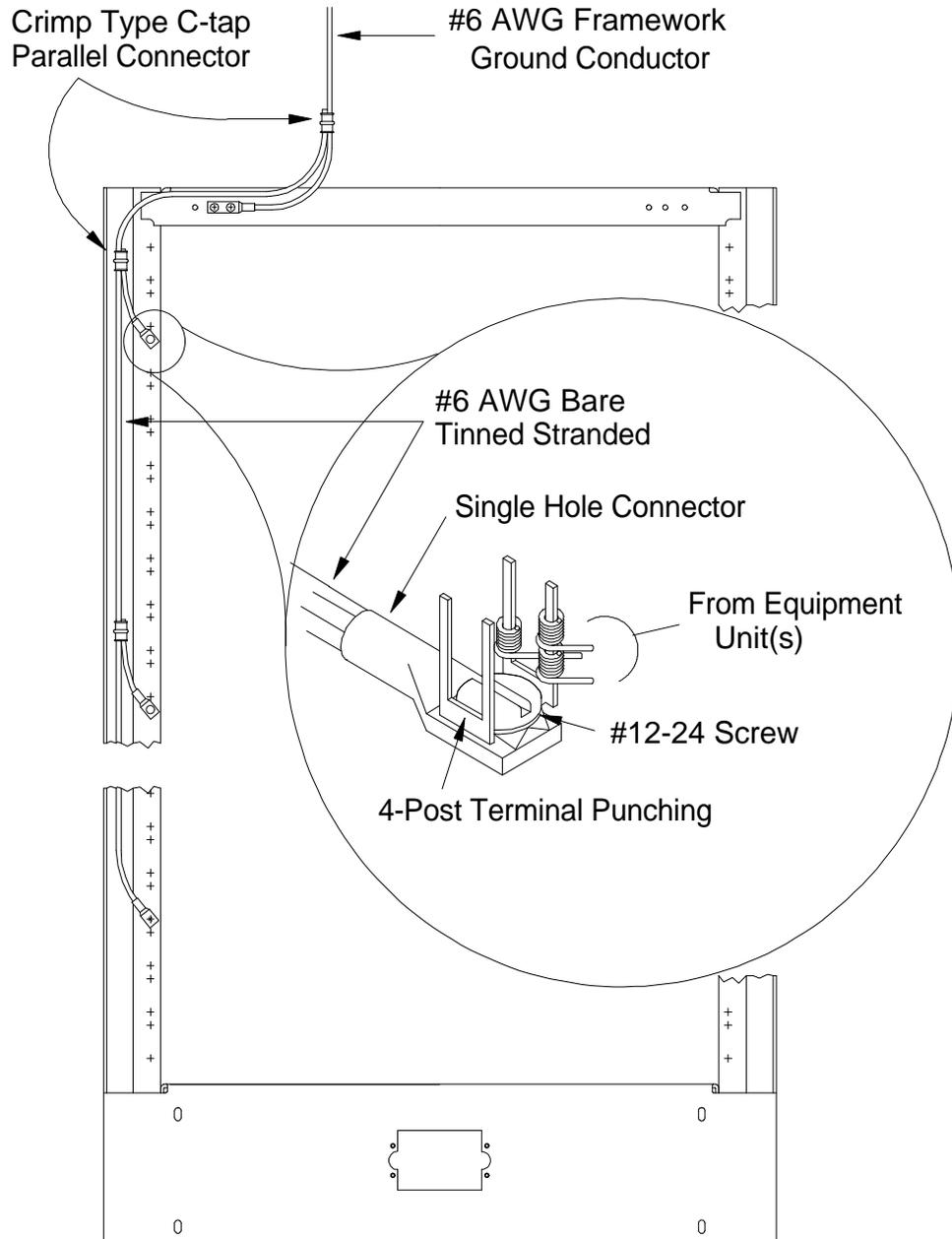


Figure 3-3
Stranded Bay Ground Lead Details

G. Conduits, Armored Cable, Shielded Wire for Other Than AC Service

3.5.21 The grounding of raceways for CO GRD system conductors and for ac service is covered in Part 2 of this Section. Application of inductive shielding of other Communication conductors is covered below.

3.5.22 Rigid conduit or other metallic raceway used solely for support or protection against mechanical damage to communication conductors (i.e., extension from cable rack to a unit) need not be grounded when at least one point of the run is fastened to metal objects such as equipment frames, cable rack, or framing channels that have continuity to ground.

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- 3.5.23 Rigid or flexible metallic conduit or armored cable, when used to reduce the transference of inductive energy shall be bonded to the CO GRD system at least at both ends. Bonds shall be provided across any intermediate points of shield discontinuity unless system specifications provide other bonding instructions.
- 3.5.24 When cables or conductors are equipped with a metallic shield used to reduce the transference of inductive energy, the metallic shield shall be bonded to the CO GRD system at least at one end.
- 3.5.25 Rigid or flexible conduit, armored cable, or other metallic raceway used for inductive shielding is considered adequately bonded when terminated at both ends with fittings approved for ac equipment grounding (ACEG). When such raceway is not so terminated, it shall be bonded from the point of discontinuity to a suitable ground bus, frame, or other point of assured continuity with the CO GRD system. The bond shall be a minimum #6 AWG conductor, except where the shielding raceway is small (1" conduit or less) and not subject to possible physical damage. In such cases, it may be reduced to a reasonable size, but not less than #14 AWG. Several shielding raceways may be bonded together and grounded with a single conductor.

3.6 DISTRIBUTING AND PROTECTOR FRAMES

- 3.6.01 Conventional type distributing frames containing protectors shall be equipped with one or more bus bars having a cross-sectional area no less than that equivalent to a #1/0 AWG conductor (105.6 kcmil or .083 in.²). The bus bar(s) shall be spliced as required to extend to every vertical equipped with protectors.

Note: The most common size bus bar in use is 1/2" x 1/4" (.125 in.²).

- 3.6.02 Bus bars shall be mounted directly to the metalwork of the protector frame, with no insulators placed between the bus bar and the mounting surface.
- 3.6.03 All modular distributing frames equipped with protectors shall have a minimum #1/0 AWG conductor routed along the top and/or bottom of the module lineup, and each module shall be bonded to the CO GRD system as follows:
- (a) If the module consists of or is equipped with only one vertical of protectors, a minimum #6 AWG conductor shall be tapped, using a crimp type parallel connector, to the #1/0 AWG lineup conductor and connected to the module with a two hole crimp type connector.
 - (b) If the module has more than one vertical of protector units, a minimum #1/0 AWG shall be tapped, using a crimp type connector, to the #1/0 AWG lineup conductor and connected to the module with a two hole crimp type connector.

Note: A copper bus bar may be used in place of the #1/0 AWG lineup conductor if it has a cross sectional area at least that of a #1/0 AWG conductor.

- 3.6.04 A minimum #1/0 AWG conductor shall be extended from a frame ground bus bar, be tapped to or be a continuation of a #1/0 AWG protector frame lineup conductor. This conductor shall terminate at the OPGP, or if on a floor other than that containing the OPGP, to a CO GRD bus bar. The length of this conductor shall be as short as practicable.

3.6.05 A distributing frame equipped with a bus bar connected to the CO GRD system requires no additional grounding. When a grounded bus bar is not provided, the frame shall be bonded to the CO GRD system with at least one minimum #6 AWG conductor.

3.6.06 When all or part of a distributing frame not having a ground bus bar exceeds 25 feet in length, additional bonds to the CO GRD system should be made at 25-foot intervals. The bonds may be connected to the ground conductor serving a nearby protector frame, or may be terminated at any extension of the CO GRD system within the common bonding network. Multiple bonds may be branched from a single minimum #2 AWG conductor extended from a point on the CO GRD system.

3.7 CABLE ENTRANCE FACILITY (CEF)

3.7.01 The metallic shield of a cable entering a structure shall be bonded to the structure's ground system. In central office cable vaults, this bond is usually made at the point designated as the protection bay. Refer to the 638-XXX-XXX layer of Practices for the applicable methods and procedures.

3.7.02 The Main conductor serving a CEF shall be #1/0 AWG minimum. Branch conductors between the Main conductor and cable shields are typically a minimum #6 AWG conductor or a conductor of equivalent cross-sectional area. Refer to the 638-XXX-XXX layer of Practices for the applicable methods and procedures.

3.7.03 The far end of the #1/0 AWG Main conductor shall terminate on the nearest of either an OPGP bus bar, a CO GRD bus bar or a protector frame ground bus bar

3.7.04 A second #1/0 AWG conductor, bonded to the #1/0 AWG Main conductor, is needed to satisfy requirements for Interbonding in 2.4 B. of this Practice. This conductor shall be supplied for all new structures, and added to existing structures during additions or upgrades to the building ground system.

3.7.05 The metallic shield of cables entering a structure shall be bonded to the metalwork of the protector or distributing frame at which the cable conductors terminate.

3.7.06 If metallic raceway is used to route a cable from a CEF to another location, the raceway shall be bonded to CO GRD at both ends. At the CEF end, the bond from the raceway should terminate on the #1/0 AWG serving the CEF or to an extension of this conductor. The other end should be bonded to the nearest appearance of CO GRD in the common bonding network.

3.8 CABLE REARRANGEMENT FACILITY

3.8.01 The grounding requirements for Cable Rearrangement Facility (CRF) cabinets are similar to the requirements in 3.7 above. The requirements apply to all CRF cabinet installations, including those in CEVs, SLC huts and Central Offices.

3.8.02 Where no more than a single CRF cabinet will be installed, a minimum #6 AWG conductor is required between the cabinet and the structure's principal ground point.

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3.8.02 Where multiple CRF cabinets are (or will be) installed, a minimum #1/0 AWG conductor shall be provided from the structure's principal ground point to the area above or below the CRF cabinets. If the CRF cabinets are located on a floor above or below the floor containing the principal ground point, the #1/0 AWG conductor may terminate on the floor ground bar if a direct route to the principal ground point is not available.

3.8.04 In a Central Office or other structure that also contains a protector frame, it is permitted to terminate the #1/0 AWG conductor at the protector frame if it is in the cable path between the CRF cabinet area and the OPGP. If the protector frame is used, the #1/0 AWG from the CRF cabinet area can terminate on the bus bar usually located at the top and/or bottom of the frame, typically at Vertical 1. The #1/0 AWG conductor from the CRF area may also be tapped to the #1/0 AWG conductor routed between the protector frame and the principal ground point.

3.8.05 When multiple CRF cabinets are installed, a separate minimum #6 AWG conductor is required between each cabinet and the #1/0 AWG conductor. The design of the CRF cabinet will determine the point(s) available to terminate the #6 AWG. Some CRF cabinets will have a ground bus bar at the top of the cabinet and an auxiliary ground bar located midway down the front of the cabinet. Others will only have the ground bar at the top of the cabinet. Either location is acceptable.

3.8.06 When interbonding is applied to a structure, a minimum #1/0 AWG conductor shall be connected between the main house service panel and a point on the #1/0 AWG conductor serving the CRF area.

3.9 FIBER OPTIC CABLE TERMINATION EQUIPMENT

3.9.01 The metallic shield and, if present, metallic strength member of all fiber optic cables shall be bonded at the CEF per 3.7 above. If the cable entering the CEF is spliced to a cable with no metallic members, no additional grounding of the cable is required at the fiber optic terminating equipment. If a fiber optic cable with any metallic member is extended to the fiber optic terminating equipment, supplemental bonds to the CO GRD system shall be installed as described in 3.9.02 thru 3.9.05 and as shown in Figure 3-4.

3.9.02 A minimum #1/0 AWG insulated conductor shall be routed along the lineup(s) containing fiber optic cable terminating equipment. The conductor may be routed, spliced, or tapped to serve more than one lineup. It shall originate at the nearest of either:

- (a) an OPGP bus bar
- (b) a CO GRD bus bar
- (c) a protector frame ground bus bar
- (d) a point on the #1/0 conductor connected between a protector frame and an OPGP or CO GRD bus bar

- 3.9.03 A #6 AWG insulated stranded copper conductor shall be tapped to the #1/0 AWG conductor and extended down the rear of the frame containing fiber optic terminating equipment. This conductor may be placed on either side (or both sides) of the rear of the frame and should extend to a point approximately 18" up from the floor. This conductor shall be routed near and tapped to the #6 AWG framework grounding conductor using a crimp type connector.
- 3.9.04 All fiber optic cable metallic shields and metallic strength members shall be bonded to the vertical #6 AWG conductor using a #6 AWG bond.
- 3.9.05 As an alternative, the vertical #6 AWG conductor bonded to the #1/0 conductor may terminate on a bus bar mounted in the frame. Bonds from metallic cable shields and strength members may terminate on this bus bar.

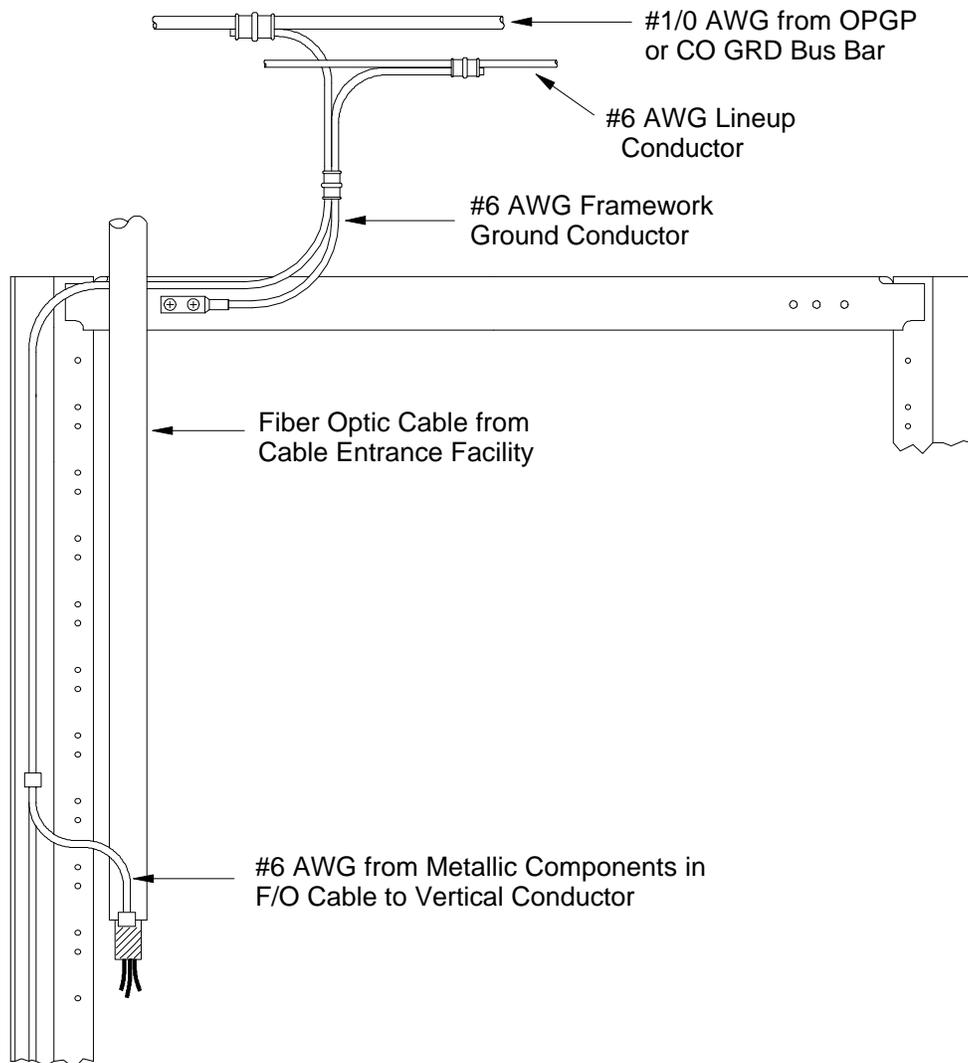


Figure 3-4
Bonding of Metallic Components in Fiber Optic Cable

3.10 NETWORK EQUIPMENT ON RAISED FLOORS

A. General

3.10.01 The requirements and recommendations in 3.10 A. – H. provide a grounding system for network equipment located on a raised floor. The requirements apply to raised floor areas containing network elements such as power, switching and transport equipment. Grounding requirements for raised floor areas containing operational support system computers, maintenance terminals, and attended position equipment are in 4.12 and 5.3 of this Practice.

3.10.02 The requirements in 3.10 A. – H. presume the raised floor support structure conforms with the design requirements of PBS-000-103PT, *Technical Requirements for Raised Floor Systems - Network Equipment Application*. Additional evaluation may be required if any of the following are **not** part of the overall design:

- (a) All equipment in the raised floor area is served by primary dc distribution circuits protected by overcurrent devices rated or set at no more than 600 amperes.
- (b) All cable racks between the raised floor area and other parts of the central office are metallic, and the stringers for each cable rack have a combined cross-sectional area of .582 in² minimum.
- (c) All raised floor support structure components and cable rack sections are interconnected by a permanent means such as welding, or a mechanical means, such as approved junctioning hardware that provides electrical continuity between all components.
- (d) Cable racks are elevated from the floor a sufficient distance to allow all grounding conductors to be run and secured using conventional methods and to permit the grounding conductors to pass under cable rack intersections.

3.10.03 Except as changed by requirements in 3.10 A. – H., all other requirements in this Practice shall be met.

B. Horizontal Equalizer Conductor

3.10.04 The requirements in 3.10 A. – H. presume that a CO GRD bus bar has been mounted in a central location and is connected to the OPGP with a 750 kcmil vertical equalizer conductor. The CO GRD bus bar should be mounted at least 12" above the raised floor

Note: In single story buildings, even though most of it is run horizontally, the conductor between the OPGP and a CO GRD bus bar is also called a vertical equalizer.

3.10.05 Originating at the floor CO GRD bus bar, a horizontal equalizer conductor shall be installed under the raised floor area and shall be sized as follows:

- (a) If all power plants serving equipment in the raised floor area have their battery return bus bars (also called discharge ground bars) connected to the CO GRD system on the same floor or within one floor of the raised floor area, the horizontal equalizer conductor shall be #1/0 AWG minimum.

- (b) If any power plant serving equipment in the raised floor area has its battery return bus connected to the CO GRD system more than one floor from the raised floor area, the horizontal equalizer shall be 750 kcmil minimum.

Note: If the Ground Window and its main ground bus (MGB) are located in the raised floor area, it may be convenient to use the conductor (or a portion of it) between the CO GRD bus bar and the MGB as the horizontal equalizer.

3.10.06 The horizontal equalizer shall be placed along one side of a main aisle cable rack serving the common bonding network equipment area. The preferred location is the side that provides the shortest bonds to BDFBs.

3.10.07 If more than one main aisle exists, the horizontal equalizer shall be branched to serve other main aisles.

Note: Branches serving other main aisles may originate at a point on the initial horizontal equalizer, or directly at the CO GRD bus bar, whichever provides the shortest route between the CO GRD bus bar and the equipment served.

C. Isolated Bonding Network Equipment

3.10.08 All conductors, connectors, frames, cabinets, and other metallic objects that are part of an isolated bonding network shall be insulated from contact with common bonding network objects. Unless special arrangements are provided, objects in a raised floor area that are always considered part of the common bonding network include:

- (a) raised floor pedestals, stringers, and tiles (all surfaces)
- (b) cable rack sections
- (c) all suspended ceiling components, including support structure, light fixtures, and air ducts
- (d) all metallic conduits and raceways serving common bonding network equipment

3.10.09 Isolated bonding network equipment shall be grounded per equipment system requirements and/or the requirements in Sub-section 4 of this Practice.

D. Common Bonding Network Equipment

3.10.10 Lineups that contain common bonding network equipment shall be equipped with a minimum #6 AWG stranded copper conductor routed along the side of the lineup cable rack that faces the front of the equipment lineup. This conductor shall originate at the horizontal equalizer or a conductor extended from it, or from a CO GRD bus bar.

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3.10.11 All common bonding network equipment frames, cabinets and other enclosures shall be equipped with a minimum #6 AWG framework ground conductor connected between the lineup conductor and a point at either the top or the bottom of the frame or cabinet. See Figure 3-5, method ①.

3.10.12 On frames, cabinets or other enclosures using a stranded bay ground lead (SBGL), the #6 AWG framework ground conductor should be C-tapped to a point on the lower portion of the SBGL's bare #6 AWG conductor. The top end of the SBGL conductor should terminate at the framework ground point at the top of the frame, cabinet or other enclosure. See Figure 3-5, method ②.

3.10.13 If a factory-equipped frame uses another arrangement (wire, bus bar, etc.) that is similar to a SBGL and is equal in cross-sectional area (26,240 circular mils), it may be used as in 3.10.12 to provide continuity to the framework ground point at the top of the frame or cabinet.

3.10.14 The framework of every BDFB shall be grounded with a #1/0 AWG conductor as described in 3.4 A. of this Sub-section.

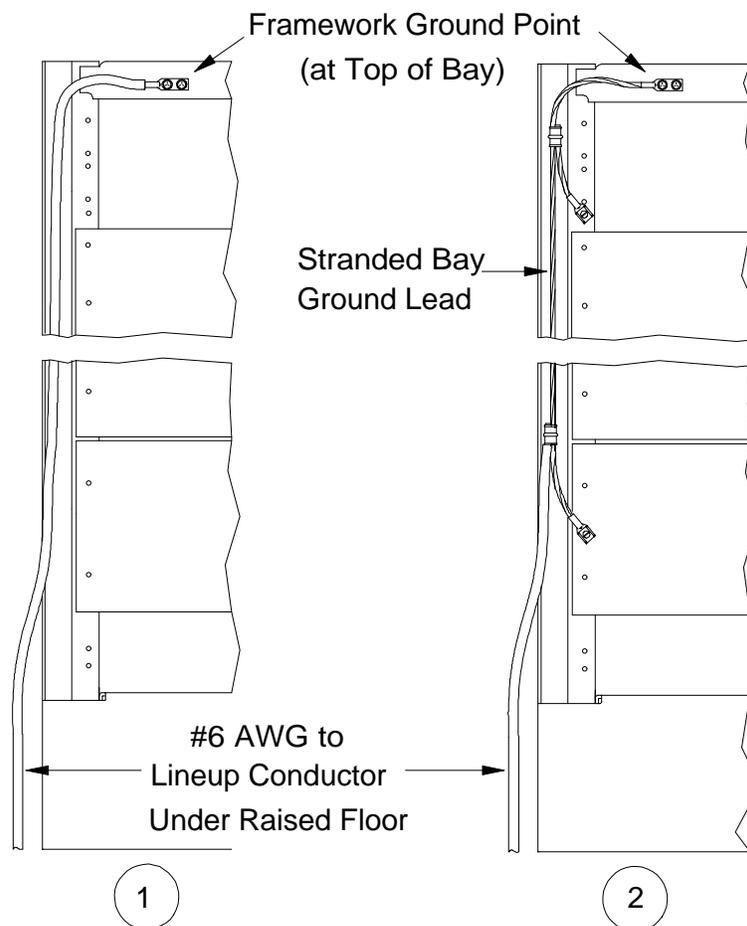


Figure 3-5
Methods of Connecting Between Lineup and Framework Ground

E. Cable Rack Bonds

3.10.15 Cable rack sections are considered adequately bonded when mechanically joined to the raised floor support system *and* approved junctioning hardware is used on both stringers at cable rack splices and both stringers of an intersecting rack

3.10.16 When any section of cable rack is not joined together and to the raised floor support structure per 3.10.15, it shall be bonded by one or a combination of the following:

- (a) a bond at each end of the cable rack section to the adjoining section of cable rack using a minimum #1/0 AWG conductor
- (b) a bond at each end of the cable rack section to the nearest point on the raised floor support system or CO GRD conductor using a minimum #1/0 AWG conductor

3.10.17 When an arrangement consisting of more than one cable rack section is not mechanically joined to the raised floor support system, the cable rack sections shall be bonded together per 3.10.16 (a) and the entire arrangement shall be bonded to the raised floor support system using a minimum of four #1/0 AWG bonds. The four bonds shall be equally spaced throughout an approximate 20' x 20' area. When a cable rack arrangement covers an area greater than 20' x 20', additional bonds shall be provided. Typical cable rack bonding is shown below.

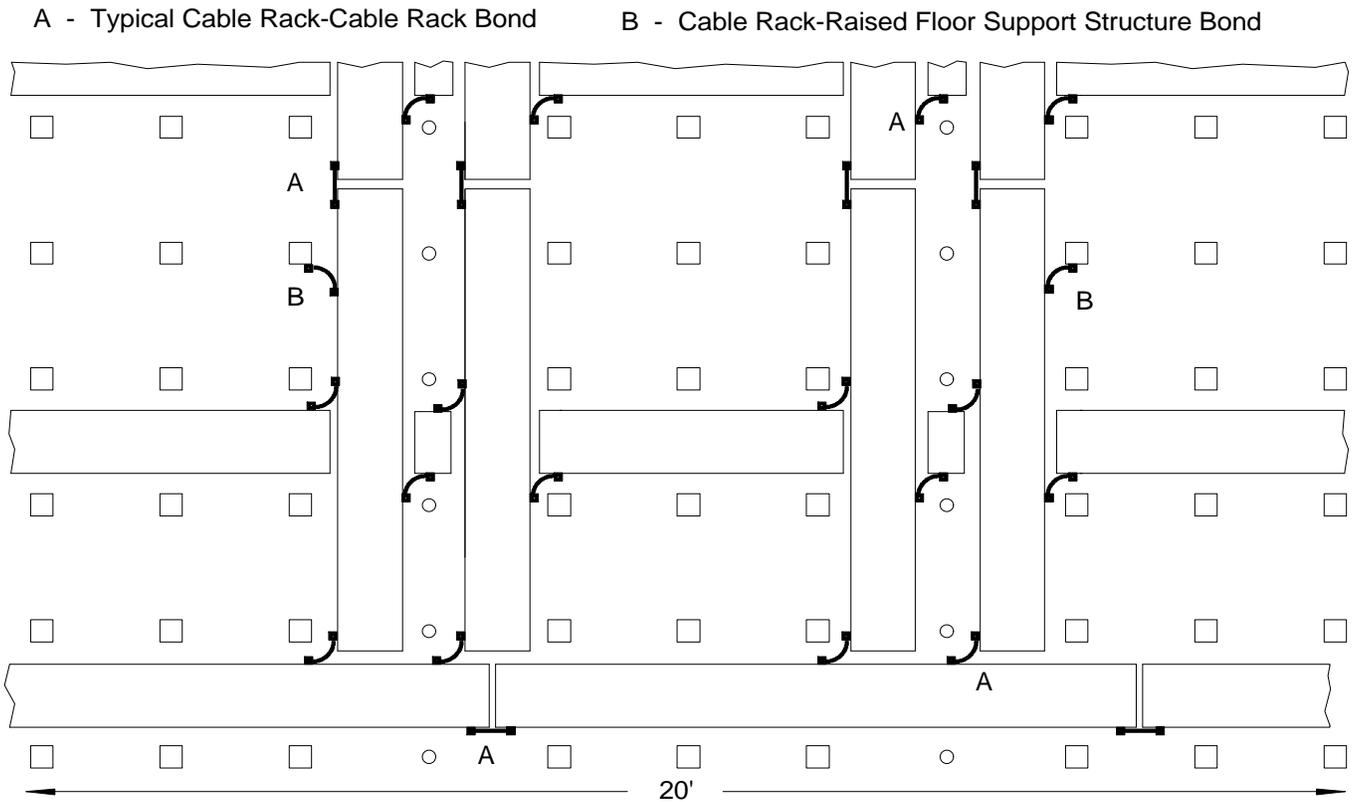


Figure 3-6
Typical Bonding Required When Cable Rack is Not Secured to the Raised Floor Support Structure

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3.10.18 Cable rack between overhead ironwork and the raised floor area shall be made mechanically continuous from the raised floor area to the first point of support in the overhead ironwork. A minimum #1/0 AWG bond shall be used to bridge any point of discontinuity in the cable rack run.

F. Power Plant Area Grounding & Bonding

3.10.19 Whether power plant frames, cabinets, battery stands, etc., are secured to a raised floor system or to the building floor, they shall be grounded per applicable requirements in 3.3 C. of this Practice.

3.10.20 Power cable racks between the power plant and the raised floor area shall have continuity to the power plant's framework ground system by either:

- (a) the mechanical interconnection of cable rack, supporting ironwork, and the power plant equipment frames, or
- (b) a bond between each run of cable rack and the main power plant framework ground conductor using a minimum #2 AWG conductor.

G. Bonds to Other Metallic Objects

3.10.21 Except for isolated bonding network objects, all metallic objects not specifically mentioned in this document that enter the raised floor area shall have continuity with the raised floor support structure. This continuity shall be provided by either:

- (a) approved junctioning hardware that mechanically joins the object to the raised floor support structure, or
- (b) a minimum #6 AWG bonding conductor connected to either a CO GRD conductor or a metallic member of the raised floor support structure.

Note: For ac conduits and other raceways containing ac circuits, the continuity is provided by the ac equipment grounding (ACEG) conductor required by Sub-section 2 of this Practice, and no additional bonding is required.

3.10.22 If a raised floor area contains only isolated bonding network equipment, a minimum #1/0 AWG bond shall be provided between a point on the raised floor support structure and the CO GRD system on that floor.

Note: In raised floor areas with common bonding network equipment, this bond is provided by the framework grounding conductors.

3.10.23 If a raised floor area in a room adjacent to the network equipment area is of a different construction than specified in PBS-000-103PT, it shall be grounded per requirements in Sub-section 4 or 5 of this Practice. The grounding conductor serving such an area may be extended from a CO GRD conductor serving the raised floor area containing network equipment.

H. Routing and Securing Grounding Conductors

3.10.24 Wherever practicable, grounding conductors shall be routed and secured to the side of cable racks. If permitted by the equipment vendor, intra-equipment grounding conductors may be routed on cable racks or in cable troughs reserved for power conductors.

3.10.25 Where grounding conductors must be routed on the floor, they shall be secured to each pedestal along their route with a cable tie or sewing twine.

Sub-section 4

Isolated Bonding Networks for Network Equipment Systems, Data Processing/Operational Support Systems Equipment

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4.1 SCOPE

4.1.01 This Sub-section contains requirements for network equipment and other systems that are installed in a single point ground environment. It includes requirements common to all systems of this type and provides information on acceptable design variations. It also covers computer equipment that incorporates some or all of the single point ground design features.

4.2 GENERAL

4.2.01 Most network switching equipment systems are of the stored program control system (SPCS) type, and are commonly referred to as *electronic* systems. Other equipment systems may be of similar design, including SS7 equipment, packet switching equipment and certain computers used in operational support systems and network adjuncts.

4.2.02 Electronic systems may be vulnerable to damage from voltage disturbances created by power utility switching transients, lightning strokes, and other surge producing conditions. They contain devices that can be damaged by transients that exceed the device's typically low breakdown voltage ratings. Inductive coupling between circuit paths can cause inadvertent operation of some devices. Ground references can be forced to different levels in different areas of a ground plane during a current surge. These and other characteristics of electronic systems often require the use of a single point ground system to mitigate voltage disturbances.

4.3 TERMINOLOGY AND CONCEPTS

A. Single Point Ground

4.3.01 Systems that are single point grounded allow no contact between ground references in the single point ground area and grounded objects outside the single point ground area except at one location. To accomplish this in equipment systems, the equipment is insulated from contact with metallic objects outside the single point ground area, and every conductor (wire, conduit, cable shield, etc.) connected to a ground reference in both the single point ground system and any point outside the single point ground system is routed through a unique transition area. This is intended to prevent stray currents generated outside the single point ground area from disrupting equipment located inside the single point ground area. The transition area is an imaginary sphere called a **ground window**. In our Company, this sphere has a maximum diameter of six feet. Within the ground window, a means is provided to bond all grounding conductors together at a single point. This "point" is a bus bar (or a portion of a bus bar) called the **main ground bus** (MGB).

4.3.02 As used in this Practice, the actual *circuit* within the single point ground boundaries includes the framework, logic ground, battery return, and any other points within an equipment system that are referenced to earth ground. In other equipment, a single point ground system may be established within an equipment unit, or it may only be a single layer of a circuit pack's backplane or a single trace in an integrated circuit. A circuit may obtain its ground reference from a branch of another single point grounded circuit.

Note: When this arrangement was used in the first electronic switching system, the term **isolated ground** was used to distinguish the switch's single point ground system from the surrounding common bonding network.

B. Isolated Ground

4.3.03 The term isolated ground is used more often than *single point ground*, even though both terms describe the same concept. Unfortunately, isolated is sometimes thought to mean *totally separated*, when a more appropriate definition is *unique*. The important point is that isolated ground systems **always** have a bond to a structure's ground system.

Note: Only under certain conditions is a power system allowed to operate without connection to a structure's ground system. The correct description for this type of system is *ungrounded*, not isolated. Discussion of ungrounded systems is not included in this Practice.

C. Isolated Bonding Network

4.3.04 All components referenced to ground at a single point reside in an isolated bonding network. When two or more equipment systems are connected to the same MGB, they are not separate isolated bonding networks, they are separate *entities* within the same isolated bonding network and are referenced to the common bonding network at the same point.

Note: Isolated bonding network is now used in place of *Isolated Ground Plane*, and the term **common bonding network** is now used in place of *Integrated Ground Plane*.

D. Ground Window

4.3.05 The ground window is an imaginary sphere with a maximum diameter of 6 feet. It may be helpful to picture it as a set of boundaries that defines the physical limits of the main ground bus (MGB), which is the actual interface between an isolated bonding network and a building's common bonding network. The diameter of the ground window ensures that the MGB provides the desired electrical environment while furnishing enough room to terminate a fairly large number of conductors. The size of the ground window also helps limit the length of bonding conductors between the MGB and objects passing through the ground window, thus providing a relatively low impedance shunt.

Note: The term *ground window* has been used as though it is interchangeable with *MGB*, even to the point where the MGB has been stenciled "Ground Window". These two terms define different objects and should be used appropriately. Because it is the physical point of connection (a bond can't be made to an imaginary object), *MGB* is the most appropriate term to use when discussing engineering, material, and installation requirements. See 4.4 A. and 4.4 B. below.

4.3.06 Some of the key elements of an isolated bonding network and its association with the common bonding network are shown in Figures 4-1 and 4-2. The difference between these figures is the location of the ground window and its MGB. The ground window in 4-1 is considered a "remote" ground window, the one in 4-2 is located at the power plant. A more detailed explanation of these and other arrangements, including specific requirements, are provided in the remaining text of this Sub-section.

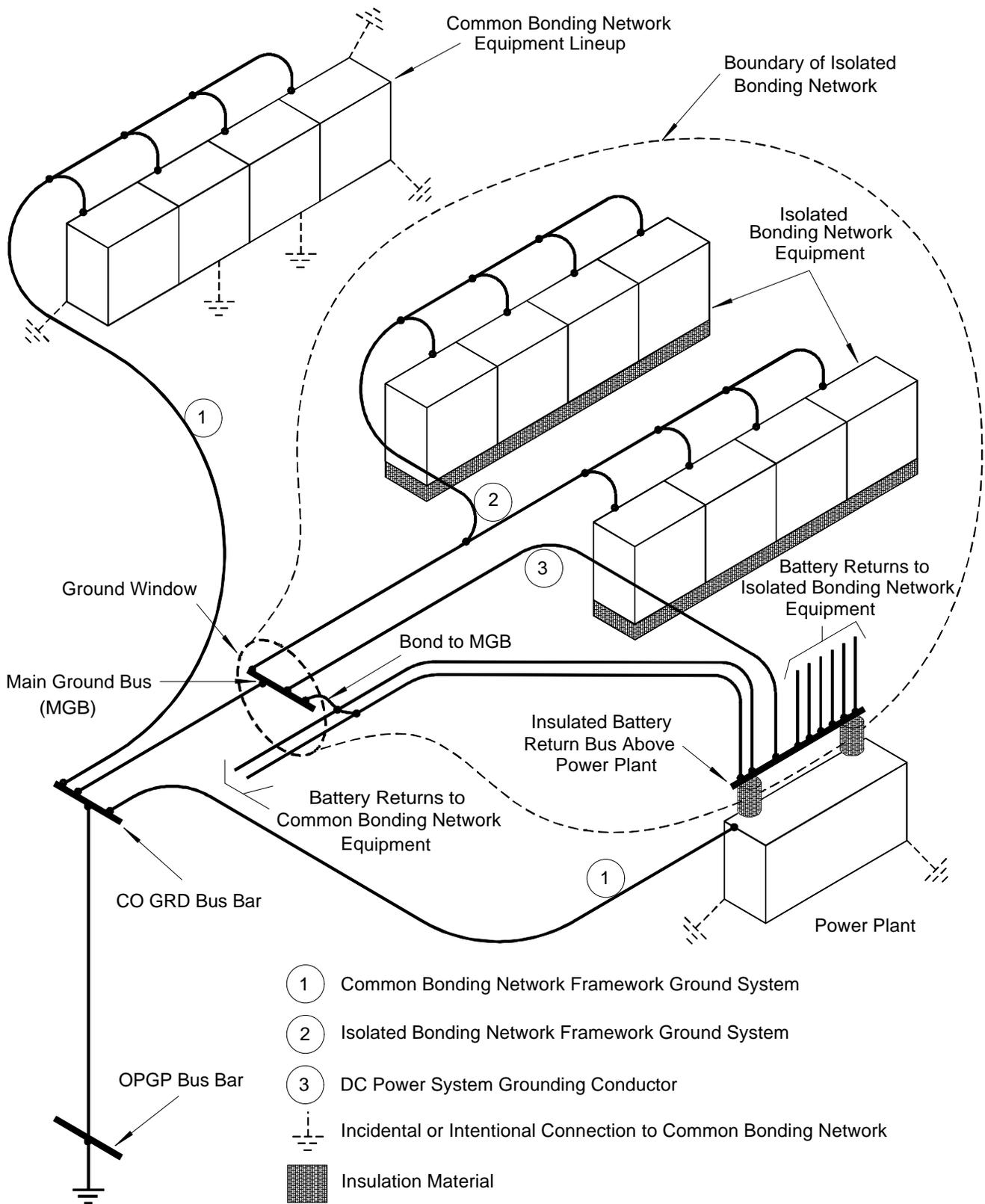


Figure 4-1
Relationship Between Common and Isolated Bonding Networks
(Ground Window is located remote from equipment and power plant)

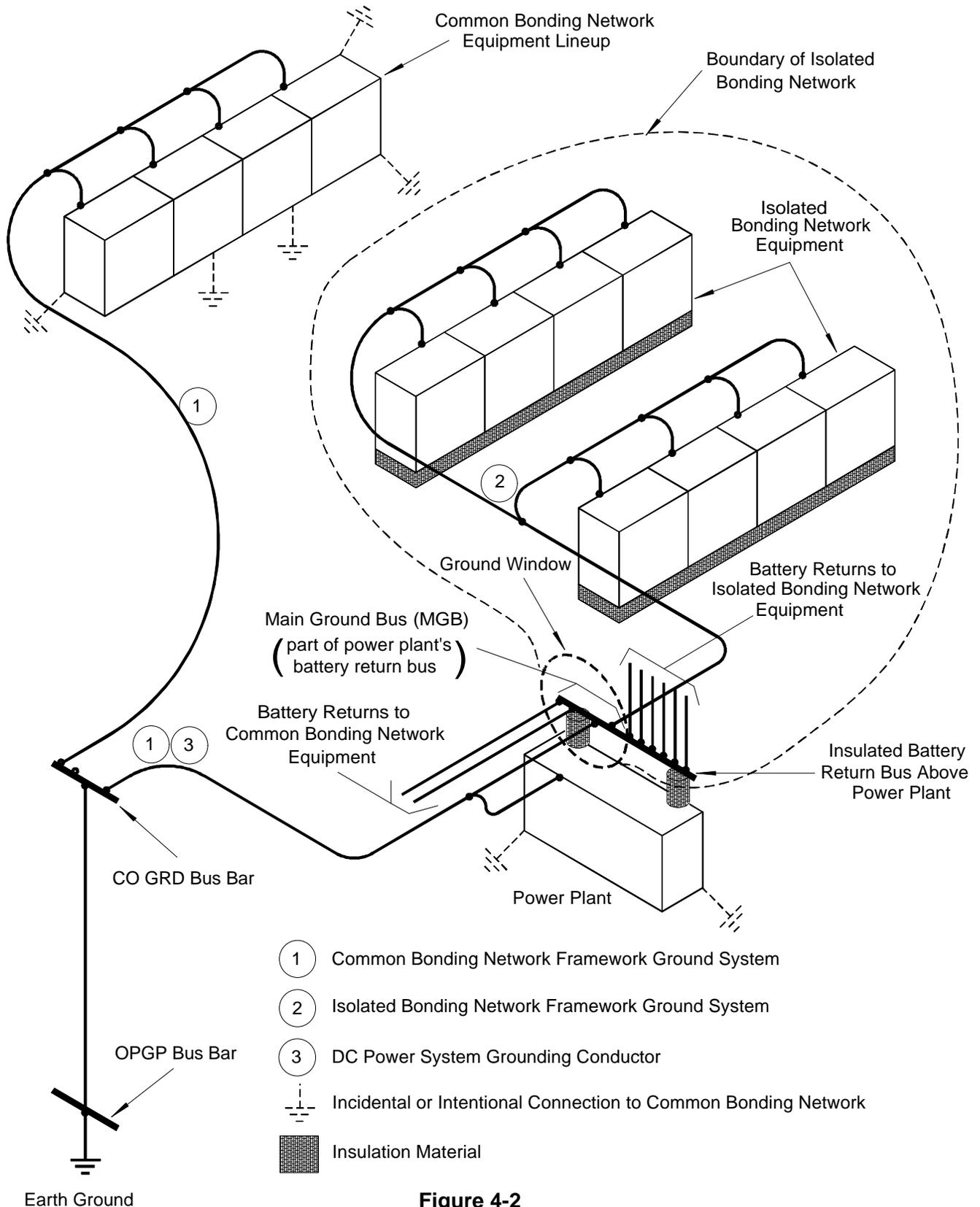


Figure 4-2
Relationship Between Common and Isolated Bonding Networks
 (Ground Window is located above power plant)

4.4 MAIN GROUND BUS (MGB)

A. Common Requirements

4.4.01 All components of an isolated bonding network equipment system shall be referenced to ground only via the MGB.

Note: There are no restrictions on connections to grounded objects in the common bonding network after a conductor passes out of the isolated bonding network through the ground window and has been bonded to the MGB.

4.4.02 Under no circumstances shall any isolated bonding network equipment be located more than one floor above or below the floor containing the MGB. The MGB may serve equipment located on three adjacent floors only if the MGB is located on the middle floor.

4.4.03 Bonding conductors between an MGB and equipment located on the same or an adjacent floor shall be the largest of either the equipment vendor's specifications or the requirements in 4.7 A. thru 4.7 C. below.

4.4.04 The bus bar (or portion of it) used for the MGB shall be copper except when the MGB is part of the battery return bus in a power plant using aluminum bus bars. The MGB bus bar or that portion of a bus bar used as the MGB should be sized per site conditions, but shall not extend beyond the 6-foot maximum diameter of the ground window.

Note: The simplest form of an MGB is a straight section of bus bar. This arrangement was commonly used in analog electronic switching systems where the MGB was actually the battery return bus bar above (or below) the first power distribution bay in the switch, typically PD-0.

4.4.05 The MGB may be mounted on cable rack, a column, a wall or any other location that provides adequate cable access.

4.4.06 The hardware securing the MGB must provide electrical insulation from any metallic object to which it is mounted. Although a bond is required between the MGB and nearby metallic objects, the connection is made at a specific location on the MGB. This location is controlled by the sequencing requirements provided in 4.5.12 below.

4.4.07 The MGB should be identified with minimum 3/4" letters by way of stenciling or a designation plate. The designation should be located so that it is easily visible from the floor. The designation may be directly on the bus bar or on the supporting cable rack or ironwork adjacent to the MGB. See 4.5.06 and Figures 4-4 and 4-5 for the acceptable arrangement when an MGB is part of the battery return bus bar in a power plant.

B. Connection to CO Ground

4.4.08 The MGB shall be bonded to the closest of either an OPGP bus bar or a CO GRD bus bar serving the floor on which the MGB is located.

Note: The 750 kcmil conductor between an MGB and a CO GRD or OPGP bus bar is considered a part of the horizontal equalizer system. Conductors normally permitted to connect to a horizontal equalizer may terminate on this conductor.

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4.4.09 The default size for the conductor between the MGB and a CO GRD or OPGP bus bar shall be 750 kcmil. A smaller conductor may be used, depending on the capacity of the power plant serving the isolated bonding network equipment. Table 4-1 shall be used to select the minimum size of the conductor using a Plant Capacity value that is the maximum possible for the type of power plant used.

Maximum Plant Capacity (Amperes)	Minimum Size of System Grounding Conductor
up to 100	6 AWG
101 - 500	2 AWG
501 - 1199	4/0 AWG
1200 or more	750 kcmil

Table 4-1

Minimum Size of Conductor Between MGB and CO GRD

4.4.10 Some equipment/power plant arrangements may use conductor sizes other than those shown in Table 4-1, for example some remote switching equipment systems. For all installations, the conductor shall be the minimum size specified by the manufacturer of the isolated bonding network equipment.

4.5 MAIN GROUND BUS LOCATIONS

A. MGB Located in Equipment Area

4.5.01 The MGB may be located above or below a power distribution frame in an equipment area. If permitted by the equipment manufacturer, it may be the same bus bar used to terminate battery return conductors from the power plant.

4.5.02 In some isolated bonding network systems, the power distribution frames are cabled from below and have battery and battery return bus bars mounted above the cable rack near the ceiling on the floor below the equipment. For the purpose of determining maximum floor separation between an MGB and parts of an isolated bonding network, the MGB is considered to be on the floor on which it is located.

Note: In a building of more than two stories (including basement), this may be important when planning the placement of the power plant, the MGB, and the equipment served.

B. MGB at Power Plant with Insulated Return Bus

4.5.03 When a power plant's battery return bus bar is insulated from the power plant's framework or supporting ironwork, a portion (up to 6 feet) of the bus bar may be used as the MGB. The plant's battery return bus bar may be a straight section of bus bar or it may be a stacked arrangement. Examples are shown in Figure 4-4.

4.5.04 When the battery return bus bar of the power plant consists of one or more straight sections of bus bar longer than six feet, the MGB may be established at any point along the bus bar. See details 1A and 1B in Figure 4-4. Battery return conductors serving common bonding network loads shall be terminated on the battery return bus bar within the boundaries of the MGB. Battery return conductors for isolated bonding network loads shall be terminated on the remaining portion(s) of the battery return bus bar.

4.5.05 To determine which part of the battery return bus bar is used as the MGB when a stacked bus bar arrangement is used, consideration must be given to:

- (a) the ampacity of all bus bars and their interconnecting details
- (b) the location on the bus bar for the plant's grounding conductor (from a CO GRD or OPGP bus bar)
- (c) the termination points for all other conductors - this is called *sequencing* and is described in 4.5.D, below

4.5.06 That portion of the battery return bus bar used as the MGB should be identified using stenciling or an identification plate as described in 4.4.07 above. Lines and Arrows should also be used to identify the boundaries of the MGB. See Figures 4-3 and 4-5.

Note: In the past, some bus bar arrangements have had one part stenciled *ISOLATED* and another part *INTEGRATED*. Most often, the part stenciled *INTEGRATED* is actually the MGB, and when appropriate, the stenciling should be corrected.



Figure 4-3
Designation of MGB When it is Part of a Power Plant's Battery Return Bus

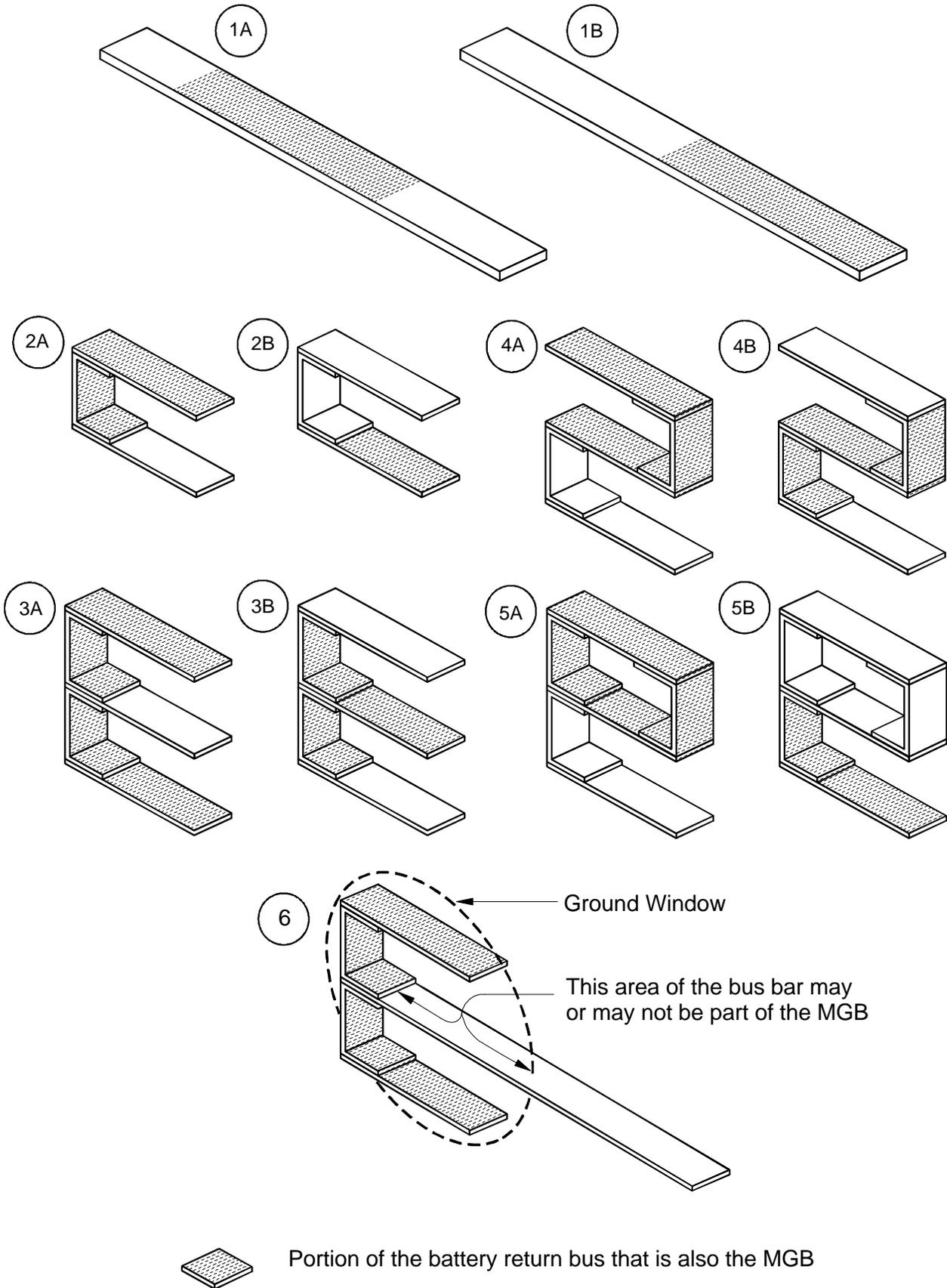


Figure 4-4
Examples of Battery Return Bus Bar/MGB Arrangements

C. MGB at Power Plant with Uninsulated Return Bus

4.5.07 While not a preferred arrangement, power plants with no insulation between the battery return bus and the framework can be adapted to serve isolated bonding network loads, but only if the ground window is established at the power plant.

Note: These are typically 302 and similar type plants, and they almost always have a battery return bus longer than six feet. Since it is impractical to insulate the battery return bus bar or re-terminate all of the existing battery return conductors within a 6-foot area, an auxiliary bus bar called an Isolated Return Bus is required.

4.5.07 The isolated return bus bar should be added to the existing battery return bus bar at a location that keeps the physical separation between the battery and battery return conductors to a minimum. The isolated return bus shall be either:

- (a) a bus bar detail with one end equipped with an insulator between the supporting ironwork and the bus bar, and the other end connected to the existing battery return bus bar, or
- (b) a separate bus bar with both ends mounted on insulators and calculated conductors (at least one 750 kcmil) between the isolated return bus and the existing battery return bus bar.

4.5.09 The isolated return bus is not considered part of the MGB, and bonds normally made to the MGB, such as those from conduits or other common bonding network objects shall not be connected to this bus bar.

4.5.10 The isolated return bus bar must be bonded to the existing battery return bus bar at a point as close as practicable to the point of connection of the power plant grounding conductor from a CO GRD or OPGP bus bar.

4.5.11 An equipment vendor's grounding specifications may require additional conductors between the isolated bonding network equipment and the MGB, such as those for framework or logic ground. These conductors may be connected to the MGB or to the isolated return bus bar. When connected to either bus bar, they shall be placed so that they are nearest the point of connection between the two bus bars.

D. Sequencing

4.5.12 Sequencing is a method used to control the placement of connections to an MGB. It is a concept that provides both electrical and practical benefits. Some conductors are arranged in groups that are considered to be either more likely to conduct fault current or are more sensitive to fault current and other transients. Listing the conductors in a specific order is done to satisfy these concerns and for the sake of uniformity.

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4.5.13 There is flexibility in the placement of conductors along an MGB. Using the connection from CO GRD as a reference point, the physical sequence of connections below should be maintained relative to the connection to CO GRD. Groups are identified by brackets, the numbers in circles are for identification, and some conductors may not be present.

Note: Connections are allowed to be in a different sequence *within* their group, for example the location of conductors ⑥ and ⑧ could be reversed.

- ① logic and other ground references in the isolated bonding network
- ② framework ground reference for isolated bonding network equipment on the same floor
- ③ framework ground reference for isolated bonding network equipment on adjacent floor(s)
- ④ insulated battery return bus of the principal power plant (*doesn't exist when the MGB is part of the power plant's battery return bus*)
- CO GRD or OPGP bus bar
- ⑤ framework ground system of the principal power plant (*may be in the form of conductor ⑨, or may not be present*)
- ⑥ bond to ac equipment ground (ACEG) and conduit/raceway of ac circuits routed between the common bonding network and the isolated bonding network
- ⑦ insulated battery return bus of other dc sources serving the isolated bonding network
- ⑧ protector frame (*if located on same floor*)
- ⑨ bond to nearby ironwork or common bonding network objects located in close proximity to isolated bonding network equipment
- ⑩ bond to battery return conductors originating in principal power plant that serve common bonding network loads (*when the MGB is part of the plant's battery return bus, these are the battery return conductors serving common bonding network loads*)

4.5.14 If a new isolated bonding network entity will be served by an MGB located above or below a power distribution bay that is a part of an existing isolated bonding network entity, it is not necessary to rearrange the existing connections to the MGB to meet sequencing requirements.

E. Remote MGB

4.5.15 It may be beneficial to locate the MGB at a location that provides more convenient routing of grounding conductors, conduits and/or battery return conductors. This may be done on the initial job adding the MGB, or it may be done during equipment growth. When the MGB is located at a point where it is neither a part of the power plant's battery return bus nor the battery return bus bar above/below an isolated bonding network power distribution bay, it is considered a *Remote MGB*.

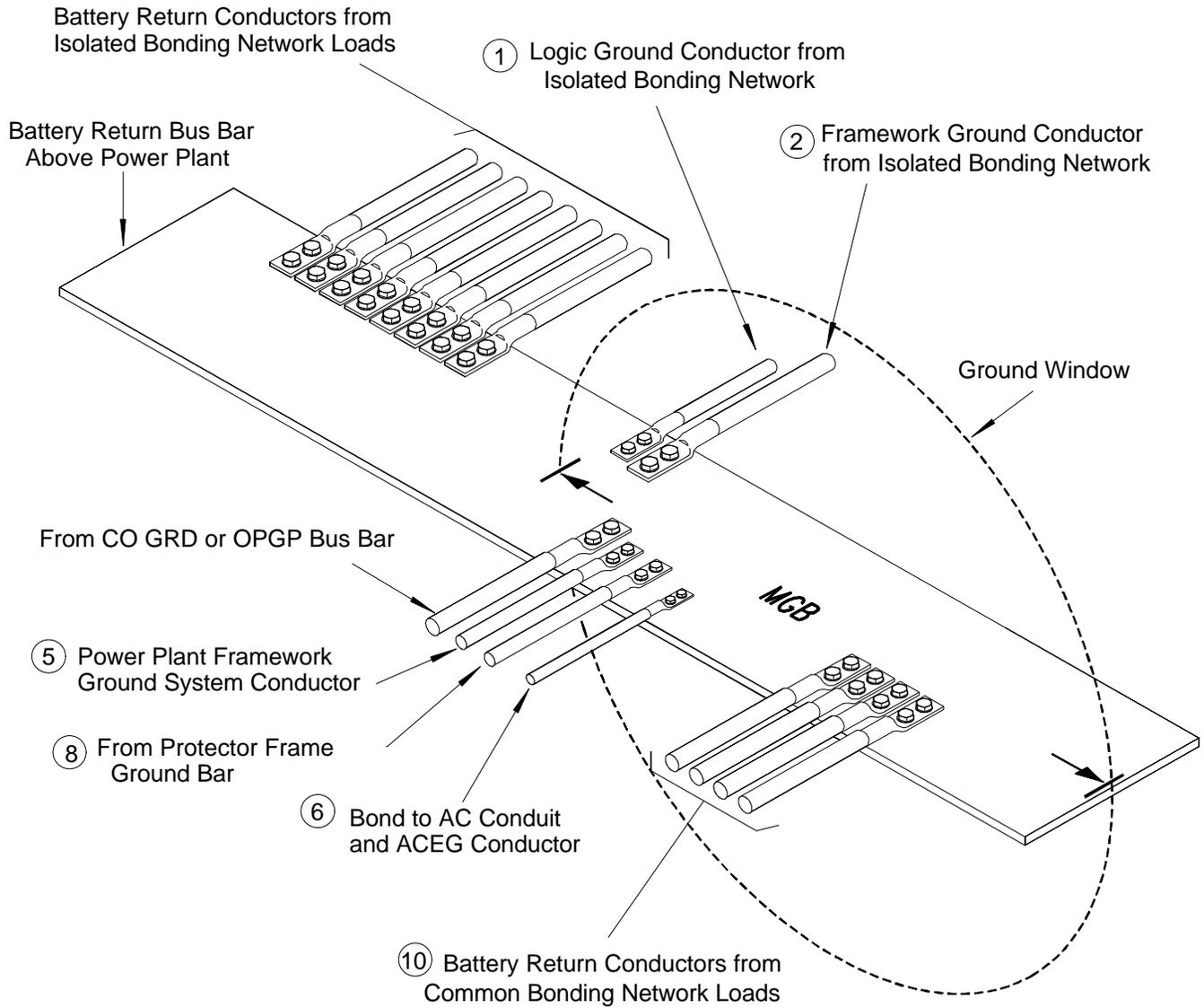


Figure 4-5

Sequencing of Conductors Along an MGB that is Part of a Power Plant's Battery Return Bus

F. Supplementary MGB

4.5.16 If space for termination on the MGB has been exhausted, a supplementary MGB may be added. This bus bar shall be located within 3 conductor feet of the MGB and shall be connected to it with a bus bar detail or a conductor equal in size to the conductor between the MGB and the CO GRD bus bar. Any conductors normally connected to the MGB may be terminated on the supplementary MGB bar.

Note: A supplementary MGB should be used only when extending the MGB is not possible.

G. Relocating an Existing MGB

4.5.17 It is not a requirement to move an MGB when the switch it originally served is removed. Relocating the MGB should be done only after careful examination of several site-specific conditions, and if possible, should include the potential impact from forecasted growth. Key factors affecting an MGB's relocation include:

- (a) floor location (vertically) of new, remaining and future isolated bonding network equipment served by the MGB
- (b) location of the power plant serving other equipment connected to the MGB
- (c) location of common bonding network equipment whose battery returns are currently bonded to the MGB
- (d) power plant battery return bus bar termination points of battery return conductors from existing common bonding network equipment
- (e) affect on length of framework grounding conductors between existing equipment and the new location of the MGB

4.5.18 When an MGB is relocated, continuity between the MGB and CO GRD must be maintained at all times. Two connections between the isolated bonding network and the CO GRD system are allowed only during the time required to re-establish a single point ground arrangement. This transition period should be as short as possible.

4.6 BONDS TO THE MAIN GROUND BUS

A. Conduits, Raceways, and Other Conductive Paths

4.6.01 Metallic conduits and raceways containing ac circuits serving isolated bonding network equipment must be routed through the ground window and bonded to the MGB. The ACEG conductor in the conduit must also be bonded to the MGB.

4.6.02 The bond to the MGB shall be made using a minimum #6 AWG conductor no more than three feet in length. Figure 4-6 shows one possible method to bond the conduit and ACEG conductors to the MGB. A mechanical connector may be used to create a collection point to provide a means to bond ACEG conductors, conduit, raceway and junction box (if used) and the #6 AWG bond to the MGB.

From AC distribution panel in
the Common Bonding Network

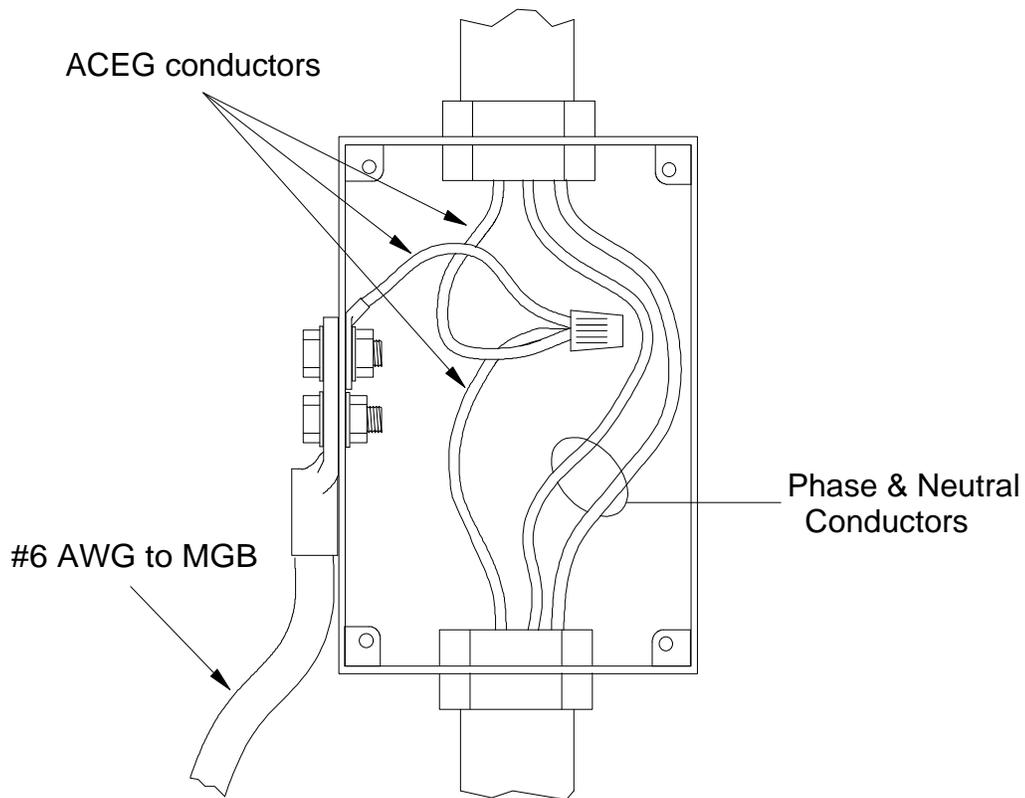
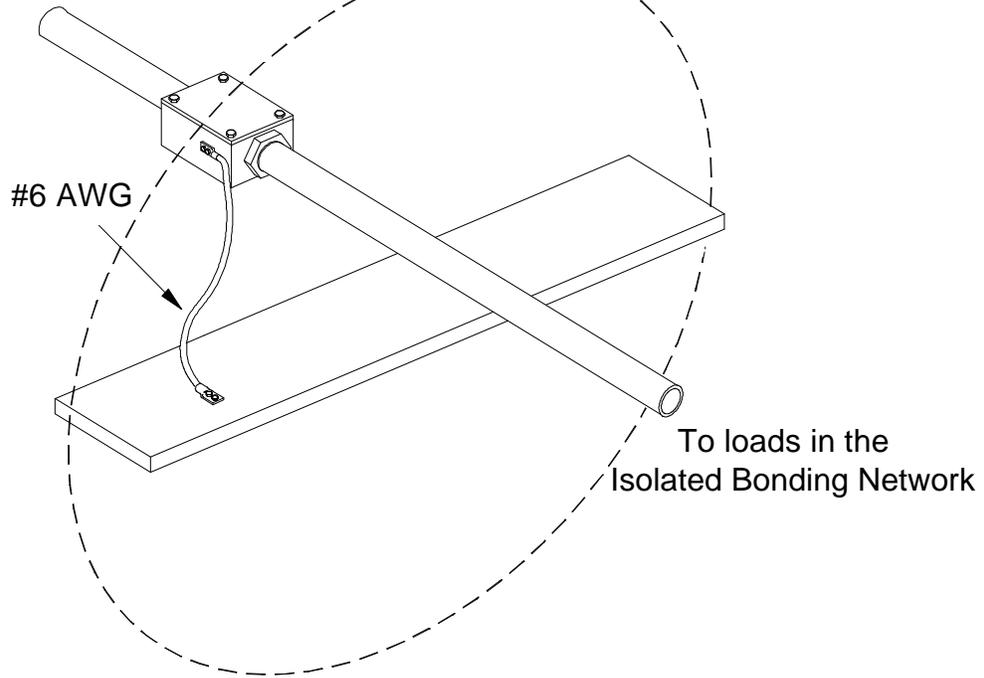


Figure 4-6
Bonding of Conduit and ACEG Conductors to MGB

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- 4.6.03 After passing through the ground window into the isolated bonding network, conduit may contact isolated bonding network metalwork, but it must remain insulated from contact with members of the common bonding network.
- 4.6.04 All metallic conduits and raceways containing ac circuit conductors shall be intentionally bonded together to form an electrically continuous enclosure. Insulating bushings, non-conductive unions, or any similar material or methods shall not be used in metallic conduits or raceways to interrupt their continuity.
- 4.6.05 Every conductor with continuity to both the common bonding network and the isolated bonding network, such as the shield of a coaxial cable, shall pass through the ground window and be bonded to the MGB with a conductor no longer than 3 feet.

B. Lighting System Components

- 4.6.06 Fluorescent lighting fixtures, supports, and ac distribution equipment should be installed as part of the site's common bonding network.
- 4.6.07 All fluorescent lighting fixtures serving isolated bonding network equipment shall be connected to the ac equipment grounding (ACEG) conductor provided in the same raceway as the phase and neutral conductors.
- 4.6.08 The ac distribution panel containing overcurrent devices for the lighting system serving isolated bonding network equipment shall be equipped with a minimum #6 AWG bond between the interior or exterior of the panel and the nearest of either the MGB, a CO GRD system conductor, or the floor CO GRD bus bar.
- 4.6.09 Continuity shall exist between metal lighting system supports in electrical contact with the fixtures and the common bonding network by one of the means described in 4.6 C., Foreign Object Bonds.
- 4.6.10 DC powered emergency lighting components shall be considered as part of the common bonding network and shall be kept separate from the components of the isolated bonding network.

C. Foreign Object Bonds

- 4.6.11 In addition to a connection to the floor CO GRD bus, bonds of minimal practical length are needed between the MGB and common bonding network objects that are in close proximity to parts of the isolated bonding network. The bonds to these "foreign" objects ensure that voltage difference between members of different bonding networks will be equalized to the greatest extent possible. They are intended to reduce the possibility of shock hazard to personnel interposed between the bonding networks. Minimal voltage difference between members would be assured using a direct bond between points of proximity, but this would provide a second path between isolated and common bonding network systems, violating the integrity of the single point ground.

Note: The foreign object bonding system is not part of the fault current path used to operate overcurrent devices protecting ac or dc circuits. These bonds are intended to mitigate the effects of transients that may be of very high amplitude, but very short duration. Thus, foreign object bonding conductors need be no larger than #6 AWG.

4.6.12 The original definition of the term "close proximity" was "*a separation of less than 3 feet when common bonding network members are interbonded with a CO GRD system or 7 feet when interconnections depend on incidental ground paths.*" Because not all equipment vendors agree on a single requirement for this dimension, the 7-foot distance should be used to determine whether or not an object is in close proximity.

4.6.13 Individual objects may be assumed to be grouped if reasonably direct paths of continuity exist between them and other objects that are also in close proximity to the Isolated Bonding Network. Continuity may consist of any metallic path that is bolted or similarly fastened together such as unistrut, ironwork, cable racks, conduit clamps, frame supports, battery return conductors, and CO GRD conductors. For example, when the ironwork above isolated bonding network equipment is an extension of the ironwork above common bonding network equipment frames, the ironwork is often adequately bonded via the framework ground connections to the common bonding network equipment frames. Additional direct bonds are usually not warranted. This is illustrated in Figure 4-7 as follows: the ironwork is connected to the common bonding network equipment frames via the top support details, the frames are connected to the CO GRD bar via the equipment grounding conductors, and the path is completed via the connection between the CO GRD bar and the MGB.

4.6.14 Electrical conduit, lighting fixtures, superstructure metal, common bonding network equipment frames, ventilation ducts, metal piping, and other conductive objects at a site are assumed to be part of the common bonding network. When electrically continuous, they may be used to provide a bonding path to other objects.

Note: Connections between points in the foreign object bonding system may be made using a "daisy-chain" arrangement. This is illustrated in Figure 4-7 by the connection between the air conditioning duct and the framing channel.

4.6.15 When objects are not considered adequately bonded by means such as mechanical connections, separate #6 AWG bonding conductors shall be provided to a point on each object or group of objects that results in the shortest run length. The most common example of this is when ventilation ducts and ironwork are suspended from separate, individual anchors instead of from a common unistrut channel.

4.6.16 A single bonding conductor may be extended to a common location on floors other than the one containing the MGB and spliced and extended to different groups requiring a bond.

4.6.17 All foreign object bonding conductors are part of the common bonding network and shall be kept insulated from contact with metallic objects that are part of the isolated bonding network.

4.6.18 Separate bonds between the MGB and foreign objects may be omitted when the bonding path afforded by a combination of adequate mechanical junctions and a connection to the CO GRD system is less than twice the length of the conductive path afforded by a separate bonding conductor. Bonding conductors may also be omitted where examination of a site's grounding arrangement indicates that a significant improvement in interbonding would not be accomplished.

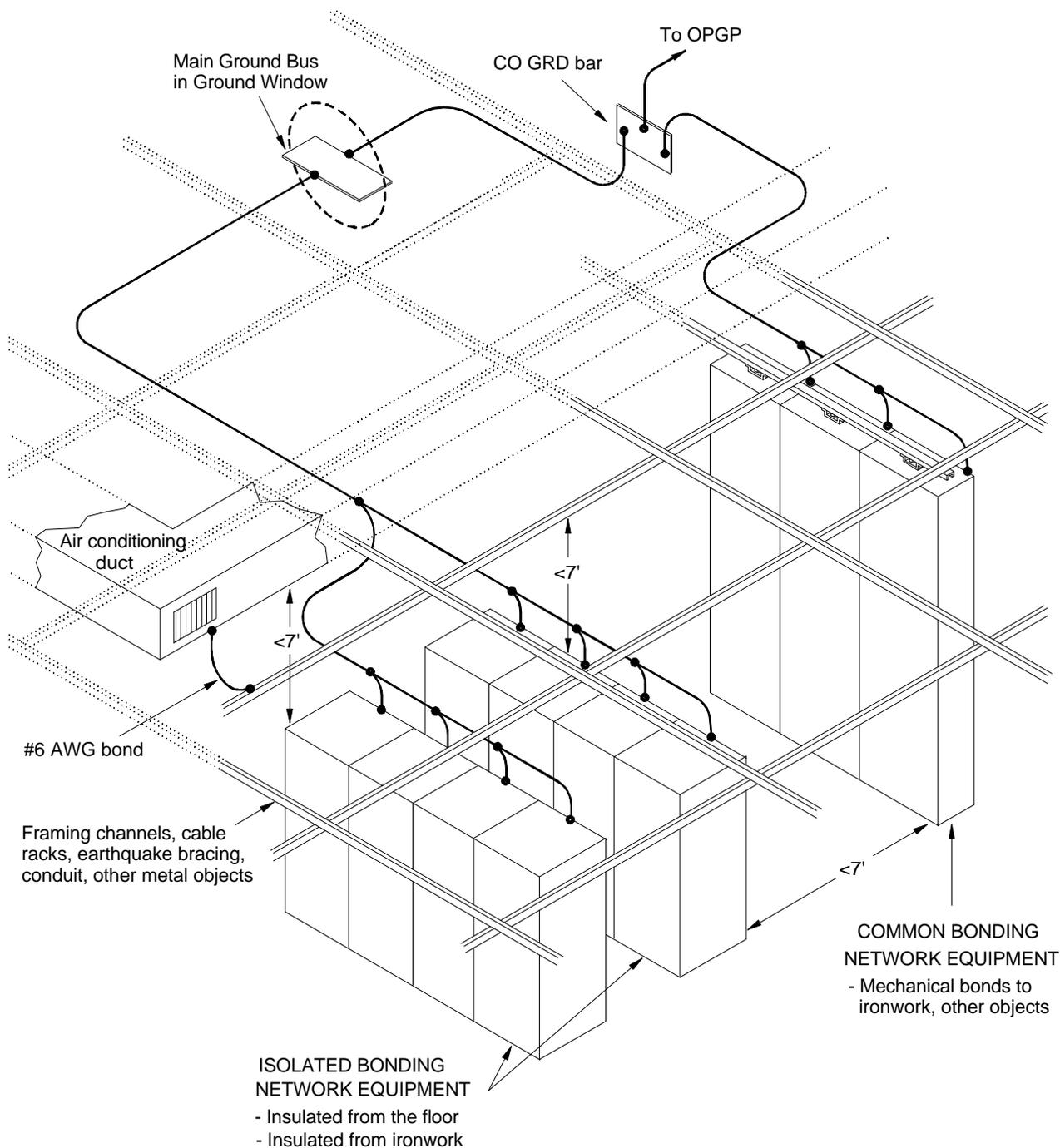


Figure 4-7
Foreign Object Bonds to Nearby Metallic Objects

4.6.19 Members of one isolated bonding network may be located on three adjacent floors, and many common bonding network objects may be in close proximity to isolated bonding network members on each floor. It is impractical and unnecessary to run a separate bonding conductor from the MGB to each object. These items may be bonded together and assumed to be one object, requiring only a single #6 AWG conductor between the MGB and a point on the group, under the allowances and restrictions outlined above.

D. Protector Frame Bonds

4.6.20 When the MGB and a protector frame are on the same floor, a minimum #1/0 AWG conductor may be required between the protector frame's ground bar and the MGB. This conductor shall be installed under either of the following conditions:

- (a) the equipment vendor's specifications require the connection
- (b) the isolated bonding network equipment is within 7 feet of the protector frame **and** the sum of the cable length between the protector frame ground bar and the MGB *plus* the cable length between the MGB and the OPGP (or CO GRD) bus bar equals twice the length of a cable if run between the MGB and the protector frame ground bar

4.6.21 When the protector frame is not on the same floor as the MGB, no connection is required between the protector frame and the MGB other than that normally provided via the CO GRD system.

4.7 ISOLATED BONDING NETWORK EQUIPMENT

4.7.01 All isolated bonding network equipment systems currently in use contain at least two grounding sub-systems, generically referred to as *framework ground* and *logic ground*. Some designs also use battery return conductors to provide ground reference to all or part of an equipment system. While battery return conductors are considered to be grounded conductors, when used to provide a ground reference, they are also acting as grounding conductors and are a part of another grounding sub-system.

4.7.02 There are three basic design concepts for single point ground systems now in use in our network equipment:

- (1) Mesh - This design intentionally creates many points of interconnection between grounding sub-systems, and may include multiple connections to battery return
- (2) Star - This design requires separation between all of the grounding sub-systems (and usually the battery return) except at either the MGB or a few collection points that are in turn connected to the MGB
- (3) Sparse-Mesh - This is combination of mesh and star designs that allows varying degrees of interconnections, and may allow multiple connections between grounding sub-systems and battery return

4.7.03 Every grounding sub-system used in isolated bonding network equipment shall be connected to a site's common bonding network system at only one point: the MGB

4.7.04 All components of every ground sub-system shall be designed to safely conduct any fault current likely to be present.

A. Framework Ground Systems

4.7.05 In isolated bonding network equipment, the framework ground system consists of all conductors and components between the MGB and the point of attachment to a frame or cabinet.

4.7.06 Some framework ground system designs include connections to other grounding sub-systems and to battery return. Some designs have restrictions that allow connection between framework ground and other grounding sub-systems only at the MGB. One design requires an intermediate bus bar between the equipment and the MGB that serves as a collection point for individual conductors from each equipment lineup.

4.7.07 Framework ground conductors shall be copper and sized per Table 4-2. The rating or setting of the largest of the first upstream overcurrent device in all dc power circuits supplying equipment located in a frame or cabinet shall be used for the left-hand column in Table 4-2. Usually, a conductor larger than #6 AWG is required only for secondary power distribution frames (PD, PDC, PCFD, etc.).

4.7.08 If a framework ground conductor is in a form other than bare or insulated stranded wire, it shall be equal in circular mil area to the conductor required per Table 4-2. For information on conductors, refer to Table 1-2 in Sub-section 1 of this Practice.

4.7.09 The framework ground conductor may be attached at either the top or bottom of the frame or cabinet. This connection shall be made with a two hole crimp type connector unless the means of attachment has been evaluated and approved for use.

Rating or Setting of Automatic Overcurrent Device in Circuit Ahead of Equipment, Not Exceeding (Amperes)	Minimum Size of Copper Equipment Grounding Conductor (AWG)
200	6
300	4
500	2
600	1/0

Table 4-2
Minimum Size of Framework Grounding Conductors

B. Logic Ground Systems

- 4.7.10 Logic ground may also be referred to as *logic return* or *signal ground*. Since it is connected to the return side of a dc-dc converter's output, the logic ground conductor is essentially a dc power source's system grounding conductor.
- 4.7.11 Depending on the design of the equipment system, logic grounds may be connected directly to the MGB, to the MGB via the framework ground system, a logic ground collection system, the battery return system, or a combination of methods.
- 4.7.12 Logic ground conductors are usually provided on an individual shelf or frame basis. Unless some other means has been evaluated and approved, logic ground conductors shall be attached using bolted crimp type connectors.
- 4.7.13 Logic ground conductors shall be sized per 3.3.06 through 3.3.08 and Table 3-2.

C. Other Ground Systems

- 4.7.14 Equipment designs may include other grounding sub-systems, such as *quiet ground* and *lightning ground*. Whatever the purpose, conductors used in other sub-systems shall be able to safely conduct any fault current likely to be present, and shall be terminated using bolted crimp type connectors.

D. Battery Return Systems

- 4.7.15 A number of battery return configurations are used within the isolated bonding network equipment. For voltage equalization, the first (analog) electronic systems used a grid system connected between the battery return bus bars of power distribution bays. Newer designs may include an equalization network, although they are usually less extensive than the early designs.
- 4.7.16 When a battery return conductor is also used as a grounding conductor, it must be of sufficient size to conduct any fault current likely to be present. Unless some other means has been evaluated and approved, battery return conductors shall be attached using bolted crimp type connectors.

E. Equipment Separation and Circuit Location

- 4.7.17 A minimum separation of 4 feet should be provided between isolated bonding network frames and equipment frames in the common bonding network. This separation also applies to cables and cross-connection fields. Cable racks and other metallic structures shall be separated so that the only point of contact between the isolated bonding network and the common bonding network is at the MGB in the ground window.
- 4.7.18 Common bonding network circuits, regardless of the type of framework on which they are mounted or whether they have been rated as operationally compatible with isolated bonding network equipment, shall be located outside the isolated bonding network. The only exception should be circuits that have been specifically designed as an integral part of the isolated bonding network equipment.

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4.7.19 The requirement that framework comprising a portion of the isolated bonding network be no more than one floor away from the ground window does not restrict location of electronic circuitry. Such circuitry may be located on any floor if:

- (a) it is electrically isolated from mounting framework but is mounted in framework that is bonded to the common bonding network via the CO GRD system, and
- (b) the circuit components are insulated or otherwise separated from members of the common bonding network so that voltage differential developed between the isolated bonding network and the common bonding network will not allow current spark-over or represent a hazard to personnel.

F. Insulation

4.7.20 Insulating material shall be installed between a metallic object that is part of the isolated bonding network and material securing or fastening it to a metallic object that is part of the common bonding network.

4.7.21 Insulating material shall have a minimum dielectric strength of 400 volts/mil and shall have sufficient mechanical strength to withstand physical forces likely to be applied during installation.

4.7.22 Floor and wall anchoring material is often in contact with concrete and may touch structural metal. An insulator shall be used between anchor bolt heads (or stud nuts) and isolated bonding network frame or cabinet metalwork.

4.7.23 Insulating material shall be placed between the floor and the bottom of all frames, cabinets or other metallic objects that are part of the isolated bonding network. The material shall be of sufficient size and strength that isolation is maintained when the securing hardware is tightened.

4.7.24 Any metal detail extended above isolated bonding network equipment to support an object that is part of the common bonding network shall use insulation material to maintain separation between the two bonding networks.

4.7.25 Conduits that are part of an isolated bonding network shall be insulated from contact with common bonding network objects using two wraps of sheet fiber placed at all support points. When specifically approved by a Company representative, plastic tape may be used if it is:

- (a) insulating type plastic tape intended for electrical use
- (b) listed by a nationally recognized testing laboratory (NRTL) such as Underwriters Laboratories Inc. (UL)
- (c) a minimum of 8.5 mils thick by 3/4" wide
- (d) applied in a minimum of 2 overlapped (half-lapped) layers that result in a minimum total of 4 layers of tape at any given point on the conduit
- (e) applied in a continuous wrap that extends a minimum of 1/2" beyond each edge of a conduit clamp or any other metallic object in contact with the conduit.

4.8 POWER PLANTS

A. Power Plant Location

4.8.01 The power plant should be as close as practical to the isolated bonding network, preferably on the same floor. In existing buildings, space restrictions or other factors may cause the power plant to be located several floors from the equipment it serves, which is not the preferred location, but is acceptable.

B. Power Plants Serving Common and Isolated Bonding Network Equipment

4.8.02 Common bonding network equipment may be served by a power plant that serves isolated bonding network equipment provided:

- (a) the secondary power distribution bays (BDFBs, etc.) for the common bonding network equipment are supplied by separate battery and return feeders from the plant's primary distribution bays, and
- (b) the battery return of the feeder circuit is routed through the ground window and bonded to the MGB before terminating in the secondary distribution bay.

Note: When the MGB is a part of the power plant's battery return bus bar, the battery return conductors serving common bonding network distribution bays shall be connected within the area of the bus bar designated as the MGB.

4.8.03 The battery conductor need not be paired with the battery return conductor for the portion of the run to and from the MGB if a significant amount of additional cable for the battery conductor is required to maintain pairing. The return conductor must be closely coupled (to itself) along the route to and from the point where it leaves the route of the battery conductor and the connection to the MGB. Where significant conductor length is not a factor, the battery and battery return conductors shall remain paired. See Figure 4-8.

Note: When the battery return conductor is longer than the battery conductor, the size of the battery return conductor shall be adjusted, if necessary, to meet any voltage drop requirements.

4.8.04 The battery return conductors of a circuit serving common bonding network equipment may be connected directly to the MGB or, to save space on the MGB, they may be bonded to the MGB with a conductor not exceeding 3 feet in length. This is shown in Figure 4-8.

Note 1: One bonding conductor may be serially connected, using crimp type parallel connectors, to more than one battery return conductor, provided the bonding conductor is no longer than 3 feet.

Note 2: The bonding conductor shall be the same size as the battery return conductor for sizes up to #1/0 AWG. Larger conductors may be bonded using a #1/0 AWG.

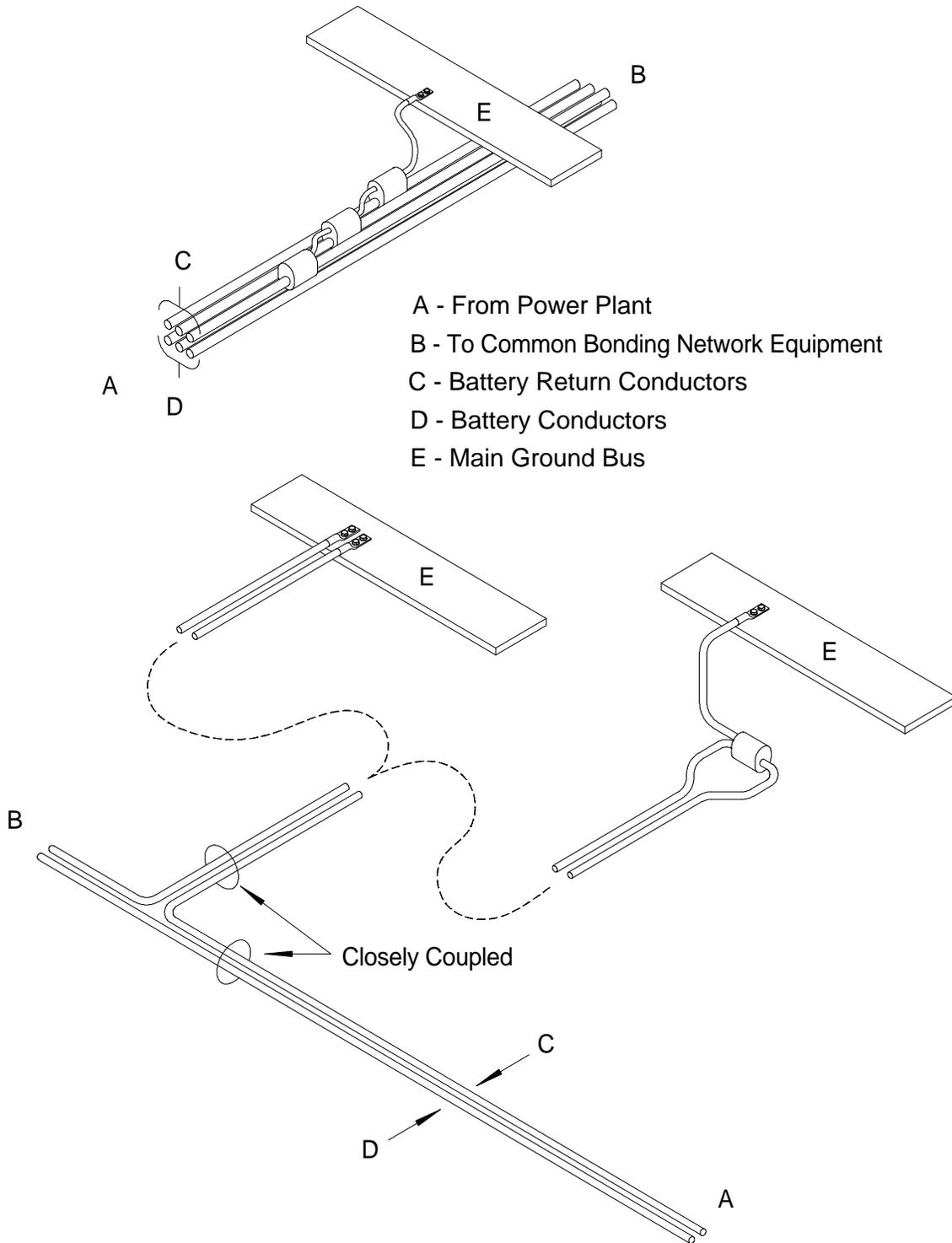


Figure 4-8
Methods of Bonding Battery Return Conductors to the MGB

4.8.05 Certain power equipment may be treated as isolated bonding network equipment even though it is physically located in the common bonding network. To qualify for this exception, the equipment must:

- (a) not have continuity between its battery return terminals and the frame or cabinet or other common bonding network objects, and
- (b) be a single load (not a secondary distribution bay).

Note: Common examples of this exception are inverters and dc-dc converters with isolated outputs.

C. Different Isolated Bonding Networks Served by the Same Power Plant

4.8.06 A power plant may serve more than one isolated bonding network entity. Every isolated bonding network entity served by the same power plant must be bonded to the same MGB. No part of these entities may be located more than one floor from the MGB.

4.8.07 Secondary power distribution frames that are a part of an isolated bonding network entity are usually prohibited (by the manufacturer) from serving equipment in other isolated bonding network systems. For this reason, power distribution equipment may serve equipment in another isolated bonding network entity **only** with the permission of both equipment manufacturers.

4.9 COMPUTER EQUIPMENT - GENERAL

A. Background

4.9.01 Grounding requirements for computers and computer sites were originally provided in a variety of documents. Eventually, the requirements were combined and published in BSP 802-001-196, dated June, 1982. The purpose of this Practice was to provide a consistent approach to all computer equipment grounding by applying single point grounding requirements used for electronic switching systems. These requirements were intended to provide an acceptable level of reliability and safety for all computer equipment, regardless of manufacturer.

Today's computer equipment vendors specify requirements similar to those in the BSP. One difference is that vendors often prohibit additional framework ground connections to their equipment as was required by the original BSP. Another is that true isolated bonding networks are seldom required. There have also been changes in ac power distribution methods. To some degree, these changes are due to advances in equipment technology. They are also due to new standards and upgrades to existing standards for the safety of computer equipment and for installation methods.

The net result of this activity led to a number of changes in the original BSP's requirements. These changes either meet or exceed the original intent of the BSP in the areas of safety and reliability.

B. Application of this Sub-section and Other Documents

4.9.02 The computer equipment referred to in this Sub-section is typically composed of several equipment cabinets, each having one or more ac power supply units. This Sub-section does not apply to personal computers or equipment incorporating personal computers unless these (or similar) requirements are expressly required by the manufacturer.

4.9.03 It is presumed that computer equipment will be installed at sites that generally conform to BSP 760-150-155 - Building Planning for Operations Support Systems. It is also presumed that installations will conform to the latest issue of National Fire Protection Association (NFPA) Publication 75 - *Protection of Electronic Computer/Data Processing Equipment*, and to Article 645 of NFPA 70 - *The National Electrical Code (NEC)*.

4.9.04 Except where specifically stated, the grounding requirements in this Sub-section do not supersede specifications published for any specific computer. Where conflicting information appears in those publications, the computer specifications shall take precedence.

C. Characteristics of Computer Grounding and Power Arrangements

4.9.05 Computer systems are similar to electronic switching systems with respect to voltage disturbance sensitivity. Computer equipment vendors often use (or require the use of) one or more of the following techniques to reduce the effects of transients:

- (1) filter devices are used in power supplies
- (2) ac power sources and distribution equipment are located as close as practicable to the computer equipment
- (3) single point grounding is used, either for power sources and distribution systems or the entire equipment system

4.9.06 Some computer equipment receives its only ground reference via the equipment grounding conductor routed with the ac supply. Some designs require multiple bonds between equipment cabinets and common bonding network references such as signal reference grids. This means that the design of the grounding and power distribution systems serving a computer area needs special attention, and must include consideration of computer equipment vendor specifications.

4.9.07 Computer equipment vendors may have no special requirements for grounding systems, they may require a single point ground only for the ACEG conductor serving the equipment, or they may require a true single point ground arrangement for the entire system. Only the last two arrangements effect the power distribution system.

4.9.08 Single point ground for ACEG conductors and a true isolated bonding network both require the use of isolated ground type receptacles. These receptacles are either colored orange, or are identified with an orange triangle.

4.9.09 A true single point ground arrangement places restrictions on the power distribution system and the equipment installation since isolation must be maintained between all isolated bonding network and common bonding network components.

4.10 COMPUTER EQUIPMENT - COMMON REQUIREMENTS

A. Bond to Structure's Ground System

4.10.01 When computer equipment is located in central offices or other buildings equipped with a CO GRD system, grounding electrode conductors or other conductors requiring direct connection to an earth ground system shall be connected to a CO GRD or OPGP bus bar.

Note: When expedient, a bond to an effectively grounded structural member of the building is permitted if it results in a run length shorter than one to a CO GRD/OPGP bus bar.

4.10.02 In buildings other than central offices where no ground system similar to a CO GRD system has been provided, all conductors requiring connection to an earth ground system shall be connected to the nearest of either:

- (a) the nearest available effectively grounded metallic structural member
- (b) the nearest available effectively grounded metal water pipe
- (c) other electrodes as specified in sections 250-81 and 250-83 of the National Electrical Code where electrodes specified by (a) or (b) above are not available

B. AC Equipment Grounding (ACEG) System

4.10.03 The ACEG system serving any computer equipment shall meet the design and installation requirements in 2.8 and material requirements in 1.5 C. of this Practice.

4.10.04 When isolated ground type receptacles are used, a separate ACEG conductor shall be provided for bonding of conduit and raceway components. This conductor shall have continuity with the isolated ground ACEG only at the source of the ac system.

4.10.05 Previously installed distribution systems consisting of rigid metal conduit, intermediate metal conduit (IMC), electrical metallic tubing (EMT) or an approved metal raceway may have used the conduit or raceway as an ACEG conductor. All new conduits or raceways or extensions or modifications of existing distribution systems shall include a separate ACEG conductor.

4.10.06 Computer and other cabinets requiring ac power shall be equipped with an electrical cord having an ACEG conductor that is effectively connected to the cabinet metalwork. The cord shall be equipped with either a straight blade or locking-type attachment plug equipped with an equipment grounding pin.

4.10.07 Certain vendor cabinets are equipped with an RF isolation inductor connected in series between the cabinet framework and the incoming ACEG conductor of the power cord. These units exhibit significant impedance to high frequency transients but adequately low impedance to 60 Hz fault current. Such arrangements are acceptable if the units are listed by a nationally recognized testing laboratory (NRTL). Such arrangements shall be identified in computer system specifications.

C. Isolated Bonding Network Requirements

- 4.10.08 Equipment systems requiring a true isolated bonding network environment shall be referenced to the structure's ground system at only a single point: the main ground bus (MGB) in the ground window.
- 4.10.09 Every conduit or raceway carrying power feeders or other conductors to isolated bonding network equipment shall pass through the ground window. The raceway and conduits and all grounded conductors within them shall be bonded to the MGB.
- 4.10.10 All isolated bonding network equipment system components shall be insulated from contact with members of the common bonding network per the requirements given in 4.7 F. of this Sub-section.
- 4.10.11 All metallic foreign objects in close proximity to isolated bonding network components shall be bonded per the requirements in 4.6 C. of this Sub-section.

D. Special Note on Isolated Ground Type Receptacles

4.10.12 This type of receptacle should only be used when expressly required by an equipment manufacturer or because of other system considerations as determined by the equipment system engineer. This type of receptacle must not be used as a means to identify an ac power system's source or backup feature, such as "inverter power."

Note: Most personal computer and work station equipment manufacturers such as IBM, Apple, H-P, Compaq, NEC, etc., only require that an ac receptacle serving their equipment be of the grounded type, also referred to as a standard receptacle.

4.10.13 From a noise mitigation standpoint, an isolated ground type receptacle is usually only effective when it is installed as part of a system-wide single point ground design that includes consideration of both the entire power system and all communication circuits between computer system components. By itself, this type of receptacle provides little protection against electrical transients.

4.11 COMPUTER EQUIPMENT - POWER AND GROUNDING CONFIGURATIONS

A. AC Power Distribution Equipment

- 4.11.01 With the exception of some large mainframe installations, most computer equipment is served by ac branch circuits from two general types of distribution equipment:
- (1) ac distribution panel - these are standard ac distribution panels (also called sub-panels) of various designs mounted on walls or columns that contain branch circuit connection hardware and overcurrent protective devices
 - (2) power distribution unit (PDU) - these are separate floor mounted cabinets located in the computer equipment area that contain a step-down isolation transformer and branch circuit connection hardware and overcurrent protective devices

4.11.02 Grounding and power arrangements are interdependent, and must make provision for the equipment vendor specifications. Most grounding and ac power arrangements will be one of five combinations:

- (1) single point ground required - power from distribution panels
- (2) single point ground required - power from a single PDU
- (3) single point ground required - power from multiple PDUs
- (4) only ACEG required - isolated ground type receptacles required
- (5) only ACEG required - standard receptacles used

B. Powered From Distribution Panel(s)

4.11.03 For isolated bonding network arrangements powered from distribution panels, the MGB shall be located near the source of the ac system, which is typically an isolation transformer or a UPS arranged as the source of a separately derived system.

Note: A grounding electrode conductor (GEC) is required from these separately derived systems. The connection of the GEC may be made at the transformer or UPS, the first disconnecting means, or any intermediate point.

4.11.04 While a distance of 3 conductor feet is preferred, the MGB shall be located no more than 6 conductor feet from the point where the GEC originates. The MGB may be bonded to the GEC with a separate conductor, or the GEC may be routed by the MGB and bonded to it with a branch conductor. The bond to the MGB shall be equal in size to the GEC.

Note: Since the GEC must terminate per the requirements in 4.10 A., no other connection to the structure's earth electrode system is required.

4.11.05 All conduit and distribution panels downstream from the source must be insulated from contact with common bonding network components.

4.11.06 Unless exempted by computer equipment vendor specifications, distribution panels shall serve branch circuits dedicated to computer and associated equipment.

4.11.07 All other requirements of 4.10 of this Sub-section shall be met.

C. Powered From One PDU

4.11.08 Because the isolation transformer in a PDU is the source of a separately derived system, all of the requirements in 4.11 B. shall be met.

4.11.09 All other requirements of 4.10 of this Sub-section shall be met.

D. Powered From Multiple PDUs

- 4.11.10 The MGB should be located at a point in the equipment area along the route of the conduits or raceways containing the *input* power to the PDUs.
- 4.11.11 A pullbox shall be provided within 3 conductor feet of the MGB to provide access to the ACEG conductors in the feeder conduits or raceways. The pullbox (or boxes) and the ACEG conductors in the feeder conduits or raceways shall be bonded to the MGB with a minimum #6 AWG conductor that is 3 feet or less in length
- 4.11.12 A GEC from each PDU shall be run to the MGB. A single #3/0 AWG GEC shall be installed between the MGB and the structure's ground system per 4.10 A., above. Splices in GECs and connections to the MGB must be made with exothermic welds or crimp type connectors.
- 4.11.13 All other requirements of 4.10 of this Sub-section shall be met.

E. Isolated Ground Type Receptacles Required

- 4.11.14 When isolated ground type outlets are required, the ac source should be located as near as practicable to the equipment loads.
- 4.11.15 The ACEG conductor serving isolated ground type receptacles shall not be in contact with any other grounded object between the power system's source and the point of connection on the receptacles serving the computer equipment. Insulators shall be installed on any bus bar used for this conductor's path between the source and the isolated ground type receptacles.
- 4.11.16 When isolated ground type receptacles are used, a separate ACEG conductor shall be provided for bonding of conduit and raceway components. This conductor shall have continuity with the isolated ground ACEG only at the source of the ac system.

F. Standard Receptacles Used

- 4.11.17 If the computer equipment system requires only a standard type receptacle, the ac distribution system shall meet all of the requirements of 4.10 B. of this sub-section.

G. DC-Powered Equipment

- 4.11.18 Frames, cabinets, or other enclosures containing dc powered equipment shall have a framework ground system meeting the requirements of 4.7 A., above.
- 4.11.19 Where used, logic ground reference conductors shall meet the requirements of 4.7 B. of this Sub-section.
- 4.11.20 If a computer system is predominantly dc powered and, per the manufacturer's requirements, must be installed in an isolated bonding network environment, all requirements in 4.4 through 4.8 of this Sub-section shall be met.

4.11.21 If the equipment is predominantly ac powered and must be installed in an isolated bonding network environment, but does have dc powered equipment, the battery return of dc feeders must be bonded to the MGB before connection to the equipment.

Note: For systems arranged per 4.11 B. or 4.11 C., the GEC must be no smaller than the largest framework grounding conductor.

4.12 COMPUTER EQUIPMENT - MISCELLANEOUS REQUIREMENTS

A. Raised Floor Applications

4.12.01 All components of a raised floor system are considered part of the common bonding network. When required by computer equipment vendor specifications, insulation as described in 4.7 F., shall be installed between the surface of raised floor tiles and equipment enclosures.

4.12.02 When computer equipment is installed in an isolated bonding network, anchor material that penetrates the raised floor tiles shall be furnished with nylon bushings or other adequate insulating hardware so that there is no electrical continuity between any anchor material and the equipment enclosure.

4.12.03 The raised floor support system in a computer environment shall be equipped with a ground system that consists of:

- (a) bare or insulated copper main conductors, sized at #6 AWG minimum
- (b) a main conductor routed around the perimeter of the raised floor area
- (c) main conductors bonded to pedestals and formed into a grid system consisting of squares with sides no longer than 40 feet
- (d) bonds between main conductors and support pedestals at 20-foot intervals
- (e) at least one #6 AWG bond from the grid system to a CO GRD or OPGP bus bar, if available
- (f) at least one minimum #6 AWG bond from the grid system to any MGB
- (g) a minimum #6 AWG bond from the grid system to metal conduits entering the grid area if no MGB, CO GRD, or OPGP bus bar is available

4.12.04 The preferred design for a raised floor support system uses metal struts between adjacent support pedestals. If metal struts are not used, the following shall be installed in addition to the ground system described in 4.12.03:

- (a) intermediate bonds between the grid system main conductors and support pedestals at 4-foot intervals
- (b) minimum #10 AWG branch conductors connected, at intervals not exceeding 4 feet, between parallel #6 AWG main conductors forming the sides of a 40-foot grid square - the branch conductors shall be bonded to every other pedestal so that every floor tile is in contact with at least one bonded pedestal

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4.12.05 There is no restriction on contact between the grid assembly and conduits, ducts, pipes, and other conductive materials installed under the floor, or extended through the floor, that are part of the common bonding network.

B. System Testing

4.12.06 If required by equipment vendor specifications, the grounding system shall be arranged to facilitate system testing. Generally, this will include a method for interrupting the ground reference temporarily to allow verification that another ground reference does not exist. Such requirements shall be detailed in the computer system specification.

C. Peripheral Equipment

4.12.07 Computer terminals, printers, and other peripheral units of less than cabinet size shall be grounded and powered per vendor specifications, as long as a fault current path is provided to the source of power for the peripheral.

Note: Where possible, it is a good practice to use the same ac circuit to power both the CPU and peripheral equipment.

4.12.08 If required, metallic isolation between computer equipment may be accomplished using current loop, back-to-back modems, or fiber optic communication links.

Sub-section 5

Electronic Equipment Enclosures, Attended Position Equipment, Equipment Trailers, Customer Premises Equipment

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5.1 SCOPE

5.1.01 This Sub-section provides grounding requirements for a variety of structures and equipment types that are often located in a structure other than a central office. This Sub-section also describes earth electrode system requirements that, while based on the same protection principles, differ in detail from those typically used at a central office.

5.2 ELECTRONIC EQUIPMENT ENCLOSURES

5.2.01 As used in this Sub-section, the term electronic equipment enclosure (EEE) is defined as a structure housing network equipment located above ground, below or partially below ground, served by a commercial ac power source and equipped with a dc power source.

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5.2.02 A number of terms are associated with EEEs. The terms used in this sub-section, their meaning, and associated terms (in parentheses) are listed below:

- (a) *Cabinet* - a pad-mounted or pole-mounted enclosure (AG/EEE, EEC, UE)
- (b) *Hut* - a prefabricated, walk-in type structure no larger than 8' x 12' (SLC hut)
- (c) *BG/EEE* - an enclosure that, except for personnel access and ventilation equipment, is completely buried (CEV, vault)

A. Principal Ground Point

5.2.03 A principal ground point (PGP) bus bar shall be installed in BG/EEEs and huts. It shall be of sufficient size to terminate all grounding conductors required for a fully equipped arrangement. This bus bar may be the only one in the structure and serve the same functions as a central office's OPGP and CO GRD bus bars, and even as an MGB. This bus bar shall be designated **Principle Ground Point** using stenciling or a permanent name plate.

5.2.04 In a BG/EEE or hut, the PGP bus bar should be mounted near the main ac service disconnect panel. In a BG/EEE, the preferred location is on, near, or in place of the hardware connecting the ground system in the two halves of the structure.

Note: In a cabinet, a bus bar may be required and/or furnished by the enclosure or equipment manufacturer. Even if not required by a cabinet manufacturer, a bus bar is recommended. It provides a uniform means of terminating grounding conductors.

B. Earth Electrode Systems

5.2.05 Cabinets and huts shall be equipped with a buried ring ground system as shown in Figure 5-1. Design and material requirements for a ring ground system are:

- (a) two 5/8" x 8' copper clad steel ground rods driven at opposite corners and approximately 2 feet out from the edge of the concrete pad supporting the EEE
- (b) a minimum #6 AWG bare copper conductor, buried at least 18 inches below grade and 2 feet out from the edge of the concrete pad, formed in a ring around the exterior of the pad, and connected to the ground rods using exothermic welds

Note 1: If right of way or other access restrictions (a curb, wall, etc.) at a site prevent the ring from being 2 feet out from the pad, a lesser dimension may be used.

Note 2: If an exothermic weld can not be used at a site, crimp type or mechanical connectors may be used provided they are listed for direct burial.

5.2.06 If a concrete encased electrode system is available at a cabinet or hut, it must be bonded to the earth electrode system. If it is the only earth electrode system available at a cabinet or hut, it shall be installed per the requirements in 2.2.23 of this Practice.

5.2.07 The earth electrode system and ac service grounding arrangement for huts and other walk-in structures larger than 8' x 12' shall meet the requirements for central office structures in Sub-section 2 of this Practice.

- A Main AC Service Disconnect Panel
- B Neutral Bus
- C Grounding Electrode Conductor
- D PGP Bus Bar
- E #6 AWG Ground Ring
- F 5/8" x 8' Ground Rod

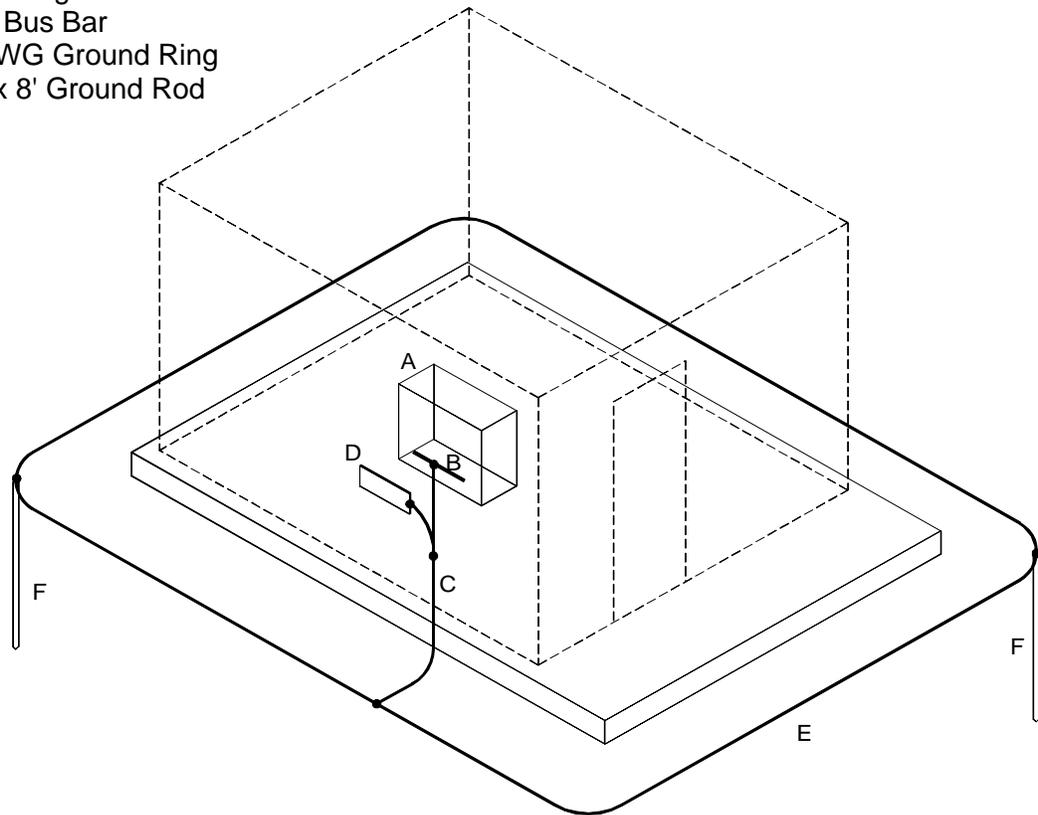


Figure 5-1
Earth Electrode System and AC Service Grounding (hut shown)

5.2.08 For a BG/EEE, provided the proper materials and construction methods are used, the enclosure can function as a concrete encased electrode (or "Ufer ground"). In order to be used as a concrete encased electrode, the following conditions must be met:

- (a) the BG/EEE is concrete, and is constructed with reinforcing steel that is intentionally bonded together
- (b) apparatus is provided to join the reinforcing steel of the top and bottom sections of the BG/EEE
- (c) apparatus is available inside the BG/EEE to attach one or more conductors to the reinforcing steel
- (d) the exterior of the BG/EEE is not coated with an insulating sealant

5.2.09 If a concrete BG/EEE is covered with an insulating material, the structure can not be used as an earth electrode. A ring ground system that meets the minimum material requirements in 5.2.05 shall be installed below the BG/EEE structure.

Note: The enclosure's reinforcing steel must be bonded to the BG/EEE's grounding system.

C. AC Service Grounding

5.2.10 Wherever practicable, the main ac service disconnect enclosure shall be mounted on or within the EEE. The most preferred arrangements for grounding the ac service are shown in Figure 5-1 and arrangements ②, ③ and ④ in Figure 5-2. All arrangements shown in both figures may be used in huts, cabinets and BG/EEEs.

5.2.11 In a cabinet or hut, the grounding electrode conductor (GEC) should be routed past the PGP bus bar and bonded to it with a conductor equal in size to the GEC.

5.2.12 For a BG/EEE, a minimum #6 AWG GEC shall be installed between the neutral bus bar in the ac service disconnect panel and the PGP bus bar. While a BG/EEE does not necessarily require additional electrodes, if others are present, all must be bonded together.

5.2.13 Site conditions may require the main ac service disconnect enclosure to be placed remote from the EEE. This enclosure is most often a power pedestal that also contains the meter. When used, a power pedestal should be located within 4 feet of an EEE. This permits the GEC from the pedestal to terminate on the EEE's buried ring ground system.

5.2.14 If the pedestal is more than 4 feet from an EEE, at least one additional ground rod must be driven near the pedestal. The GEC from the pedestal shall be connected to this rod. Another minimum #6 AWG conductor is required between this rod and a point on the EEE's earth electrode system. In order of preference, this connection shall be made at:

- (a) a point on the buried ring ground system external to the EEE
- (b) the PGP bus bar in the EEE
- (c) in a BG/EEE, the bonding details between the upper and lower halves of the enclosure
- (d) if equipped, the protector ground bus bar

5.2.15 Figure 5-2 shows variations of acceptable ac service grounding arrangements. Key points about these arrangements are:

- ① The power pedestal contains the main ac service disconnect, and is located within 4 feet of the EEE.
- ② The main ac service disconnect is located in an enclosure on the outside of the cabinet. The connection between the neutral bus and the grounding electrode conductor could also be made as shown in arrangement ④.
- ③ In this arrangement, the ac distribution cabinet (e) would also have to contain the main ac service disconnect. In both ② and this arrangement, the conductor serving the PGP is spliced to the grounding electrode conductor.
- ④ In this arrangement, the grounding electrode conductor is spliced to the conductor connected to the PGP bus bar. This splice must be made using either a crimp type parallel connector or an exothermic weld. As in ③, the ac distribution cabinet would have to contain the main ac service disconnect.

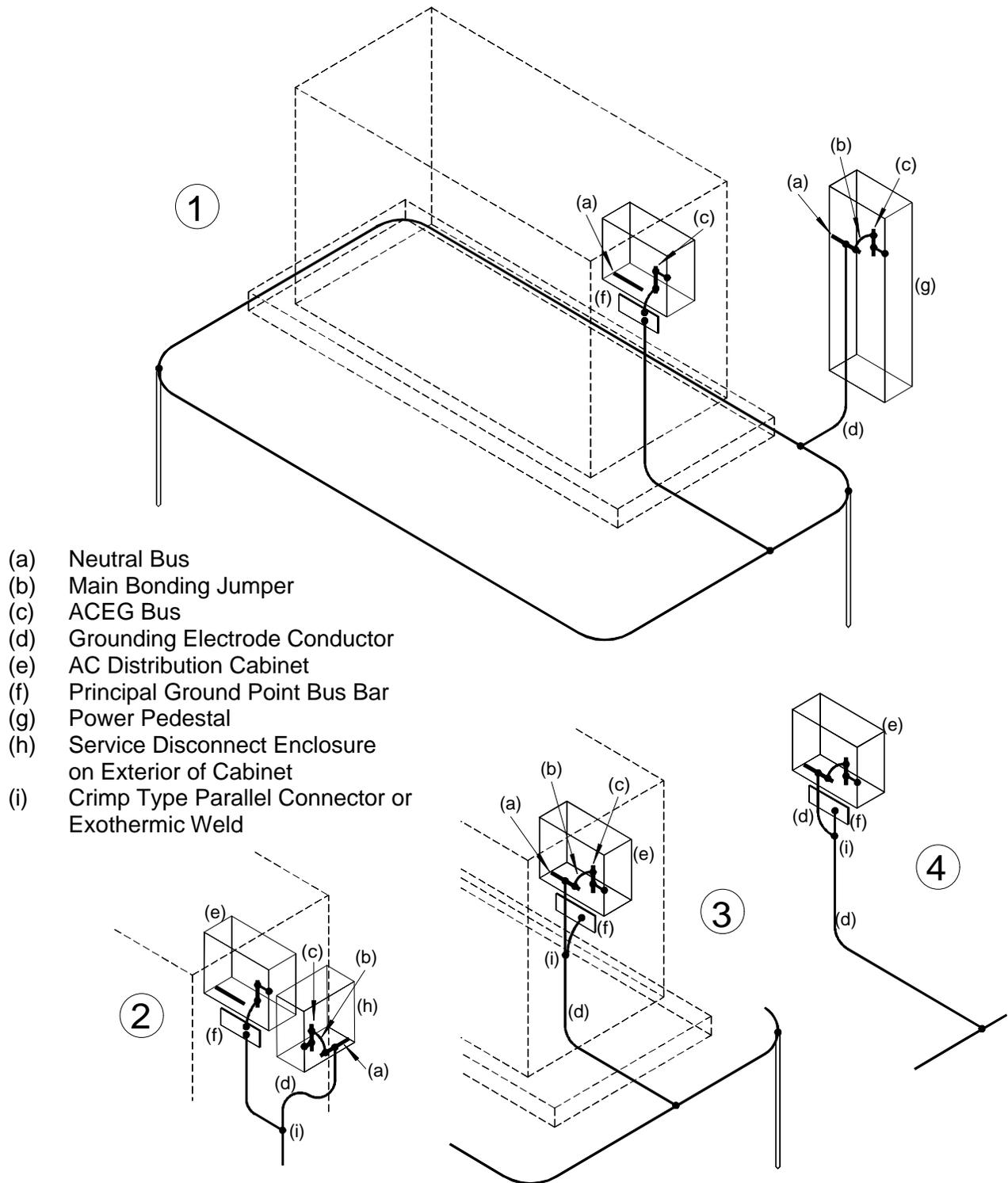


Figure 5-2
Variations of AC Service Grounding (pad-mounted cabinet shown)

D. Additional Considerations

- 5.2.16 Even in the unlikely event that an EEE is equipped with a metallic water pipe, a supplemental earth electrode per section 250-81 of the NEC is still required.
- 5.2.17 The conductors downstream from the panel containing the main ac service disconnect are considered either feeder or branch circuits. This is noted here because certain grounding conductors may only be connected at a point on the earth electrode system or a service raceway or enclosure. This means that feeder or branch circuit raceways, enclosures and equipment grounding conductors must not be used in place of a separate bonding conductor from protectors, cable shields or some other earth electrode. While all of these items must be bonded together, the acceptable location and methods for the bonds must be evaluated.

E. Grounding Conductor Placement and Sizes

- 5.2.18 Conductors between earth electrodes shall be minimum #6 AWG.
- 5.2.19 An EEE's grounding electrode conductor shall be minimum #6 AWG. A larger conductor is required only if ac service phase conductors are larger than #1/0 AWG copper or #3/0 AWG aluminum. If this is the case, the conductor shall be sized per Table 2-2.
- 5.2.20 A conductor equivalent to the horizontal equalizer in a CO shall be installed in a hut or BG/EEE. This conductor is referred to as the main grounding conductor. For huts and BG/EEEs, the minimum size for this conductor is #2 AWG. This conductor shall originate at the PGP bus bar and be routed through the EEE in a way that allows access to add crimp type taps for branch conductors. See Figure 5-3.
- 5.2.21 If used in a cabinet, a main grounding conductor shall be a minimum #6 AWG. This conductor may serve as a connection point for other grounding conductors in a cabinet whether or not the enclosure has been equipped with a PGP bus bar.
- 5.2.22 The main grounding conductor shall serve as a connection point for other grounding conductors in the BG/EEE or hut. It may also serve as the system grounding conductor for the power plant, unless the output of the dc power plant exceeds 500 amperes.
- 5.2.23 In huts and BG/EEEs, the #2 AWG main grounding conductor shall be used in place of the #1/0 AWG required in Sub-section 3 of this Practice as a termination point for bonds from protectors, protector frames/modules, and fiber optic cable terminating equipment.

F. DC Power System and Equipment Grounding

- 5.2.24 Every dc power system in an EEE shall be operated as a grounded system. The dc system grounding conductor shall be connected between the EEE's grounding system and the battery return bus in the power plant.
- 5.2.25 In cabinets, the dc power system grounding conductor shall be a minimum #6 AWG, for huts and BG/EEEs, a minimum #2 AWG is required. The EEE's main grounding conductor can also serve as the dc power system's grounding conductor.

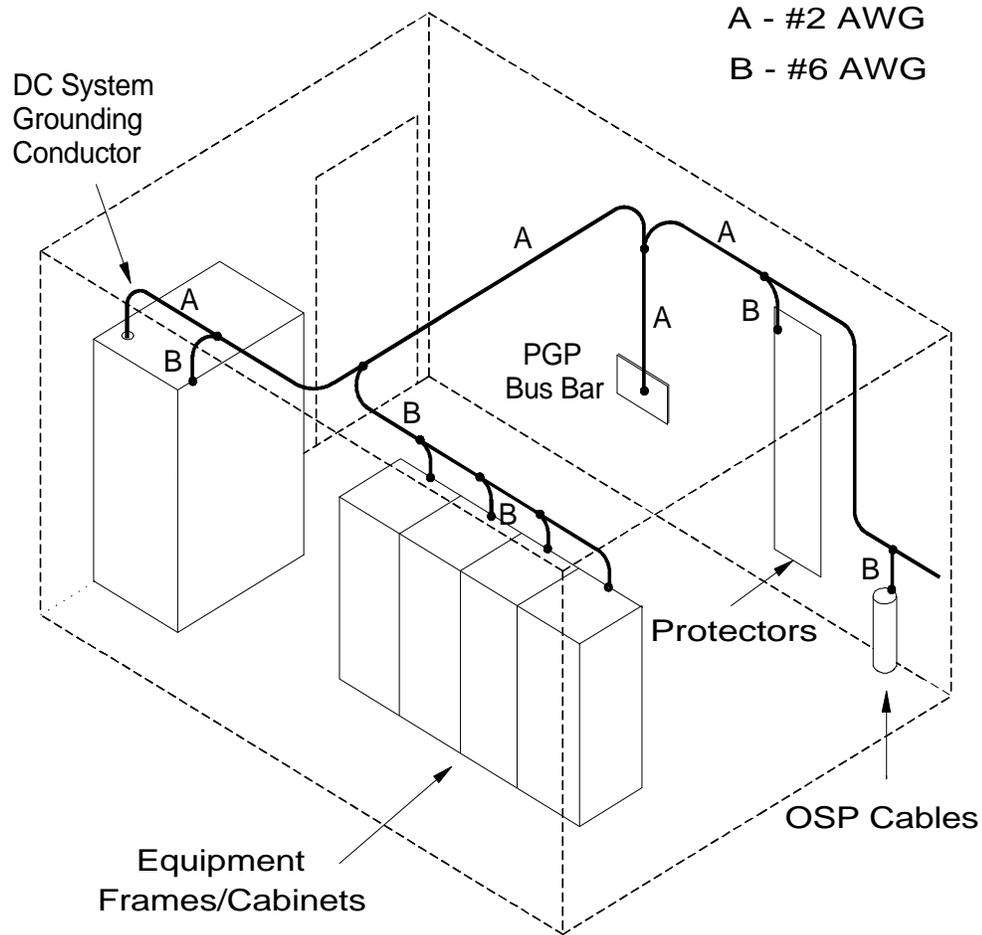


Figure 5-3
Typical Grounding Conductor Arrangement in an EEE (hut shown)

5.2.26 All frames, racks, cabinets and other metallic enclosures require a connection to the EEE's grounding system. The minimum size for this conductor is #6 AWG, and need be larger only when required by equipment vendor specifications.

5.2.27 For huts and BG/EEEs, a single #6 AWG may serve a lineup of equipment, with separate #6 AWG conductors tapped from the lineup conductor to serve each frame, cabinet, etc.

5.2.28 Wall mounted units served by an ac equipment ground (ACEG) conforming to the requirements in Part 2 are considered adequately grounded via the ACEG system.

Note: If these units also contain dc-powered components, they will require a separate bond to the EEE's grounding system.

G. Requirements in Other Sub-sections

5.2.29 Except for the alterations in A. through F. above, all EEE grounding and bonding systems shall meet the engineering, material and installation requirements in all other Sub-sections of this Practice.

5.3 ATTENDED POSITION EQUIPMENT

A. Position Bonding Grid System

5.3.01 Some attended position equipment requires a grounding network referred to as a *position bonding grid system* or *grid system*. The grid system is created by bonding together all grounding conductors, all accessible metallic objects and all equipment used by position attendants. The grid system described below assumes that the attended position equipment is located on a raised floor, but it may be adapted to other environments.

5.3.02 The basic grid system consists of minimum #6 AWG row and cross link conductors. The row conductors shall be routed as close as practicable to the center line of each row of position clusters. The crosslink conductors shall be placed in a way that bonds the row conductors together at intervals of no more than 15 feet.

Note: Most position arrangements are not symmetrical. While the majority of the positions will be located within the area of the basic grid system, some will be in remote locations separate from the rest of the positions.

5.3.03 Remote positions that are at least 15 feet from the basic grid system may be served by a single #6 AWG extended from the grid system. Positions that are within 15 feet of the basic grid system shall have the #6 AWG conductor serving them connected to the grid system in at least two places.

5.3.04 Below each position cluster, a length of minimum #10 AWG conductor shall be C-tapped to a row conductor. For most arrangements, this #10 AWG conductor can serve two positions; one at each end. This conductor must be as short as possible, and in no case can it exceed 6 feet in length from the C-tap (on the row conductor) to either end.

5.3.05 Positions separated from the main group of positions, such as supervisory and training positions, may use a single #10 AWG C-tapped to either a row or cross link conductor as long as all length limitations are not exceeded. This means that even a single position located more than 6 conductor feet from a row or cross link conductor must have a separate minimum #6 AWG routed to it. Careful evaluation of the position layout will provide the most efficient layout for the #6 AWG conductors and avoid an excessive number of separate branches.

5.3.06 The termination point for the #10 AWG conductor will depend on the type of equipment used at the positions. The preferred point of termination is at the most prominent piece of position equipment, such as the chassis of a controller unit. For some equipment, the best point of termination will be at a central location on a metallic member of the position furniture.

5.3.07 The grid system must be bonded to ACEG conductors serving position equipment. The bonds may be made at conduit junction boxes, pullboxes or the ACEG bus bar in the ac distribution panel(s) serving the position equipment.

5.3.08 Isolated ground type receptacles shall not be used to serve position equipment. If a piece of ancillary equipment (mini-computer, etc.) is required by the manufacturer's specifications to be served by an isolated ground type receptacle, the equipment shall not be co-located with any position equipment. A physical separation is required between mini-computer and position equipment to prevent a person using a working headset from touching the equipment served by an isolated ground type receptacle.

Note: This also prohibits the ACEG conductor serving the isolated ground receptacle from being directly connected to the grid system.

5.3.09 In all raised floor environments, a minimum of 4 bonds shall be installed between raised floor stanchions and the #6 AWG grid system. The bonds shall be placed as near as practicable to each corner of the grid system. The bonds shall be made using a minimum #6 AWG conductor tapped to the #6 AWG grid system and terminated on the support stanchions. The connection to the stanchion may be made using a crimp type terminal or an approved ground clamp.

5.3.10 Any other metallic objects entering, exiting or located within the area served by the grid system shall be bonded to the grid system. This includes conduits, cable racks, water pipes, etc. The bond shall be made with a minimum #6 AWG conductor, and preferably at a point along the perimeter of the grid system.

5.3.11 If position equipment is on a floor served by a CO GRD system, the grid system must be bonded to the CO GRD system with at least one #6 AWG conductor. This bond should be made between the two systems at a point near the floor CO GRD bus bar.

5.3.12 All grounding connections must be completed before power is applied to any position equipment or before other circuit conductors are connected to position equipment.

5.3.13 All position bonding grid system conductors shall be routed in a manner that avoids sharp bends and provides the largest bending radius possible.

5.3.14 Grid system conductors shall not be routed in metallic conduit. If required by a local jurisdiction to be routed in metallic conduit (such as when penetrating a wall), the grid system conductor must be bonded to the conduit at both ends.

5.3.15 All terminals, C-taps, H-taps and other connectors must be crimp type. Wherever possible, single hole terminals shall be ring type. All material shall be listed for its intended use by a nationally recognized testing laboratory.

5.3.16 All grid system conductors shall be type THW or THHW stranded copper and have green insulation.

B. Miscellaneous Requirements

5.3.17 The ac distribution system serving attended position equipment shall be equipped with a separate ACEG conductor, and shall comply with all other requirements in 2.8 of this Practice.

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- 5.3.18 The power cords for all ac powered attended position equipment shall be equipped with an ACEG conductor connected to the chassis of the equipment.
- 5.3.19 All attended position equipment and furniture shall be capable of having an additional #10 AWG grounding conductor connected to a point at chassis ground potential. This point may be a stud, a terminal strip, or a tapped or untapped hole in the equipment chassis or furniture metalwork.
- 5.3.20 Position equipment grounding arrangements shall be installed per the requirements of the equipment manufacturer only after verification of that such requirements comply with Company grounding requirements.
- 5.3.21 All information, operator or other system desks or positions that have exposed metal components and contain dc powered equipment shall have a connection to the CO GRD system. If a grounding conductor is included in the dc power cable, it shall be equal in size to the battery conductor. If a grounding conductor is not furnished with the power cable, a grounding system shall be installed, and at a minimum shall consist of:
- (a) a minimum #6 AWG conductor extended from a point in the CO GRD system, branched as needed to serve groups or lineups of desks or positions
 - (b) minimum #14 AWG conductors branched from the #6 AWG conductor and connected to the metalwork of each desk or position

5.4 EQUIPMENT TRAILERS

- 5.4.01 A trailer containing network equipment, often referred to as a *restoration trailer*, must meet the same grounding requirements as a central office, except as noted below. The trailer must also meet requirements of Article 551 of the National Electrical Code, which covers trailers, campers and recreational vehicles.
- 5.4.02 The trailer should be equipped with a main ground bus bar that is the equivalent of an OPGP in a central office. The bus bar should be placed to allow access from outside the trailer, and should be designated **MAIN TRAILER GROUND**. If convenient, this bus bar may also serve as a CO GRD and/or MGB bus bar.
- 5.4.03 The metal chassis of the trailer shall be bonded to the main trailer bus bar. This may be done by mounting the bus bar directly on the chassis, or by the use of a minimum #1/0 AWG copper conductor between the chassis and the bus bar. If the trailer has a metal exterior covering, the covering does not require separate bonding unless intentionally insulated from its support members and the chassis.
- 5.4.04 The trailer must have an earth ground reference. If the trailer receives commercial power from the structure, it must use the same ground reference as the structure. A conductor shall be added between the main trailer ground bus bar and the structure's OPGP bus bar. If no OPGP is provided or it is not available, the conductor from the trailer may terminate at a point on the structure's grounding electrode conductor.
- Note: The ACEG conductor that must be included in the feeder between the structure and the trailer may not be used as the earth ground reference for the trailer.

5.4.04 If the trailer is dispatched to a site with an inaccessible or non-existent earth electrode system, ground rods shall be driven and connected in a triangular pattern. The rods shall be spaced at least 10 feet apart, with 20 feet the preferred separation. This array should be as near the trailer, and connected to the trailer's main ground bus bar.

5.4.06 The trailer shall be equipped with the material needed to create a driven ground system or to connect to a structure's ground system. The following items will provide the ability to adapt to most situations:

- (a) 100' - 150' of #1/0 insulated stranded copper cable
- (b) 3 copper-clad steel ground rods, 3/4" x 10'
- (c) 2 two-hole mechanical type connectors, #1/0 AWG to bus bar
- (d) 4 mechanical type connectors, #1/0 to 3/4" ground rod
- (e) 1 mechanical type parallel connector, #3/0 to #1/0
- (f) 1 mechanical type parallel connector, #1/0 to #2

5.4.07 When a trailer is capable of being connected to a commercial ac source and is equipped with an engine-alternator or the ability to connect to one, the transfer switch on the trailer shall be of the type that switches the neutral conductor.

5.4.08 An engine-alternator, whether portable or mounted on the restoration trailer, shall be grounded as a separately derived source. A grounding electrode conductor (GEC), sized per Table 2-2 of this Practice, is required between the trailer's main ground bus bar and the engine-alternator's neutral conductor. This connection must be made at a point between the alternator and its first disconnect means. A main bonding jumper, equal in size to the GEC, is required between the neutral and the ACEG, and must be made at the same point. The most appropriate location for these connections is usually in the engine-alternator disconnect panel.

5.4.09 A trailer may be equipped with a main power transformer for use when a site's commercial power is usable but not compatible with that required by the trailer. The transformer may be portable or attached to the trailer. The grounding of the transformer will depend on its location. If permanently mounted on the trailer or if portable and located near the trailer, it must be grounded in the same manner as a trailer-mounted engine-alternator. If located in or near the CO or other structure, the grounding electrode conductor must connect to the nearest of either the structure's earth electrode system, OPGP, or building steel.

Note: The ACEG conductor required with the transformer's primary feeder conductors shall not be used as a substitute for the grounding electrode conductor.

5.4.10 All permanent ac circuits routed on the exterior of the trailer must be contained in either rigid non-metallic or metallic conduit, IMT or EMT. Flexible conduit is not allowed on the exterior of the trailer.

5.4.11 Every temporary cable connected to outside plant cables (copper or fiber optic) shall be equipped with a means to maintain cable shield continuity. The minimum size for this bond shall be no smaller than #10 AWG, with a #6 AWG conductor or equivalent strap preferred. This conductor shall be terminated using crimp or mechanical type connectors. Slip-on connectors shall not be used.

5.5 CUSTOMER PREMISES EQUIPMENT

A. General

5.5.01 The grounding requirements in 5.5 A. – G. apply to network equipment located on customer premises. The term "network equipment" applies to any piece of ac or dc powered Company-provided equipment that is located between the primary over-voltage protectors and equipment owned by the customer.

NOTE: The requirements in 5.5 A. – G. **do not** cover equipment grounding at electric power stations. Refer to 876-310-100 and 638-600-200. For information on grounding and bonding of primary over-voltage protectors, refer to 876-300-100.

5.5.02 The Company usually does not design or control systems in customer's structures to which connections must be made, such as power and earth electrode systems. When network equipment is installed at these sites, adjustments may be needed to some of the grounding requirements that would normally be applied to the same equipment if located in a Company-owned structure. A Company representative should confer with the customer to obtain the most preferred arrangement as described below and in associated documents.

5.5.03 Except as modified by the contents of 5.5 A. – G, the engineering, material and installation requirements in all other sub-sections of this Practice should be applied to network equipment at customer premises. Grounding specifications from the network equipment vendor should also be reviewed.

5.5.04 The grounding systems shown in Figures 5-4 and 5-5 are examples of the maximum and minimum arrangements likely to be the responsibility of the Company when network equipment is placed at a customer's site.

5.5.05 Several items will affect the design of the grounding system that must be furnished with the network equipment, regardless of the amount of equipment provided. The following are addressed in 5.5 A. – G and should be evaluated early in the provisioning process:

- appearance of site's earth electrode system in equipment room
- presence of equipment grounding system in customer's equipment room
- location of cable entrance(s)
- type(s) of power required by network equipment
- type(s) of power provided by customer
- equipment and framework/cabinet grounding

NOTE: As used in 5.5 A. – G, "equipment grounding system", "central office ground" and "CO GRD" should be considered equivalent terms.

B. Access to a Site's Earth Electrode System

5.5.06 A metallic path to the site's earth electrode system must be available in the area where the network equipment is located. Using either a direct connection to network equipment or a connection to the equipment grounding system, a bond must be made, in order of preference, to one or more of the following:

- (1) a dedicated grounding conductor extended from the site's earth electrode system (see Figure 5-4) - this conductor may or may not be terminated at a bus bar; either arrangement is acceptable.
- (2) building structural steel, provided it is bonded to the site's earth electrode system
- (3) a continuous metallic water pipe, provided it is accessible along its entire length to the point where it is bonded to the site's earth electrode system
- (4) a metallic conduit, raceway or panel containing service conductors
- (5) the metallic shield of a copper or fiber cable that has been bonded to the site's earth electrode system at the cable entrance
- (6) a separate grounding conductor extended from the ground system at the cable entrance, that is routed with the copper/fiber cable(s) serving the network equipment (see view B of Figure 5-5)
- (7) If it furnishes a continuous metallic path to the site's earth electrode system, a metallic conduit, raceway or panel containing feeder conductors
- (8) If it furnishes a continuous metallic path to the site's earth electrode system, a metallic conduit, raceway or panel containing branch circuit conductors

NOTE 1: When required per 876-300-100, the conductor to an approved floor ground that serves the primary over-voltage protectors may also serve network equipment.

NOTE 2: The locations in (7) and (8) should only be used when no other location is available.

NOTE 3: Any conduit bonding hardware (bushings, clamps, etc.) must be listed for the purpose.

C. Customer's Equipment Grounding System

5.5.07 Installation of network equipment may be planned for an area served by a customer-furnished equipment grounding system. This system may also serve network equipment if the following two conditions are met:

- (1) The grounding system must be connected to the site's earth electrode system by at least one of the methods describe above.
- (2) The minimum size for the conductor serving frames, cabinets or other enclosures containing network equipment is #6 AWG.

NOTE: A customer may have equipment grounding system requirements that specify conductors larger than the minimum sizes specified in 5.5 A. – G and this Practice.

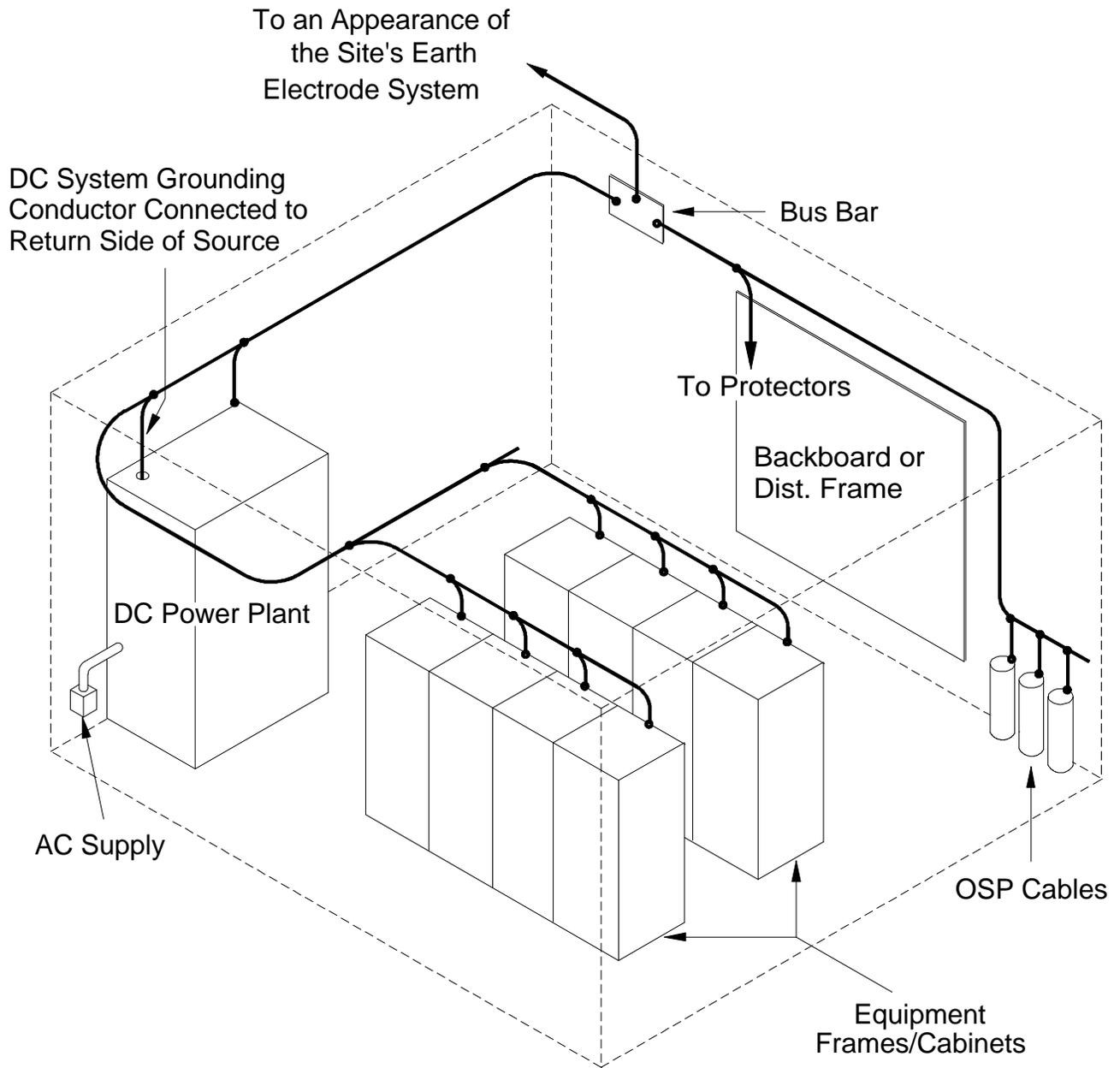


Figure 5-4
Typical Grounding Arrangement for Customer Premises Telephone Room

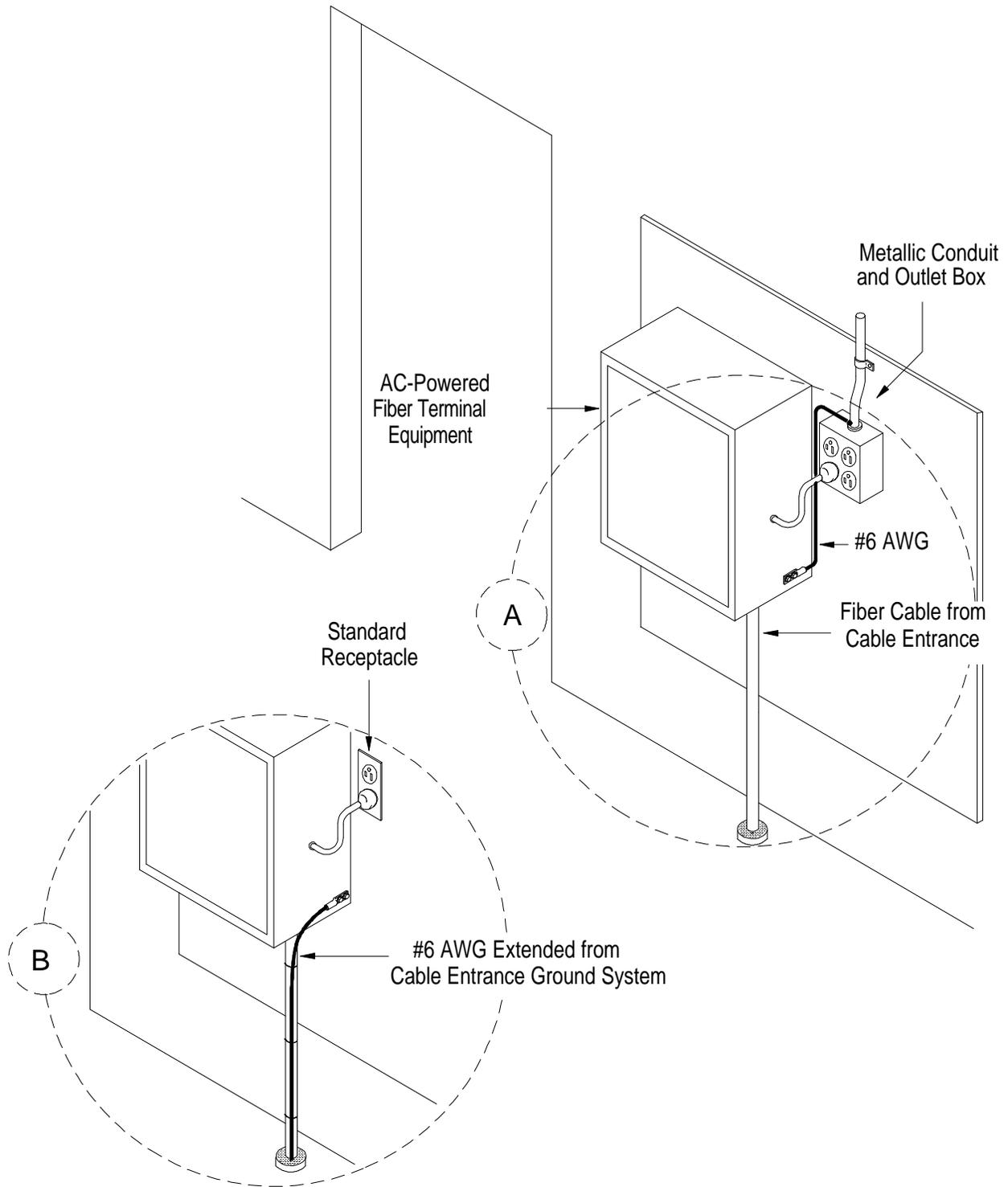


Figure 5-5
Grounding Arrangements for Wall-Mounted Customer Premises Equipment

D. Cable Entrance

5.5.08 The cable entrance(s) may or may not be located in the same area as the network equipment. This document does not cover cable entrance grounding and bonding. Refer to 876-300-100.

Note: There may be sites where consideration of the grounding requirements for a cable entrance and network equipment will result in a mutually beneficial arrangement. Figure 5-4 shows a single conductor from the site's earth electrode system serving the cable entrance and the equipment area.

E. DC Power Systems Provided with Network Equipment

5.5.09 If a dc power source is provided with Company-owned network equipment, it shall have the return side of the dc system grounded to the site's earth electrode system. It must also be bonded to the equipment grounding system serving frames, cabinets or other enclosures containing network equipment served by the power source.

5.5.10 The dc system grounding conductor must be connected to an appearance of the site's earth electrode system as described above. Figure 5-6 shows a dc system grounding conductor bonded to the bay ground lead, which, via the framework ground conductor, is eventually bonded to an appearance of the earth electrode system.

5.5.11 For dc power systems with a rated capacity of no more than 100 amperes, a minimum #6 AWG conductor must be used for the dc system grounding conductor. For dc systems with a capacity larger than 100 amperes, the conductor shall be sized per requirements in 3.3.03 and Table 3-1 of this Practice.

5.5.12 The point of connection within the dc power system for the system grounding conductor will depend on the type of components used. If a bus bar is used to terminate battery return conductors from the batteries, rectifiers and fuse panels (or directly from the equipment), it is the most preferred point. If a bus bar is not used, the next preferred point is the battery return terminal on the output of the rectifier.

F. Power System(s) Provided by Customer

5.5.13 All ac receptacles serving network equipment must be of the grounding type.

NOTE: While verification is beyond the scope of this document, that portion of a customer's ac power system serving network equipment should be equipped with an ac equipment ground (ACEG) system in compliance with Article 250 of the latest edition of the NFPA 70, *The National Electrical Code*.

5.5.14 In the event that an ac branch circuit is to be hard wired (not cord-connected) to network equipment, the serving conduit or raceway must be equipped with a separate ACEG conductor routed with the other circuit conductors. The metallic raceway alone may not be used as the ACEG. See Sub-section 2 of this Practice.

5.5.15 If customer-provided dc power is used, the equipment grounding system serving the frames, cabinets or other enclosures containing network equipment must be bonded to the return side of the dc system.

G. Grounding and Bonding Within Frames, Cabinets & Enclosures

5.5.16 A variety of network equipment may be deployed at a given site. Equipment units that are installer mounted at the site or assembled off-site into a frame or cabinet may require one or more connections to the equipment grounding system. When required, a bay ground lead can be used to extend the equipment grounding system into equipment frames, cabinets and other enclosures to allow termination of grounding conductors from units and cable shields. A bay ground lead may be a solid or stranded conductor, bus bar, or other conductive path.

5.5.17 The bay ground lead shall not be used to conduct normal load (battery return) current.

Note: A stranded bay ground lead (SBGL) is described in, and ordered per drawing PBSD-ED-6501. The SBGL allows conductors between #6 AWG and #26 AWG to be crimped, wire wrapped, or wrapped and soldered to the SBGL components. It is the preferred method to extend the equipment grounding system into equipment frames, cabinets and other enclosures.

5.5.18 Network equipment (units, shelves, etc.) requiring connection(s) to the equipment grounding system may be installed in a customer's frame or cabinet. If the equivalent of a bay ground lead is not present in the frame or cabinet, the grounding conductor(s) from the equipment should be terminated on the closest appearance of the equipment grounding system.

Figure 5-6 depicts a generic configuration of an equipment frame equipped with a dc power system, network equipment, etc., all supplied by the Company. Note that the SBGL is used as the point of connection for the dc system grounding conductor.

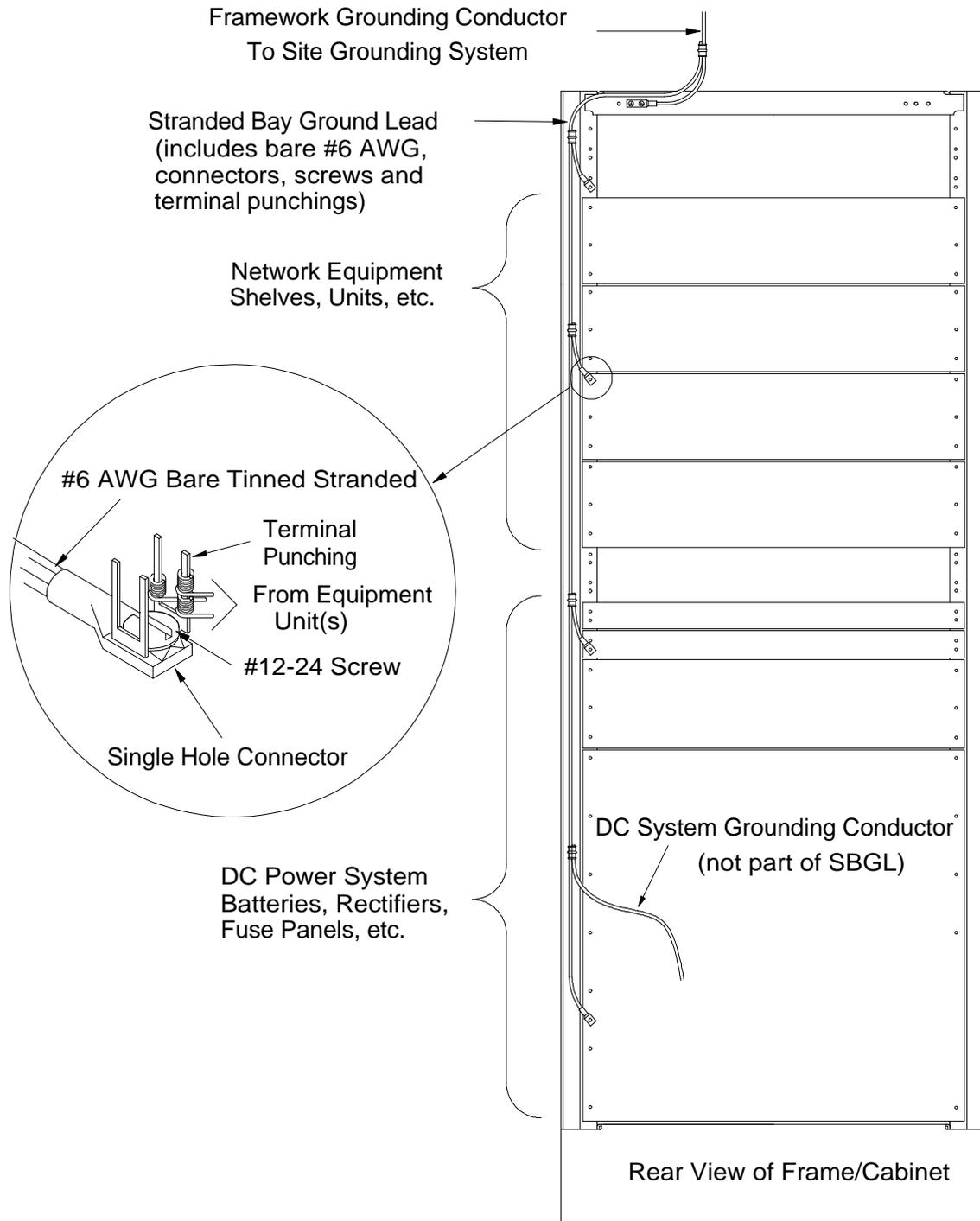


Figure 5-6
Network Equipment Frame/Cabinet Grounding Details

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6.1 SCOPE

6.1.01 This Sub-section provides grounding and bonding requirements for radio equipment, structures and rooms containing radio equipment, antennas, antenna towers, other antenna support arrangements, and transmission media between antennas and radio equipment. The requirements are applicable to systems used for network service, maintenance, receive only, and systems located on customer premises.

6.1.02 The grounding and bonding system is a fundamental part of the protection scheme for a radio site and radio equipment. However, other elements, not covered in this Practice, must be considered including:

- (a) electrical protection of the ac service
- (b) electrical protection of all other copper and fiber optic cables entering the structure by either aerial or underground means

6.2 GENERAL

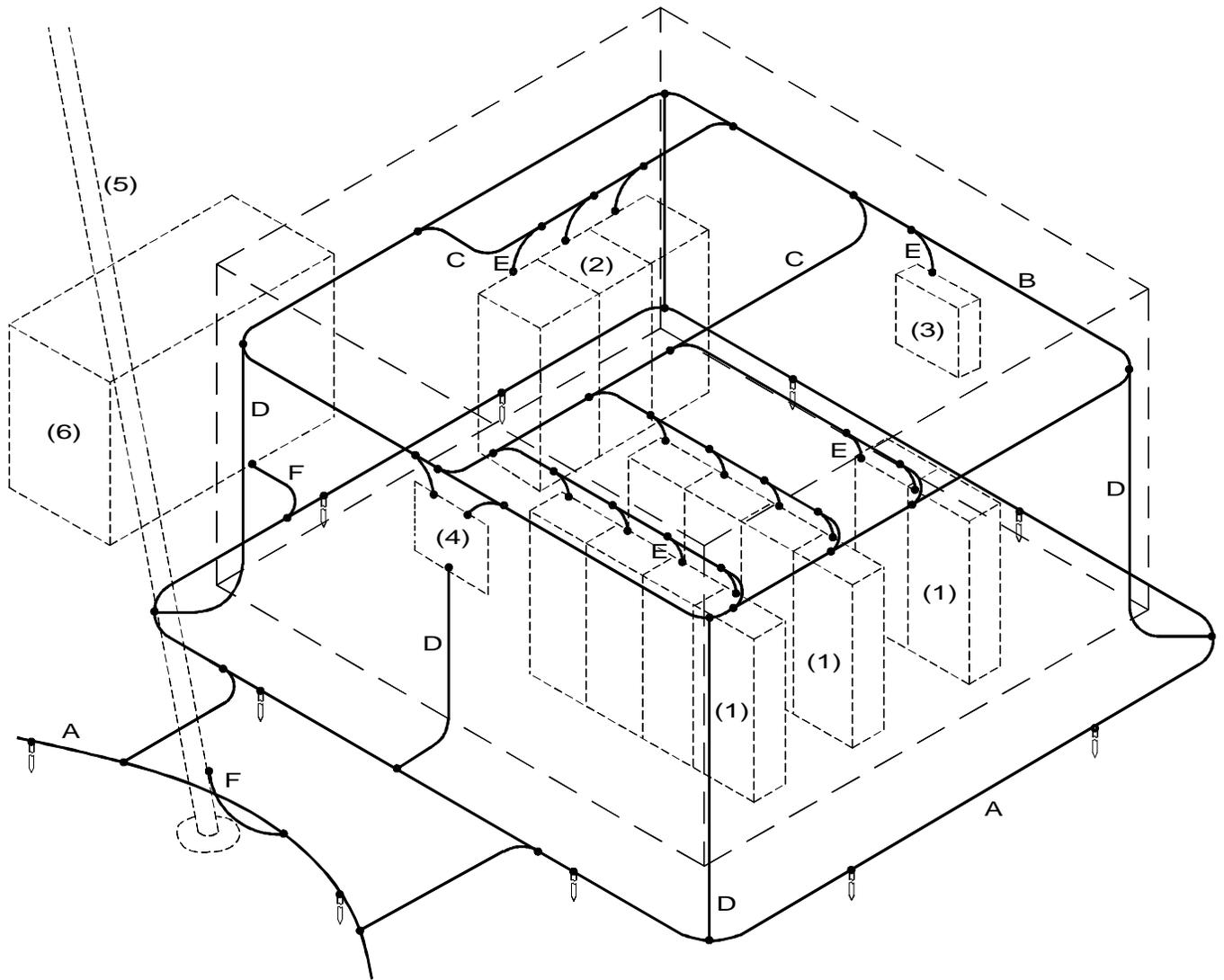
6.2.01 The intent of a grounding and bonding system for a radio site and its equipment is to establish low impedance paths to earth and low impedance bonds between nearby metallic objects. This reduces the voltage differential between objects and the earth, and between nearby objects within a structure during a lightning stroke. During a stroke, extreme voltage differential may develop between points on a conductor. Inductive reactance is the major component of the impedance of a lightning current path. An increase in the size of a conductor will reduce its dc resistance but will not significantly reduce the voltage differential between points along this path. Reducing a path's dc resistance by using conductors larger than #2 AWG results in little reduction in impedance. A #2 AWG conductor will carry substantial current without thermal damage, and it is resistant to mechanical damage.

6.2.02 Voltage differential can be minimized by ensuring that the path is of lowest practical impedance and/or by providing parallel paths of minimum impedance. A straight conductor of shortest possible length is the path of lowest impedance.

6.2.03 Every type of transmission media between an antenna tower and a structure housing radio equipment consists of one or more conductive paths that can carry current during a lightning strike to the tower. The designs described in this Practice are intended to conduct lightning current on conductors external to the building and equipment to the greatest extent possible.

6.2.04 Figure 6-1 depicts a typical radio site grounding and bonding system and consists of:

- (a) an exterior ring ground system
- (b) a peripheral conductor
- (c) supplementary conductors
- (d) interior-exterior ring ground bonds
- (e) interior unit bonds
- (f) exterior unit bonds



- | | |
|-----------------------------|-----------------------------------|
| A - Exterior Ring Ground | (1) - Equipment Lineup |
| B - Peripheral Conductor | (2) - Power Plant |
| C - Supplementary Conductor | (3) - Miscellaneous Unit |
| D - Interior-Exterior Bond | (4) - Waveguide Hatchplate |
| E - Interior Unit Bond | (5) - Antenna Tower Leg |
| F - Exterior Unit Bond | (6) - Engine-Alternator Enclosure |
| ⦿ - Ground Rod | |

Figure 6-1
Typical Radio Site Grounding System

6.3 EXTERIOR RING GROUND SYSTEM

A. Earth Electrode System

6.3.01 The exterior ring ground conductor is the main element of the earth electrode system. It shall be a minimum #2 AWG bare solid copper conductor.

Note: Earth electrode material and installation requirements not specified in this Sub-section shall be installed as described in 2.2 C. of this Practice.

6.3.02 The earth electrode system shall form a ring around the building and the tower, and where possible, consist of a driven ground rod system. Wherever possible, a single ring should be used to enclose both the tower and the building..

Note: When site conditions prevent the use of driven rod system, another ring type earth electrode system, or a combination of systems described in Sub-section 2 of this Practice shall be provided.

6.3.03 The earth electrode system shall be installed around an antenna tower's legs and/or guy anchors. Each guy anchor and tower leg shall have a driven ground rod that is bonded to the tower ring ground system and the guy anchor and/or tower leg.

6.3.04 Where separate ring ground systems have been provided for the tower and the building, at least two bonds shall be made between the tower ring ground system and the building ring ground system using minimum #2 AWG solid copper conductors. The bonds should be as short as possible, and should originate at two corners of the tower ring system.

B. Roof Ring Ground System

6.3.05 When an antenna tower is mounted on the roof of a structure, a roof ring ground system is required. The roof ring ground system shall be formed around the tower's legs similar to a buried tower ring ground system. Bonds shall be extended to tower legs and other metallic objects on the roof.

6.3.06 On buildings not exceeding 75 feet in height that are reinforced concrete or other type of construction, where continuity to earth through building steel is not assured, a minimum of two #2 AWG down conductors shall be extended from the roof ring ground system to the exterior ring ground system. A down conductor is required for each 100 feet of building perimeter or fraction thereof. For example, a building with a perimeter of 420 feet would require at least 5 down conductors.

Note: On buildings more than 75 in height, down conductors shall be minimum #2/0 AWG.

6.3.07 On steel frame buildings, regardless of height, building steel may serve in place of separate down conductors. At least two bonds shall be made between the roof ring ground system and building steel from opposing points on the ring. Additional bonds to building steel shall be made at an interval not exceeding that for down conductors in 6.3.06 above.

6.3.08 When structural steel serves as down conductors between a roof ring ground system and an exterior ring ground system, bonds between building steel and the exterior ring ground system shall be made at every other steel column along the building's perimeter.

6.3.09 When structural steel is used in place of down conductors, a bond must exist between the OPGP and a structural steel member. The bond may be in the form of the OPGP bus bar's mounting studs, a minimum #2 AWG conductor between the OPGP and structural steel, or a connection between a driven ground rod system that is bonded to the OPGP and a structural steel member.

6.3.10 If any guy wires are anchored to the roof or other part of a structure, a #2 AWG down conductor shall be installed between each guy anchor on the structure and the exterior ring ground system.

6.3.11 All roof-mounted hatchplates (equipped and unequipped) shall be connected to the roof ring ground system with a minimum #2 AWG conductor.

C. Interior-Exterior Bonds

6.3.12 Primary and secondary bonds shall be placed between the interior and exterior ring ground systems. Primary bonds originate on hatchplates, secondary bonds originate at other points along the peripheral conductor.

6.3.13 Structures that do not require a roof ring ground system shall have roof mounted hatchplates bonded to the exterior ring ground system with a minimum #2 AWG primary bond. The bond shall be connected to the hatchplate on the interior side, routed past and bonded to the peripheral conductor, and then extended to the exterior ring ground conductor in PVC conduit.

Note: The bonds between hatchplates and a roof ring ground system are considered primary bonds since the roof ring ground system is bonded to the external ring ground system.

6.3.14 Wall mounted hatchplates shall be bonded to the exterior ring ground system using a minimum #2 AWG conductor. The bond shall be connected to the hatchplate on either the exterior or interior side. If connected to the interior side of the hatchplate, it shall be extended to the exterior ring ground conductor in PVC conduit.

6.3.15 When the radio equipment is in a central office building, a minimum #2 AWG primary bond shall be installed between hatchplates and the closest of either the OPGP or CO GRD bus bar. The bond shall be connected to the hatchplate on the interior side, routed past and bonded to the peripheral conductor and extended to the applicable bus bar.

6.3.16 Minimum #2 AWG secondary interior-exterior bonds shall be installed between the peripheral conductor and the exterior ring ground system in at least four locations. At minimum, these bonds shall be placed at the corners of the structure. Additional bonds shall be added when the distance between secondary bonds or between primary and secondary bonds exceeds 50 feet. These additional bonds shall be evenly spaced between other bonds.

D. Bonds to Antenna Towers

6.3.17 A bond is required between the tower metalwork and the transmission media (coax, waveguide, etc.) at the point where the media turns toward the structure. The media should make this turn as near as practicable to the base of the tower. See Figure 6-2.

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6.3.18 Bonds between a tower and rigid waveguide may be made via the waveguide's mounting hardware. If the mounting hardware does not provide continuity, a minimum #6 AWG bonding conductor is required.

6.3.19 The outer shield of coaxial cable and elliptical waveguide must be bonded to the tower structure. A convenient method for this bond is by the use of a "grounding kit" which includes a #6 AWG bonding conductor. An example is shown in Figure 6-2.

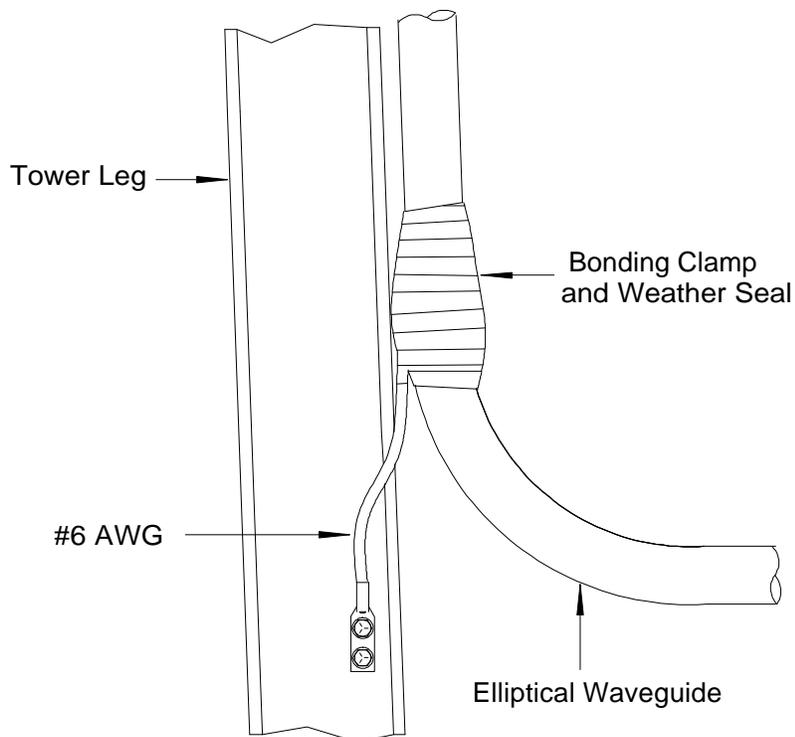


Figure 6-2
Bond to Tower Leg

6.4 INTERIOR RING GROUND SYSTEM

6.4.01 The interior ring ground system consists of:

- (a) a #2 AWG peripheral conductor along the boundary of the radio equipment area
- (b) #2 AWG supplementary conductors
- (c) #2 AWG bonds between a peripheral conductor and the exterior ring ground system
- (d) unit bonds

Note: When properly bonded to the exterior ring ground system, a connection to a peripheral or supplementary conductor is considered equivalent to a connection to an OPGP, and equipment located within the area of the peripheral conductor may obtain earth potential reference from any point on peripheral or supplementary conductors.

A. Peripheral Conductor

6.4.02 When a building or one of its floors is used primarily for radio and associated equipment, a peripheral conductor shall be formed into a ring around the interior of the entire building or floor. This is the primary element of the interior ring ground system.

Note: When the radio area occupies only part of a floor area (e.g., less than half), the ring shall encircle the radio area only. If separated from the radio equipment area, power equipment associated with the radio system need not be included within a ring ground system in central office installations.

6.4.03 The peripheral conductor shall be a minimum #2 AWG, and may be a bare solid, bare stranded or insulated stranded conductor. When an insulated conductor is used, the insulation should be green in color. Aluminum conductors shall not be used.

Note: Generally, a stranded insulated conductor will provide the least expensive, most reliable installation. With the exception of support strap sizes, construction methods using bare stranded wire are virtually identical. See ED-82138-31.

6.4.04 The peripheral conductor need not be installed as a single continuous conductor. Unnecessary splices should be avoided, but when installation is simplified by installing the peripheral conductor in segments, and segments are joined by an exothermic weld (preferred) or crimp type parallel connector, such segmentation is permitted.

6.4.05 Routing of the peripheral conductor through metallic objects that form a ring around the conductor, such as metallic conduits or sleeves through walls or floors, shall be avoided whenever possible. Non-metallic material such as PVC conduit is preferred for floor or wall penetrations. If non-metallic conduit is prohibited by local code, the peripheral conductor shall be bonded to each end of the metallic conduit.

6.4.06 To minimize impedance and incident of arcing, the peripheral conductor shall be installed with a minimum number of bends. Bends shall be made with the greatest practical radius, with a preferred radius of no less than 1 foot. When this is impractical, the minimum radius shall not be less than 6 inches. Use of 90-degree bends to avoid obstructions shall be avoided when lesser bends (e.g., 45-degrees) can be adequately supported.

6.4.07 The peripheral conductor shall be run exposed to allow inspection of the system and to connection of branch conductors. PVC conduit should not be used for support.

6.4.08 The peripheral conductor shall be located at a height from the floor that allows for convenient bonding of supplementary conductors. In an installation with 9'-0" frames, the recommended height is 9'-8".

6.4.09 Supports shall be provided at an interval of between 18 and 24 inches. Extra supports may be provided where the peripheral conductor may be distorted, such as at bonding points. When the peripheral conductor is not located on a wall, it should be supported from cable racks or auxiliary framing channels.

6.4.10 Bonds to the peripheral conductor shall be made using either exothermic welds or crimp type parallel connectors. These connections need not be insulated.

B. Supplementary Conductors

6.4.11 Supplementary conductors are also part of the interior ring ground system, and are usually needed between points on the peripheral conductor to ensure that radio and associated equipment meet the two fundamental requirements for unit bonding:

- (1) All metallic objects within the area of the interior ring ground system not directly bonded to the peripheral conductor shall be connected to the peripheral conductor via a minimum of two paths.
- (2) All metallic objects within 7 feet of each other must be bonded together.

6.4.12 The requirements (1) and (2) above are normally met via paths formed by unit bonds to the ring ground system. The following shall be used to determine maximum allowable lengths of bond paths between objects:

- (a) For objects located within 1 foot of each other, the bond path length shall not exceed 15 feet.
- (b) For objects located from 1 to 7 feet of each other, the bond path length shall not exceed 30 feet.
- (c) When (a) or (b) cannot be met via connections to a peripheral conductor, the objects shall be bonded via a supplementary conductor or by a direct bond between objects.

Note: Mechanical connections between metallic objects (e.g., inter-frame bolting) shall not be considered as a bond path except where the interconnective device is a relay rack ground bus bar or a metal pipe used as a frame ground.

6.4.13 Supplementary conductors shall be installed over and between equipment lineups. To provide a parallel path, the conductors must provide two paths to the peripheral conductor. One end of a supplementary conductor may be terminated on another supplementary conductor to provide the second path.

6.4.14 Supplementary conductors shall be the same size (minimum #2 AWG) and material as the peripheral conductor. Aluminum conductors shall not be used. Other conductors shall be bonded to the peripheral conductor using either exothermic welds or crimp type parallel connectors. These connections need not be insulated.

Note: See 6.5 C. for other acceptable material for supplementary conductors over lineups.

Supplementary conductors may be supported from cable rack stringers or framing channels using sewing twine, cable ties, clamps or clips. If clamp or clip supports are used, a type that does not require drilling of channels and stringers is preferred. All supports shall be placed at an interval of 18 to 24 inches. Removal of paint from the channel or stringer is not required when clamps or clips are used. Scratches in the finish shall not be painted, and clamps or clips shall not be painted. A job-fashioned detail may be used to route the conductor around obstructions at cable rack junctions or other points interfering with the conductor.

6.4.15 The supplementary conductor shall be bonded to a channel or stringer at an interval not exceeding 15 feet when the conductor parallels the channel for a distance greater than 20 feet. The channel or stringer shall be drilled and a crimp or mechanical type clamp shall be secured to the channel or stringer. The preferred means is shown in Figure 6-3, using a Burndy GB26 connector or equivalent.

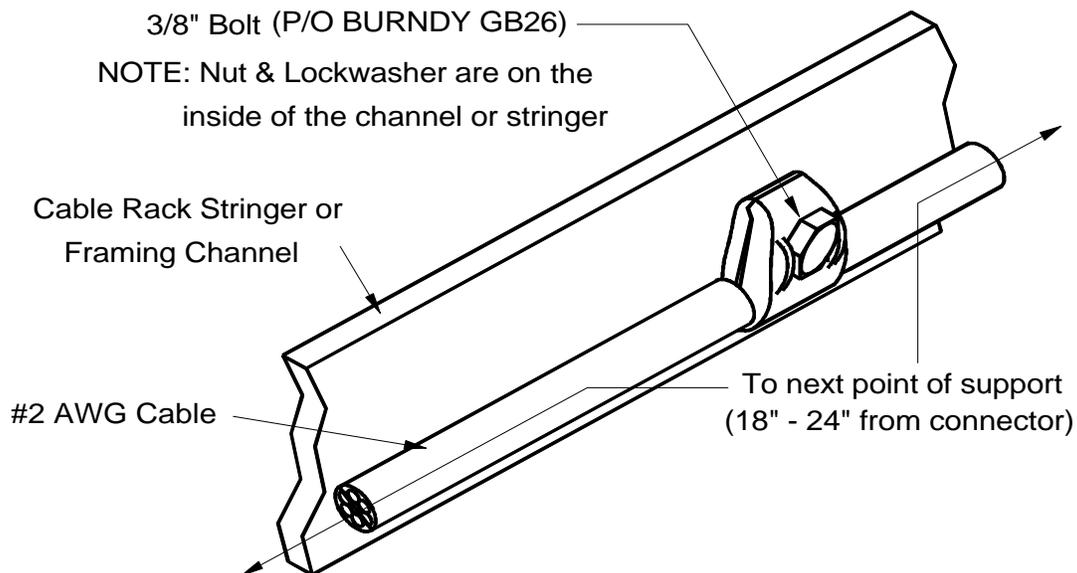


Figure 6-3
Method of Bonding Supplementary Conductor to a Framing Channel

6.4.17 To minimize impedance, special attention must be paid to the direction of turns at all junctions of supplementary and peripheral conductors. At the junction nearest a hatchplate, the supplementary conductor shall turn in the direction of the hatchplate. The other end of the conductor shall turn in the opposite direction, toward a bond between the exterior ring ground and the peripheral conductor more remote from the hatchplate than the connection of the supplementary conductor.

6.4.18 When there is no significant difference in the length of the bond paths to a hatchplate from either end of a supplementary conductor, both ends shall turn in the direction of the hatchplate. When the building is equipped with more than one equipped hatchplate, the end of the supplementary conductor shall turn in the direction of the nearest hatchplate.

6.4.19 If one or more hatchplates are not equipped with waveguides, the supplementary conductor shall turn in the direction of the nearest equipped hatchplate. When coax or waveguide is added to the unequipped hatchplate, a second bond shall be made at the turn, in the opposite direction, to create a bi-directional turn.

Note: Where doubt exists as to the correct direction for a turn, a bi-directional arrangement may be used. Universal application of bi-directional bonds is not recommended.

C. Waveguide and Coaxial Cable Bonds

6.4.20 Waveguides and coaxial cables require no bonds to the interior ring ground system when they are bonded to a hatchplate that is located within 25 feet of the interior ring ground system.

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6.4.21 When the hatchplate is located more than 25 feet from an interior ring ground system peripheral or supplementary conductor, waveguides and coaxial cables shall be bonded to the interior ring ground system. Waveguides and coaxial cables within 7 feet of each other shall be bonded together with a minimum #6 AWG. The bond shall be extended to a peripheral or supplementary conductor at a point where the waveguides or coaxial cables enter the area protected by the interior ring ground system.

Note: Primary bonds between such remotely located hatchplates and interior conductors may be omitted when waveguides and coaxial cables are so bonded.

6.5 UNIT BONDS

6.5.01 At radio sites, every metal object that is buried or above ground on the building exterior, part of the building structure, or located inside the building should be regarded as a path for lightning current, and shall be bonded to the site's grounding system. An object is exempt from this requirement when **all** of the following conditions are met:

- (a) It would require an extraordinary expense to bond the object.
- (b) The object is not in contact with the earth.
- (c) The object is more than 7 feet from an object that is either bonded to a grounding system or in contact with the earth.

6.5.02 Objects assembled to provide low impedance continuity between components do not require inter-component bonding. Such objects include units mounted on a common metal frame or cabinet, air ducts (when joined to constitute a reliable electrical connection) and similar assemblies.

A. Exterior Unit Bonds

6.5.03 Metallic objects, external to or mounted on the building, shall be bonded to the exterior ring ground system. This includes earth supported metallic objects located within 7 feet of the exterior ring ground system or an object bonded to the exterior ring ground system.

6.5.04 Metal fences within 7 feet of the exterior ring ground system or objects bonded to the exterior ring ground system shall be bonded. If the fence runs continuously within 7 feet of the exterior ring ground conductor, it shall be bonded at an interval not exceeding 25 feet. Bonds shall be made across gate openings.

6.5.05 Conduits or pipes located on a roof or exterior wall shall be bonded at an interval not exceeding 25 feet.

6.5.06 Exterior unit bonds may be connected to the buried ring ground conductor, the roof ring ground conductor, or a down conductor between the roof and buried ring ground conductors.

6.5.07 A tree grounding system is recommended to bond objects on the exterior of a building. This system consists of main and branch conductors. A main conductor is connected to an exterior ground conductor, and is routed toward a group of units requiring bonds, terminating on the unit farthest from the exterior ground system. Branch conductors bond individual units to the main conductor, and sub-branches may be extended from branch conductors.

6.5.08 Main conductors shall be minimum #2 AWG and branch conductors shall be minimum #6 AWG. Branch conductors should be no longer than 15 feet. Where units bonded to different main conductors are within 7 feet of each other, the branch conductors of the two main systems should be bonded together so that the length of a direct bond between the units is not greater than 30 feet.

6.5.09 All buried connections shall be made using an exothermic weld. Connections made above ground shall be made with exothermic welds or a crimp type connector. Any connection other than an exothermic weld shall be located to permit periodic inspection.

B. Interior Unit Bonds

6.5.10 Every metal frame, cabinet, and individual metallic unit located within the area of the peripheral ring ground conductor requires unit bonding. The minimum size for a unit bond is #6 AWG. The length shall be determined using the requirements in 6.4.11 and 6.4.12.

6.5.11 Assemblies of known low impedance such as conduits and framework shall be considered as an extension of the unit bond conductor. When assessing the total bond conductor length for compliance with 6.4.12, the calculation shall include the distance from the bond point on an object to the point of proximity with another object. Figure 6-4 shows two cabinets separated by 6 inches. The cabinets are 3 feet wide, and are bonded at the top center. Both unit bond conductors are 3 feet long and connect to a peripheral conductor at points 4 feet apart. The total bond length is 13 feet, which meets the 15-foot requirement.

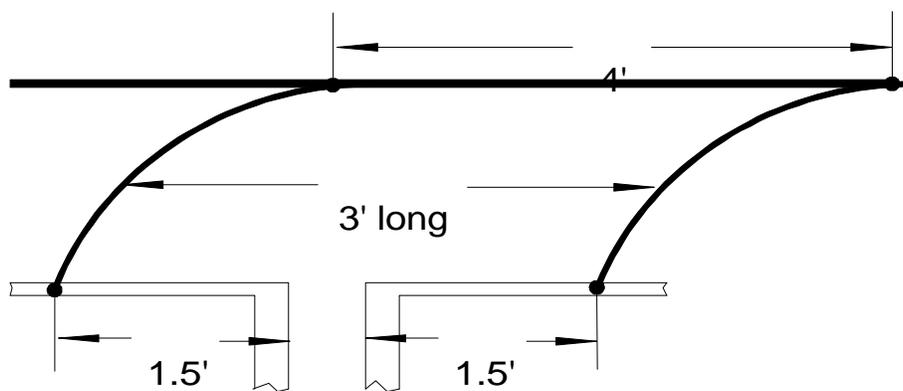


Figure 6-4
Determining the Distance Between Metallic Objects

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- 6.5.12 Grounding conductors routed along interior walls and units located next to such walls may be in proximity to other conductors or units mounted on the other side of the wall. When the peripheral or supplementary conductors that run on either side of a wall are bonded together at both ends, intermediate bonds may be omitted. Bonds to conductors on both sides of a wall shall be made to objects such as conduits or pipes that penetrate the wall.
- 6.5.13 Unit bond conductors shall be installed with a minimum number of bends. Bends shall be made with the greatest practical radius. The bend radius should not be less than 1 foot, but when that radius is not practical, the minimum radius shall not be less than 6 inches.
- 6.5.14 Where unit bond conductors join peripheral or supplementary conductors, they should turn in the direction of the nearest hatchplate. A single conductor connecting two units to a peripheral or supplementary conductor may be used without regard to the direction of turns.
- 6.5.15 All interior unit bond connections to flat surfaces shall be made with 2 hole crimp type terminals. Conductors shall be joined using only exothermic welds or crimp type splices or parallel connectors. Connections to pipe clamps or conduit clamps may be made using a single hole crimp type terminal (preferred) or the mechanical means provided with the clamp.

C. Frame/Cabinet Bonding Requirements

- 6.5.16 Every group of frames, cabinets or other enclosures arranged in a lineup shall be equipped with a conductor that provides a means to terminate unit bonds from every frame or cabinet in the lineup. If a peripheral conductor cannot serve in this capacity, this conductor is considered a supplementary conductor. It shall be a minimum #2 AWG copper conductor (preferred), a steel pipe, a series of inter-junctioned copper bus bars (RR GRD), or a mixture of these methods.
- 6.5.17 When a #2 AWG conductor or steel pipe is used, separate minimum #6 AWG unit bonds shall be added between each frame or cabinet and the #2 AWG lineup conductor or pipe. Bus bars, where still in use, are inherently bonded to framework metal.
- 6.5.18 When bus bar or steel pipe is used, a minimum #2 AWG conductor shall be extended from each end of the pipe or bus bar to a peripheral or a supplementary conductor. These bonds shall be installed per the requirements in 6.4 B for supplementary conductors.
- 6.5.19 AC cabinets used for distribution, control, etc., shall be unit bonded to nearby ring ground conductors. Other metal cabinets (such as tool cabinets) mounted within 7 feet of units requiring a bond shall also be bonded to the ring ground system.
- 6.5.20 Connections to frames, cabinets, bus bars and steel pipe (when used as a lineup grounding conductor) shall be made using two hole crimp type terminals. Conductors shall be joined with crimp type in-line splices or parallel connectors.

D. Miscellaneous Unit Bonding

- 6.5.21 Metal battery stands and similarly constructed metallic units shall be bonded to the interior ring ground system. Metallic objects, not classified as bays or cabinets, such as engine-alternator sets, fuel tanks, fans and similar units require unit bonding. Some of these units are long enough to require additional bonds to meet the requirements of 6.4.12.
- 6.5.22 Units of similar nature to the above that are associated with heating, air conditioning, electrical toilets, metallic partitions, protective grillworks and other metallic items furnished as part of building facilities shall be unit bonded.
- 6.5.23 Portable metallic items, such as ladders, wheel mounted test cabinets and equipment of similar nature do not require unit bonds, but may be stored in a manner that alters the spacing between bonded objects. When the item placed in its storage space reduces the space between bonded objects to less than 7 feet, but not less than 1 foot, and the item is entirely isolated from incidental contact with metalwork, the item may be considered adequately protected when a bond of less than 15 feet exists between the bonded objects. If storage of an item results in a separation of less than one foot, a direct bond of shortest practical length shall be provided between the bonded objects, at or near the point of nearest proximity.
- 6.5.24 Miscellaneous unit bonds shall be minimum #6 AWG, and shall use two hole crimp type terminals and/or crimp type parallel connectors.

E. Conduit, Pipe and Duct Bonding

- 6.5.25 Pipes, conduits, raceways and air ducts, when permanently joined by means other than slip joints, are considered electrical conductors. When these objects are mechanically joined to bonded units within the area of the peripheral conductor, they are considered adequately bonded by that unit's bond for a distance of:
- (a) 15 feet if insulated from metallic support hardware
 - (b) 30 feet if in electrical contact with support hardware at an interval not exceeding 15 feet

Note: When objects exceed these length limits, additional #6 AWG bonds shall be made between the units and a peripheral or supplementary conductor. They shall be located at an interval not exceeding those in (a) or (b) above.

- 6.5.26 Fluorescent lighting system fixtures and conduit installed within the ring ground area shall be bonded in the same manner as conduit runs. Per Sub-section 2 of this Practice, an ac equipment ground conductor shall be furnished in all conduit and raceways.
- 6.5.27 When radio equipment and its ring ground system occupy only a portion of a floor and conduits, ducts, or similar objects supported above the radio equipment extend into other areas of the floor, each object shall be bonded to the peripheral conductor at or near the point where the objects exit the ring ground system area. A tree arrangement using a supplementary conductor and unit bonds may be employed.
- 6.5.28 Points of discontinuity in conduit, raceway, pipe and duct runs shall be made electrically continuous by a minimum #6 AWG bond across a point of discontinuity.

F. Bonding of Units Outside the Ring Ground Periphery

6.5.29 Equipment units on the same floor as radio equipment but located more than 7 feet from the area of the peripheral conductor (or a unit bonded to it) shall be considered adequately bonded by their connection to the CO GRD system.

6.5.30 Equipment located outside the area, but within 7 feet of the peripheral conductor or units bonded to it, shall be bonded to the peripheral conductor. Such bonds may be direct bonds or a tree arrangement using a supplementary conductor and unit bonds. Unit bonds shall terminate at the same point on the unit as the framework ground conductor, or they may be tapped to the framework ground conductor using a crimp type parallel connector.

6.5.31 A lineup of frames, cabinets or other enclosures that runs parallel to the peripheral conductor and is within 7 feet of units bonded to the peripheral conductor shall be bonded to the peripheral conductor. A bond shall be made between each end of the conductor serving as the lineup grounding conductor and the peripheral conductor. If the length of the bonds plus the length of the lineup conductor exceeds 60 feet, a second bond is required, and shall be placed between the peripheral conductor and the approximate midpoint of the lineup.

6.6 BONDS AT STRUCTURE ENTRANCES

A. General

6.6.01 Transmission media from antennas and other conductive paths from towers may enter a structure through:

- (a) a hatchplate
- (b) a weather barrier (either metal or non-metallic, but too thin to be a hatchplate)
- (c) a hole or other opening in a roof or exterior building wall

6.6.02 A hatchplate is the preferred point to bond the antenna media. However, a site may not be equipped with a hatchplate, or the hatchplate may not have room to terminate bonding conductors. This sub-section provides requirements for hatchplate bonds as well as alternative methods for antenna media bonding at the structure's entrance.

B. Auxiliary Bus Bar

6.6.03 An auxiliary bus bar can be added when a hatchplate doesn't exist, when the weather barrier supplied is too thin to be used as a hatchplate, or when there is no room to terminate bonding conductors. A bus bar may also be used to provide a more convenient means to mount a protective device required for coaxial or other multi-conductor cable.

6.6.04 An auxiliary bus bar should be mounted so that it does not interfere with waveguides, coax or other cables and also allows access to terminate bonding conductors and/or mount protective devices.

6.6.05 If a hatchplate exists, the distance between it and an auxiliary bus bar should be kept as short as practicable, preferably no more than 18 inches.

6.6.06 An auxiliary bus bar and any associated bus bar details should be 1/4" copper. The bus bar should be sized to accommodate the quantity of connections and/or protective devices likely to be used.

Note: See 6.6 E. for bonding requirements for auxiliary bus bars.

6.6.07 Figure 6-5 shows one possible arrangement of an auxiliary bus bar located on the inside wall of a structure next to a hatchplate. The 2" standoffs at the top and bottom of the bus bar should not be insulators. They may be a threaded type or they may be brackets.

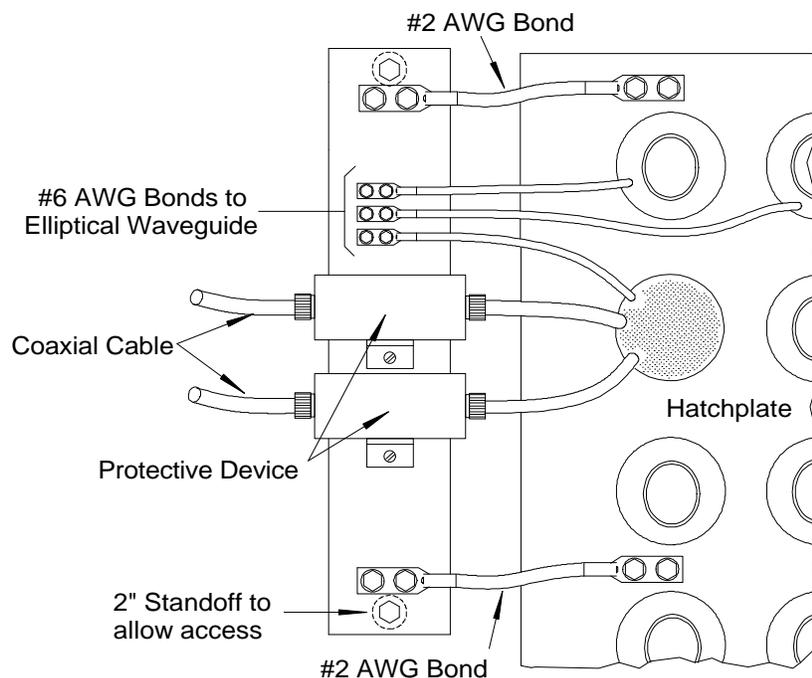


Figure 6-5
Auxiliary Bus Bar Details

C. Other Arrangements

6.6.08 The radio system's design or some other aspect of the site's structure may warrant the use of entrance hardware that does not include a conventional style hatchplate. The following characteristics should be included in the design of the entrance:

- (a) If a metal plate is used for bonding purposes, it should be at least 1/8" thick.
- (b) Any metallic components should provide a means to accept bonding conductors, or they should be bonded via junctioning material (bolts, rivets, welds) to objects that are adequately bonded to the site's grounding system.
- (c) It should be bonded to both the interior and exterior ring ground systems.

D. Exterior Bonds

- 6.6.09 A means shall be provided at the point of entry into the structure to connect a bond to the structure's earth electrode system using a primary bond as described in 6.3 C., *Interior-Exterior Bonds*.
- 6.6.10 All conductive paths from antenna towers entering a structure shall be bonded at their point of entry into the structure. The most common paths are waveguides, coaxial cables and tower lighting conduits.
- 6.6.11 Rigid waveguide is usually bonded to the hatchplate via flange mounting hardware. A separate #6 AWG bond is only required when no such bond exists.
- 6.6.12 When a waveguide requires a separate bonding conductor, a single hole crimp type connector, secured under the head of a flange bolt, may be used on the waveguide end of the bonding conductor.
- 6.6.13 Metallic support framework for coax or waveguide within 7 feet of an entrance that is not mechanically joined to a hatchplate or other grounded object shall be bonded to the exterior surface of the hatchplate, bus bar or primary interior-exterior bonding conductor with a minimum #6 AWG conductor.
- 6.6.14 Any metallic conduit entering the building within 7 feet of the entrance shall be bonded to the exterior surface of a hatchplate, bus bar or primary interior-exterior bonding conductor with a minimum #6 AWG conductor.
- 6.6.15 When an entrance through the structure's roof is used, the bond to the exterior ring ground system can be completed via the bond between a hatchplate or bus bar and the roof ring ground conductor. This conductor can also be used to terminate #6 AWG bonds from elliptical waveguides or other objects that must be bonded. This shown as the 2nd preferred location in Figure 6-6.
- 6.6.16 When no hatchplate exists and a bus bar is used instead, the bus bar must be bonded to the exterior ring ground system with a minimum #2 AWG conductor.
- 6.6.17 Figure 6-6 shows some acceptable points for terminating #6 AWG bonding conductors from elliptical waveguide. Also shown are a number of other #2 AWG bonds between:
- (a) the hatchplate and the external ring ground system (only 1 bond required) - run on the inside or outside of the structure
 - (b) the hatchplate and the interior ring ground system (2 bonds are required) - these bonds and the bond in (a) make up one of the required interior-exterior bonds
 - (c) the hatchplate and the auxiliary bus bar (2 bonds required)

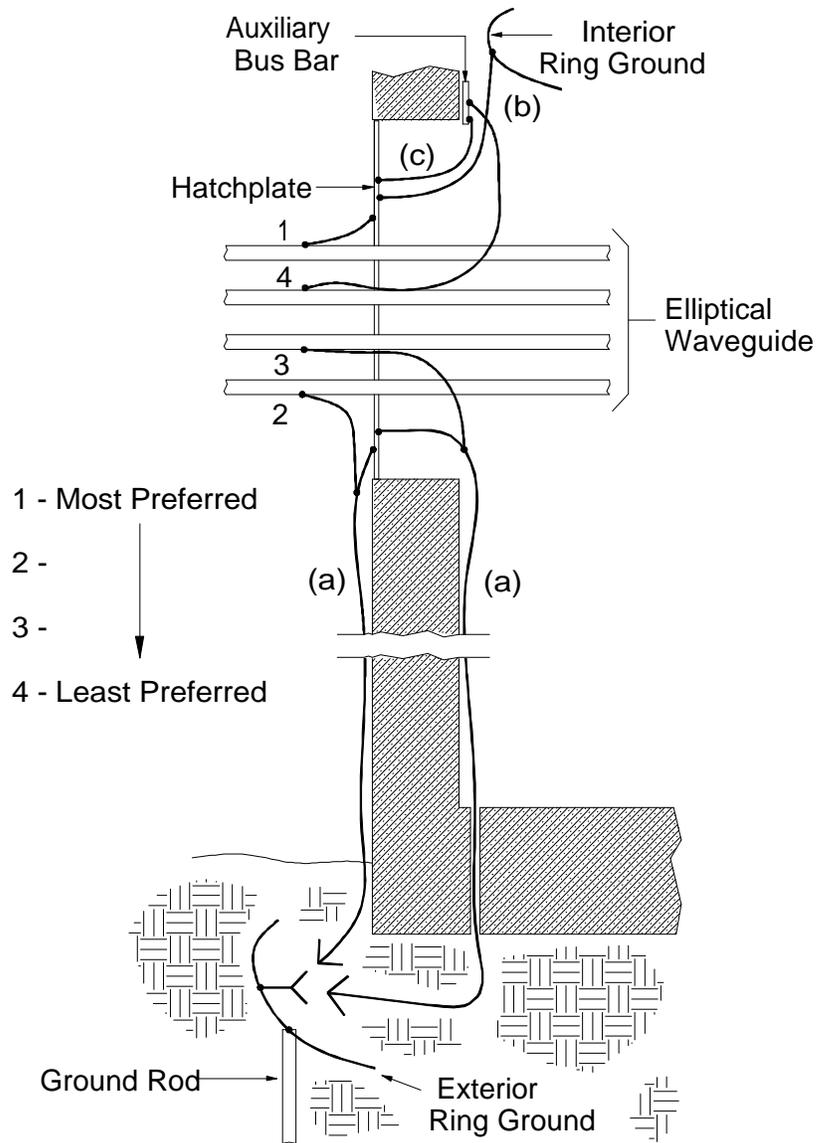


Figure 6-6
Preferred Bonding Locations

E. Interior Bonds

- 6.6.18 Wall mounted hatchplates shall be bonded to the peripheral conductor with two #2 AWG conductors. The bonds shall turn toward the hatchplate.
- 6.6.19 When no hatchplate exists and a bus bar is used instead, the bus bar must be bonded to the interior ring ground system with two #2 AWG conductors.
- 6.6.20 When a hatchplate and an auxiliary bus bar are both present, the bus bar must be connected to the hatchplate or to the interior ring ground using two #2 AWG conductors or with bus bar detail(s) of equivalent cross-sectional area.

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6.6.21 When a hatchplate and an auxiliary bus bar are both present, but the hatchplate does not have room to terminate the 2 required bonds, the bus bar may be bonded to the interior ring ground system. The two #2 AWG bonds may be tapped to either the interior ring ground conductor or the bonds between it and the hatchplate.

6.6.22 If an interior ring ground system is not required, the hatchplate or bus bar must be bonded to the structure's grounding system with a minimum #2 AWG conductor routed directly to the nearest CO GRD or OPGP bus bar.

6.7 BONDING OF STRUCTURAL MEMBERS

6.7.01 Building construction methods described in 6.7.nn will not cover every arrangement likely to be encountered. The bonding requirements described below can be used as a guide when other construction techniques are used.

6.7.02 If steel mesh is used between courses of a concrete block or similar form of masonry wall, each mesh shall be provided with a minimum #6 AWG bond conductor that protrudes from the wall. This bond shall be connected to the closest of either a peripheral conductor or an interior/exterior bond conductor. If steel mesh is used in concrete block columns in outer walls, each mesh shall be bonded in the same manner as in the walls.

6.7.03 When rebars (reinforcing bars or welded steel mesh) in poured concrete walls are inter-connected, and connected to rebars or structural steel in columns by welding or conductor-wrap, they shall be bonded as follows:

- (a) Rebars at the bottom of the wall shall be connected to the exterior ring ground at the midpoint of the wall between columns.
- (b) Rebars at or near the top of the wall shall be connected to the interior peripheral conductor at the midpoint of the wall between columns.

Note: If it is known that rebars are not inter-connected, they shall not be bonded to exterior or interior ring ground conductors.

6.7.04 If precast concrete exterior panels are reinforced with steel bars or mesh, the reinforcement steel in each panel shall be bonded to the exterior ring ground.

6.7.05 When the rebars in concrete columns are electrically continuous but not in electrical contact with wall rebars, (e.g., knockout wall panels) the column rebars shall be bonded near the top to a peripheral or supplementary conductor. Rebars not made electrically continuous throughout the column, they shall not be bonded to the exterior or interior ring ground conductors.

6.7.06 Peripheral structural steel columns that are bare or encased in concrete or masonry, when not part of a steel frame construction, shall be bonded to the exterior ring ground conductor and to an interior ring ground conductor.

- 6.7.07 Structural steel beams and trusses supporting the roof of a building are generally sufficiently bonded to earth through hanger rods and other hardware that support superstructure, conduits, pipes, ducts and other metallic units above the radio equipment area. Individual beams not obviously grounded in this manner or by contact with grounded steel frame or columns of the building shall be bonded to the peripheral conductor at both ends.
- 6.7.08 Pre-stressed concrete beams with rebars that make no contact with grounded structural members shall be bonded to peripheral conductors at both ends.
- Note: Rebars of poured concrete roof beams are normally integrated with column rebars so that continuity exists throughout the structure. When such continuity exists, additional bonds to such beams are not required.
- 6.7.09 Metal framed openings in walls, such as door frames, may or may not be grounded through continuity with rebars or other metallic objects bonded to the exterior ring ground conductor. Such frames shall be bonded to the peripheral ring ground system.
- 6.7.10 Metal frames in the roof, other than those bonded through contact with bonded metal objects (hatchplates), shall be bonded to peripheral or supplementary conductors.
- 6.7.11 Small prefabricated buildings or huts of metallic frame and exterior surface construction are often used to house radio equipment. They shall be equipped with an interior peripheral ring conductor (sometimes called a *J-rail*) to which all unit bonds terminate. Such structures require no additional bonding other than those between the structure and the exterior ring ground system.

6.8 SMALL RADIO/ANTENNA SYSTEMS

A. Scope

- 6.8.01 The requirements in 6.8 A. – E. apply to comparatively small equipment/antenna systems. These systems may be located at central offices, remote terminals or other types of structures and typically:
- (a) provide service to a single customer,
 - (b) are receive-only systems, or
 - (c) are systems used by Company maintenance forces.
- 6.8.02 The radio equipment usually consists of 1-3 units designed to mount either in a miscellaneous relay rack or a separate, cabinet. The radio equipment may also be a combination of mast-mounted RF unit(s) and rack-mounted multiplexer unit(s).
- 6.8.03 The antennas/reflectors covered by the requirements in 6.8 A. – E. are **not** mounted on towers. They are most often secured to a structure using brackets, tripods, or other hardware, or they may be mounted on poles.
- 6.8.04 Except as modified by the contents of 6.8 A. – E., all other engineering, material and installation requirements in this Sub-section shall apply.

B. System Component Location and Other Considerations

6.8.05 The vertical and horizontal structural members of a building are usually made of either reinforced concrete, structural steel or a combination of the two. Since structural steel often simplifies the addition of the grounding and bonding in 6.8 A. – E., determining the actual type of construction is a key element in the planning process.

Note: The responsible Building Engineer should be contacted when the type of construction can not be readily determined.

6.8.06 Because the length of grounding and bonding conductors is critical in any lightning protection system, the location of radio system components, especially the antenna and radio equipment, needs to be evaluated and engineered on a site-by-site basis. While locating the antennas and equipment per 6.8.08 and 6.8.09 below may result in longer runs of antenna, power and network interface cabling, the additional effort is acceptable because of the additional protection provided by these measures.

6.8.07 The primary consideration when placing a line-of-sight antenna or reflector is that it is free from obstructions. However, there is usually some flexibility in its exact location on a structure. When a building is not structural steel construction, every attempt should be made to place the antenna no more than 7 feet from the edge of the roof along that portion of the structure's perimeter that is directly above the driven ground rod system.

6.8.08 Within the area described above, a point should be chosen that, in order of importance:

- (a) provides the shortest path for the 2 down conductors to the driven ground rod system
- (b) provides the most unobstructed path down the side of the building, avoiding windows, doors, piping, etc.
- (c) is more than 7 feet from metallic objects on the roof (A/C units, pipes, ladders, etc.)
- (d) provides the shortest path for antenna cables

Note: Omni-directional antennas should always be placed in the area described except when the building is structural steel construction.

6.8.09 Whenever practicable, radio equipment should be located near the OPGP bus bar in one or two story buildings. In multi-story buildings, the equipment should be located on the top floor near a vertical riser. To the greatest extent possible, the equipment should be separated from other network equipment (except other radio equipment). Consideration should be given to creating and reserving a dedicated radio equipment area.

C. Down Conductors

6.8.10 Except for antenna mountings bonded to building structural steel, a minimum of 2 down conductors shall be provided between a structure-mounted antenna mounting and the site's driven ground rod system. These may serve more than one antenna mounting.

6.8.11 Down conductors between a structure-mounted antenna mounting and the structure's driven ground rod system shall be #2 AWG minimum.

- 6.8.12 For any horizontal portion of their route on the roof where the down conductors are run parallel to each other, they shall maintain a minimum separation of 1 foot .
- 6.8.13 The down conductors should maintain a separation of approximately 50 feet on the vertical portion of their runs to the structure's driven ground system. If a driven ground array is less than 50 feet in length, the down conductors should connect to the opposite ends of the ground rod array.
- 6.8.14 When an antenna must be located outside the preferred area on a building without structural steel, the horizontal portion of the down conductors should be routed in a manner that provides the shortest path to the vertical portion of the runs, avoids unnecessary turns, and will require the fewest bonds to metallic objects.
- 6.8.15 When an antenna is placed on a building of structural steel construction, a single bond to a structural steel member (horizontal or vertical) may be used in place of the 2 down conductors. The bond between the antenna support and building steel may be made using a welded or bolted connection, or a single #2 AWG bonding conductor. Examples of these are shown in Figure 6-7.

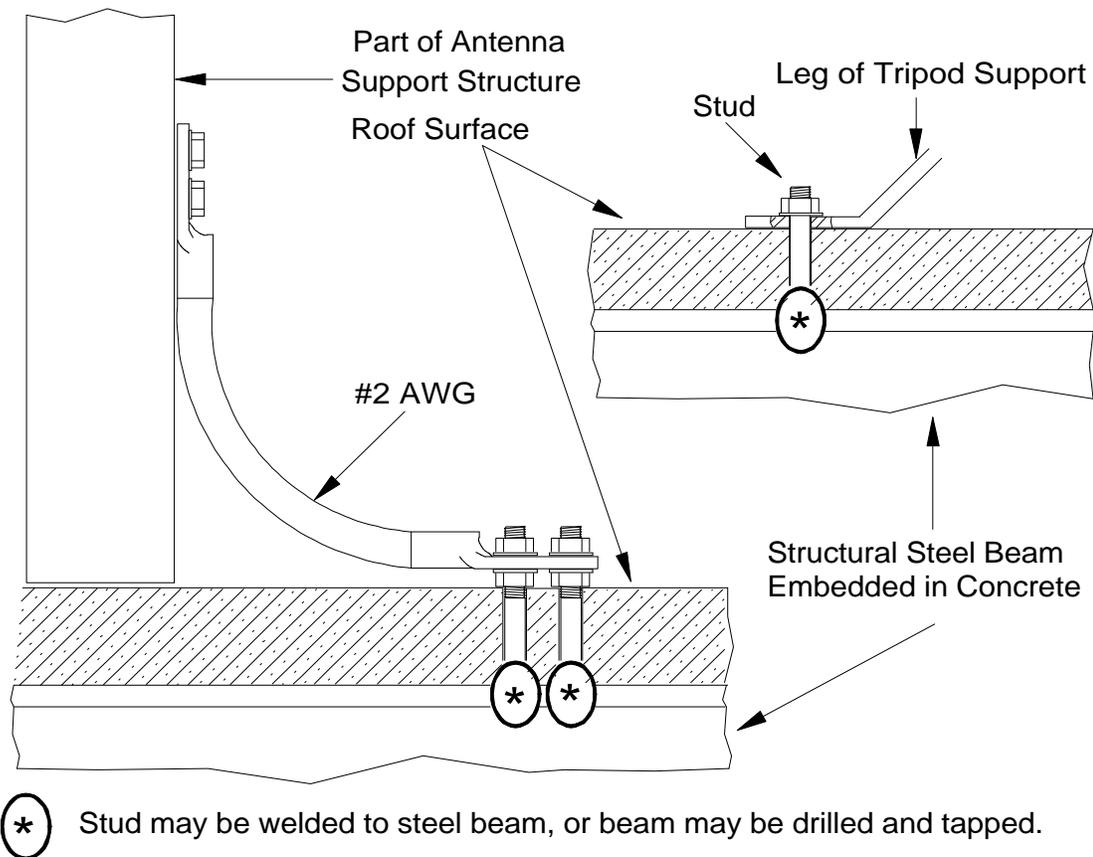


Figure 6-7
Bonds to Structural Steel

D. Pole-Mounted Antennas

- 6.8.16 A pole-mounted antenna shall be equipped with a minimum of one down conductor, which may serve more than one antenna or pole-mounted radio equipment unit.
- 6.8.17 A down conductor serving a pole-mounted antenna shall be #6 AWG minimum. The conductor shall be routed along the entire length of the pole, regardless of the location of the antenna(s).
- 6.8.18 Pole-mounted antennas shall be furnished with a driven ground system arranged in a triangular pattern using 3 ground rods. The legs of the triangle shall be at least 8 feet long, with 12 feet the preferred length. The ground rods shall be connected in a closed loop pattern using a #6 AWG (minimum) bare solid copper conductor. The down conductor may be connected to any point along the loop.
- 6.8.19 If an H-frame arrangement is used, 3 driven ground rods shall either be placed in a triangular pattern or arrayed in a straight line, whichever best suits the site conditions and still maintains the separation requirements above. Each pole shall be equipped with a down conductor that terminates at opposite points on the triangle's loop or, if a straight line arrangement is used, at opposite ends of the array.

Note: The down conductors shall be routed along the entire length of the poles, regardless of the location of the antenna(s).

E. Bonding Conductors

- 6.8.20 Every metallic object within 7 feet of an antenna mounting or down conductor shall be bonded to the mounting or down conductor using a minimum #6 AWG bonding conductor.
- 6.8.21 When an antenna cable passes through metallic conduit or raceway, the end of the conduit or raceway on the roof shall be bonded to the closest of either a metallic antenna mounting or a down conductor with a minimum #6 AWG bonding conductor. The far end of the conduit or raceway must be bonded to the nearest appearance of the CO ground system
- 6.8.22 When a portion of the radio equipment is mounted on an antenna mast or pole, the unit shall be bonded to the closest of either a metallic antenna mounting or to a down conductor with a minimum #6 AWG bonding conductor.

6.9 MATERIAL

A. Protective Devices

- 6.9.01 Protective devices are required for coaxial cable, each conductor in an antenna control cable, and any other multi-conductor cable between the antenna and equipment inside the structure.

Note: Protective devices are normally included in the radio equipment specification.

6.9.02 Whenever practicable, the protective device should be located outside the structure, or be mounted directly to the inside of the hatchplate.

6.9.03 Every protective device must be bonded to a hatchplate, bus bar or to a primary interior-exterior bonding conductor. The bond may be made via the device's mounting flange, mounting stud, or by a minimum #6 AWG conductor.

B. Conductors

6.9.04 Except where expressly stated, radio site grounding and bonding conductors may be either stranded or solid copper. For stranded conductors, only those with standard stranding should be used. If a flat strap or bus bar is used in place of a conductor, it must be equal in cross-sectional area to that of the cable required for a given application. See Table 6-1 for conductor information.

Cable Size	Circular Mils	Area (in. ²)	Stranding
6 AWG	26240	0.021	7
4 AWG	41740	0.033	7
2 AWG	66360	0.052	7
1/0 AWG	105600	0.083	19

**Table 6-1
Conductor Information**

C. Connectors

6.9.05 All terminals should be 2-hole crimp type. A single hole crimp type terminal should only be used at waveguide flanges, protective devices and other locations where only a single bolt or stud is available.

6.9.06 Terminals may be straight, 45 or 90 type. The type of terminal should be chosen based on the specific job conditions.

6.9.07 All parallel tap connectors and in-line splices shall be crimp type.

6.9.08 Mechanical connectors should only be used:

- (a) where site conditions prevent the use of crimp tools
- (b) where a mechanical connector is an imbedded part of an equipment unit
- (c) where specified in the standard drawing
- (d) to bond supplementary conductors to cable rack or auxiliary framing

D. Other Material

6.9.09 The preferred grounding kit for elliptical waveguide and larger coaxial cable is the ribbon style available from Andrew Corporation, or an acceptable equivalent. The desirable attributes of the ribbon clamp are that it has an indicator that shows when sufficient clamping force has been applied and it is equipped with a stranded copper bonding conductor.

Note: Kits using braided conductors are not recommended.

6.9.10 Only material specifically intended for grounding and bonding should be used. For example, an adjustable metal hose clamp should not be used to secure a cable shield bond unless it is a component of a kit of parts that includes installation instructions.

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