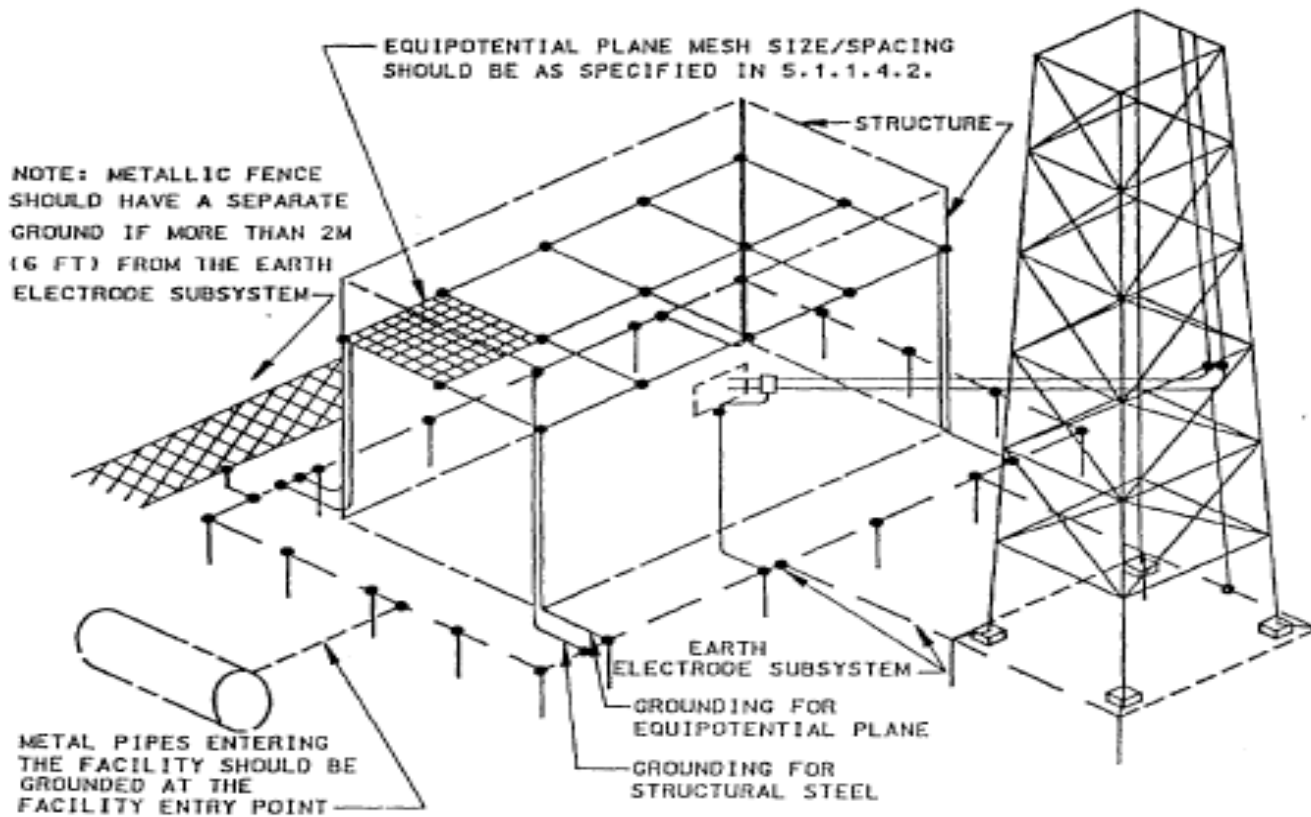


Grounding & Bonding Electrodes /Conductors /Components /Structures



Grounding

- The establishing of a 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.
- Provides a path for surges in your power systems, conducting electrical energy to earth to prevent arcing, heating, or an explosion during a lightning strike.

Within a building or single facility there is only one common ground for all of the electrical systems. This system is referred to as the “Grounding Electrode System” (GES).

Bonding

When a potential difference exists between two metallic components joined by a conductor, electrons flow from one component to the other in attempts to equalize the two components.

- The permanent joining of metallic parts to form an electrically conductive path.
- Ensures electrical continuity and has the capacity to conduct safely any current likely to occur.
- Equalizes ground potential and eliminates static discharge between components and equipment.
- When equalization occurs, the electrons can damage any equipment or person in its path.

Electrons

- A subatomic particle carrying a negative electric charge.
- No known components or substructure and generally believed to be an elementary particle.
- A mass approximately $1/1836$ of a proton.
- Intrinsic angular momentum is a half-integer value in units of the Planck constant.
- Around 6,241,000,000,000,000,000 (6.241 quintillion) electrons passing a given point each second constitutes one ampere.
- The ampere is a measure of the amount of electric charge passing a point per unit time.

Grounding Requirements

Requirements and guidelines are primarily to enhance personnel safety and equipment reliability, derived from the following standards sources:

NFPA 70 & 780

ANSI T1.313, TIA-222F, & J-607-A

S24-809 : NOAA/NESDIS Grounding Standard

MIL-STD-188 - Military Standard Grounding, Bonding, and Shielding

MIL-HDBK-419A - GBS Electronic equip and Facilities

Grounding Requirements & Guidelines

- Main focus of correct grounding at any communications site is the safety of personnel and protection of electronic equipment from ground faults, lightning, electrical surges, and impulses.
- Low-impedance external GES helps minimize damage from unexpected electrical events like lightning strikes and power surges which cannot be prevented.
- The GES limits the voltage caused by accidental contact of the site AC supply conductors with conductors of higher voltage.
- Dissipates electrical surges and faults to minimize the chances of injury from grounding system potential differences.
- Stabilizes the AC voltage under normal conditions relative to the earth.
- AND provides a common signal reference ground.

LIGHTNING SAFETY

- Both lethal and dangerous voltages are present within your equipment.
- Do not wear conductive jewelry while working on the equipment.
- Always observe all safety precautions and do not work on the equipment alone.
- Some equipment is electrostatic sensitive, observe correct antistatic grounding precautions.
- There WILL be instances where noncompliance results in equipment damage or personal injury.

LIGHTNING



Lightning Facts

- Lightning is an atmospheric discharge of electricity accompanied by thunder, which typically occurs during thunderstorms, and sometimes during volcanic eruptions or dust storms.
- In the atmospheric electrical discharge, a bolt of lightning can travel at speeds of 140,000 mph, and can reach temperatures approaching 54,000° F, packs between 35,000 to 40,000 amperes of current, travels as far as 40 miles, strikes somewhere on earth every second, hot enough to fuse silica sand into glass, and CAN AND DOES strike the same place twice.
- An irrational fear of lightning (and thunder) is called astraphobia.
- There are over 16 million lightning storms in the world every year.

HOW lightning initially forms is still a matter of debate!!

Scientists have studied root causes ranging from atmospheric perturbations (wind , humidity , friction , and atmospheric pressure) to the impact of solar wind and accumulation of charged solar particles. Ice inside a cloud is thought to be a key element in lightning development, and may cause a forcible separation of positive and negative charges within the cloud, thus assisting in the formation of lightning.

DESIGN REQUIREMENTS GROUNDING ELECTRODE SYSTEMS (GES)

➤ The Communications Site

- ❖ Type A - Light Duty**

- ❖ Type B - Light Industrial/Commercial**

- ❖ Soil pH (Hydrogen Ion Concentration)**

TYPE A LIGHT DUTY

Requirement: Site resistance to earth is **25 Ω or less** and have the following characteristics:

- One repeater, single chassis, base station, or outdoor cabinet
- Not part of a larger system infrastructure
- Single voting receiver site
- RF alarm/reporting site
- Single control station
- May be located in a commercial office or residence
- Bonded to an existing grounding electrode system

Disaster Recovery Terminal



Disaster Recovery Terminal



TYPE B

LIGHT INDUSTRIAL/COMMERCIAL

Requirement: Type B site resistance to earth is 5 Ω or less and have the following characteristics:

- Telecom repeater equipment such as a cellular, PCS, or wide-area repeater.
- Communication system dispatch console equipment.
- Equipment with specific manufacturer requirements for a 5 Ω GES.
- Site power supplied only by a generator.
- Telephone or Electronic Switches
- LANs/WANs
- Mobile Switching Offices

Soil pH

(Hydrogen Ion Concentration)

- Test for acidic soils, (pH below 7), destructive affect on copper and other metals.
- Test using a commercially available soil pH meter or a swimming pool acid/base tester.
- Acidic soils, (pH of 5 or below), take precautionary measures to maintain the GES life expectancy.

The Communications Site

- Only one low electrical impedance Grounding Electrode System is needed.
- Conductors large enough to withstand high fault currents.
- Grounding media in or on a structure are interconnected to provide a common ground potential.
 - ✓ Lighting Protection, Electric Service, Telephone
 - ✓ Antenna system grounds, and underground Metallic Piping Systems
 - Underground metallic piping systems: water service, well castings located within 25 ft. of the structure, gas piping, underground conduits, and underground liquefied petroleum gas piping systems.
 - The lower the impedance the more effective the system can dissipate high energy impulses into the earth.

GES COMPONENT REQUIREMENTS

The external grounding system may consist of, but is not limited to, the following components, shown in Figure 6-1:

- Grounding electrodes
- Grounding conductors
- Tower ground bus bar
- External ground bus bar
- Tower ground ring
- Building or shelter ground ring
- Ground radials
- Guy wire grounding conductors (guyed towers only)
- Fence grounding conductors

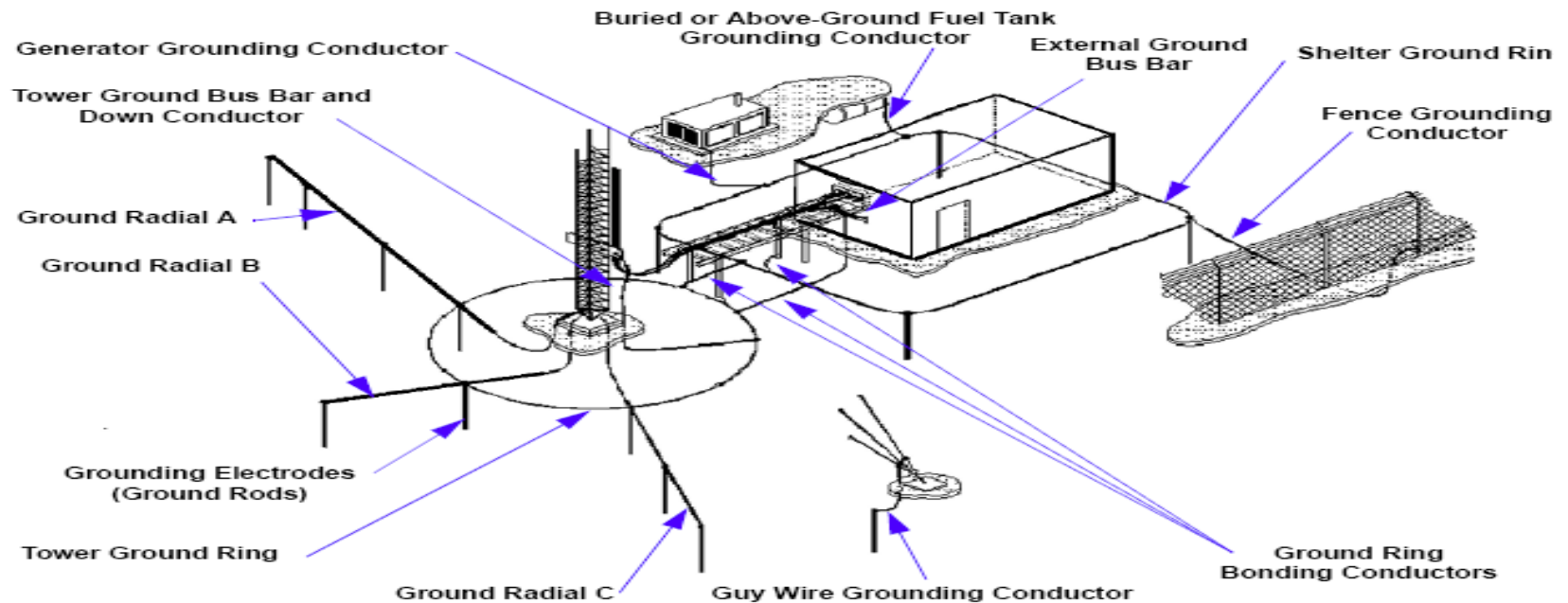


FIGURE 6-1 TYPICAL TYPE B EXTERNAL GROUNDING ELECTRODE SYSTEM

GROUNDING ELECTRODES

The conducting elements are used to :

- Connect electrical systems and/or equipment to the earth to maintain the equipment at earth potential and dissipate over voltages into the earth
 - The electrodes may be ground rods, metal plates, concrete encased conductors, ground rings, electrolytic ground rods, the metal frame of building or structure and metal underground water pipes.
- ❖ NOTE: **DO NOT** use metallic underground gas piping as a grounding electrode, it is bonded upstream from the equipment shutoff valve to your grounding electrode system as required by Industrial Standards.

GROUND RODS

Typical ground rods are shown in Figure 6-2. Requirements for ground rods are listed below.

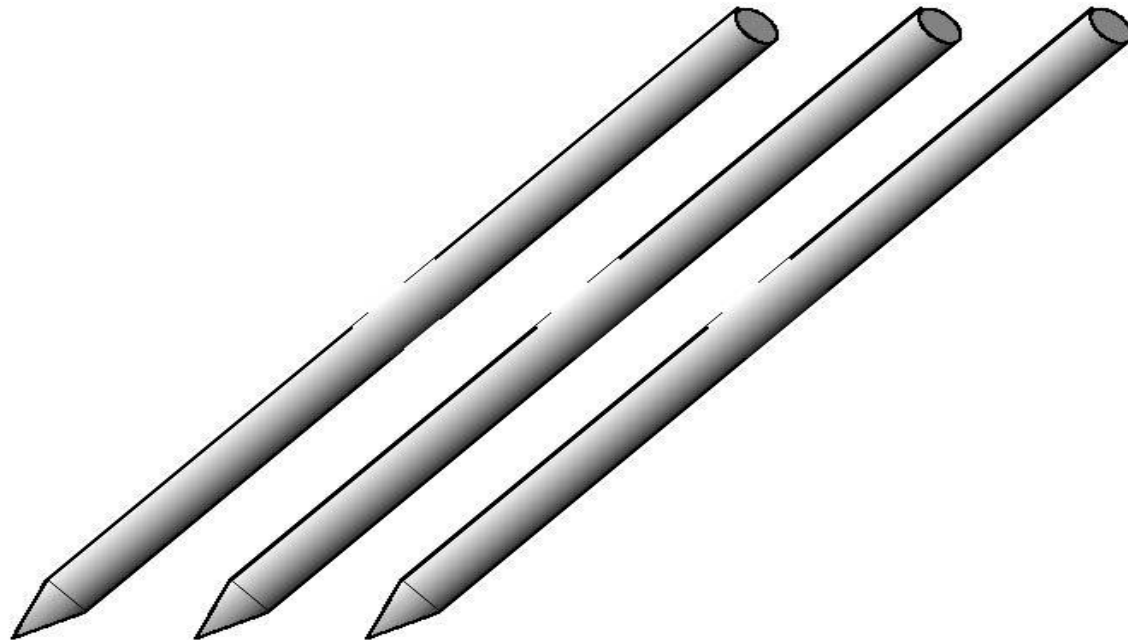


FIGURE 6-2 TYPICAL GROUND RODS

Ground Rod Requirements

- Copper-clad steel, solid copper, galvanized steel, or stainless steel.
- 8 ft. in length and have a diameter of 0.625 in., or required by the STD's
- Quantity of rods required based on site dimensions
- Bonded to grounding conductors compatible with the metals types
- Free of paint or other nonconductive coatings
- Where practical, buried below permanent moisture level
- Installed a maximum of 16 ft. apart and a minimum of than 6 ft. apart
- Buried to a minimum depth of 30 in. below finished grade, or buried below the freeze line, whichever depth is greater.
- Driven at an oblique angle of not greater than 45 degrees from vertical, or buried horizontally and perpendicular to the structure, in a trench a minimum of 30 in. deep to avoid rock foundations

Ground Rod Requirements

- Driven at an oblique angle of not greater than 45 degrees from vertical, or buried horizontally and perpendicular to the structure, in a trench a minimum of 30 in. deep to avoid rock foundations

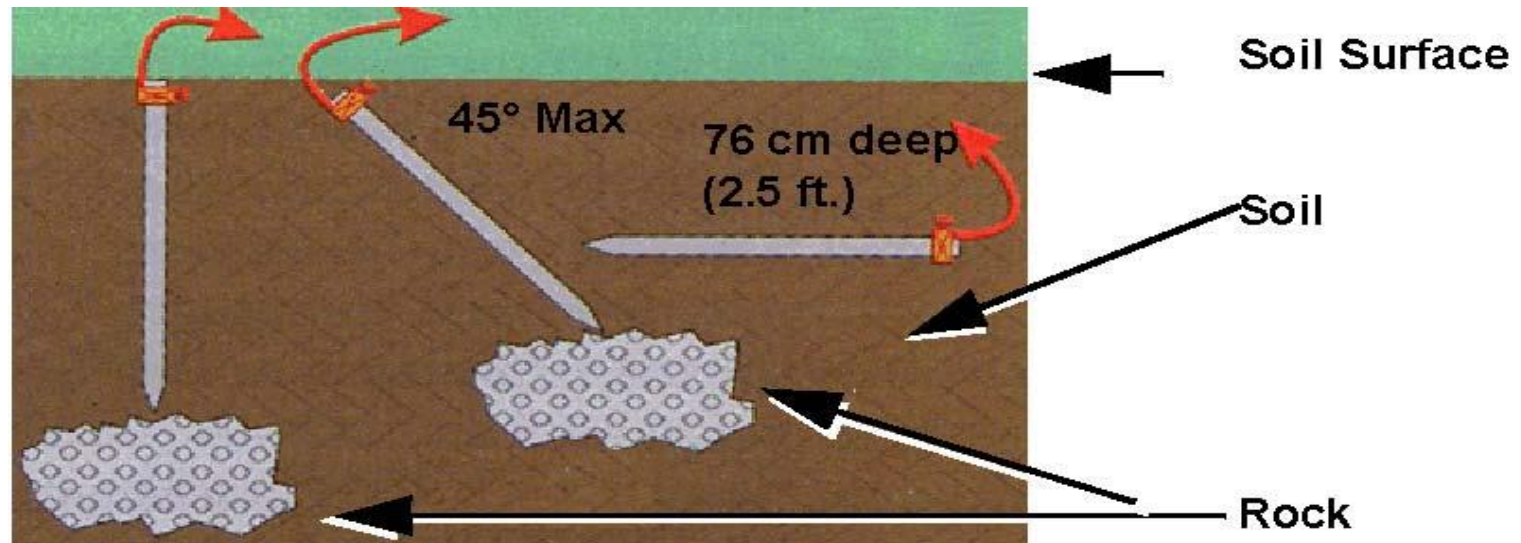


FIGURE 6-3 ANGLED GROUND ROD INSTALLATION

Ground Rod Requirements

- Hammer drills or electric jackhammers can be used to drive in the ground rods. Do not deform the head of the ground rod.
- Ground rods used to ground galvanized tower guy wires are to be installed in accordance with “Self-supporting Towers and Guyed Lattice Towers” Grounding Standards.
- If the grounding system design requires a deeper grounding electrode, two or three ground rods **shall** be exothermically welded end-to-end . Do not use any other method to connect the rods together .

SPLICING TWO GROUND RODS



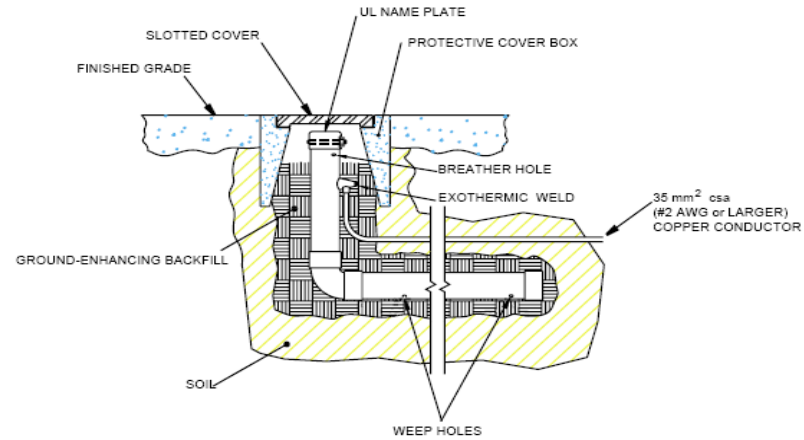
ELECTROLYTIC GROUND RODS

Electrolytic ground rods can be used at sites with high resistivity or limited space and acceptable GES resistance cannot be achieved using the standard ground rods.

- Available in straight or L-shaped versions with various lengths from 10 ft. to 20+ ft. , 2.125 in. diameter hollow copper pipe.
- The copper pipe is filled with salt. Holes at various locations allow moisture to be hygroscopically extracted from the air into the salt forming conductive electrolytes. They then leach out of the pipe into the soil, improving soil conductivity.
- The copper pipe is inserted into a pre-drilled hole
- L-shaped rods are placed into a trench a minimum of 30 in. deep, and encased in a ground enhancing material.
- This type of ground rod is used in GES covered by concrete or pavement. Allowing moisture to enter the electrolytic ground rod improves the resistance of the GES. This can also be done using the condensation of the HVAC system.

ELECTROLYTIC GROUND RODS

L-Shaped



Straight

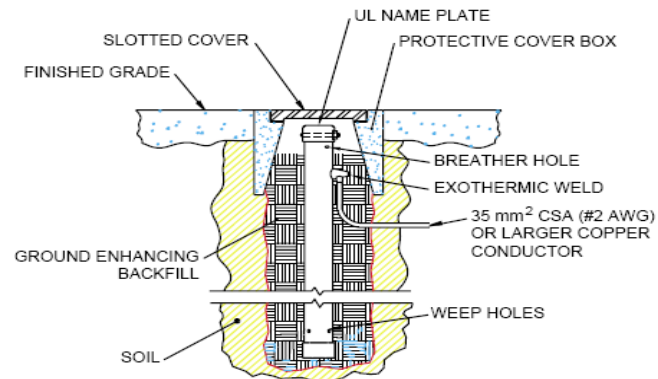
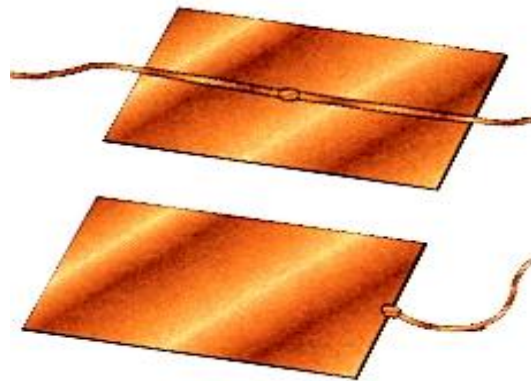


FIGURE 6-5 ELECTROLYTIC GROUND RODS

GROUND PLATES

Ground plates are used in special cases due to soil conditions.

- The ground plate electrode exposes a minimum of 2 sq. ft. of surface to exterior soil
- Buried a minimum of 2.5 ft. below the surface of the earth.



GROUNDING CONDUCTORS

- Grounding conductors are the conductors used to connect equipment or grounded circuits to the GES. The conductors are wires that join the ground electrodes, form buried ground rings, and connect objects to the GES.
- **GENERAL SPECIFICATIONS**
- Size requirements: Bare tinned solid or stranded #2 AWG or larger.
- Solid straps or bars with a cross-sectional area equal to or greater than the specified grounding conductor.

EXTERNAL GROUND RING

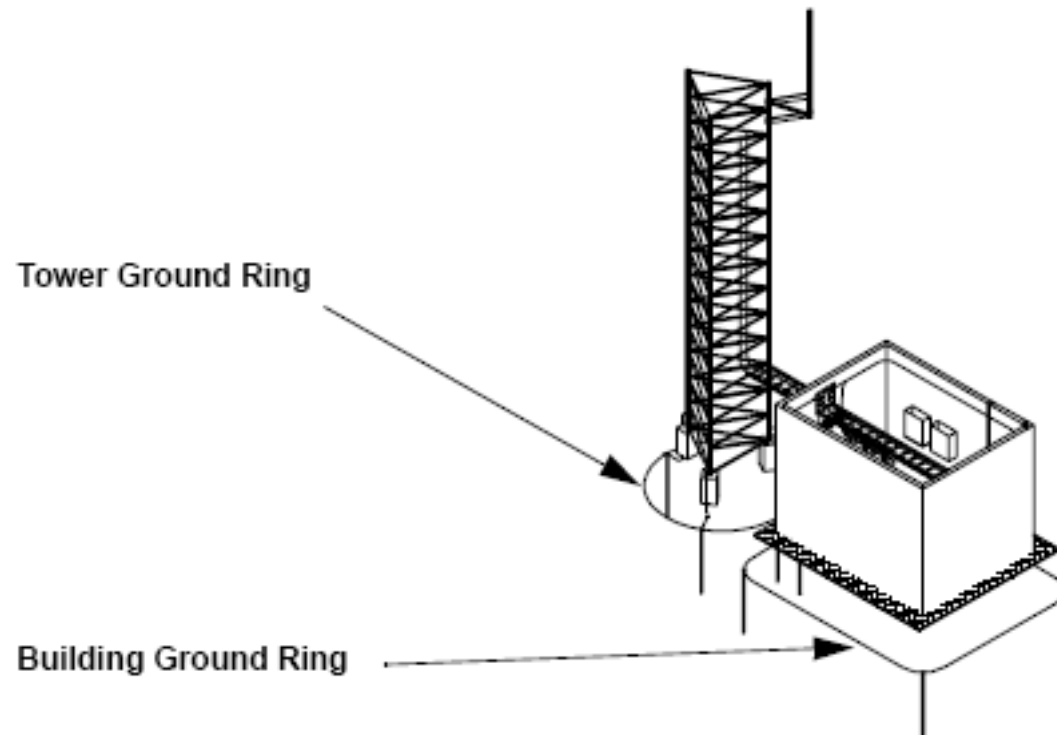


FIGURE 6-10 SITE GROUND RING SYSTEM

EXTERNAL GROUND BUS BAR

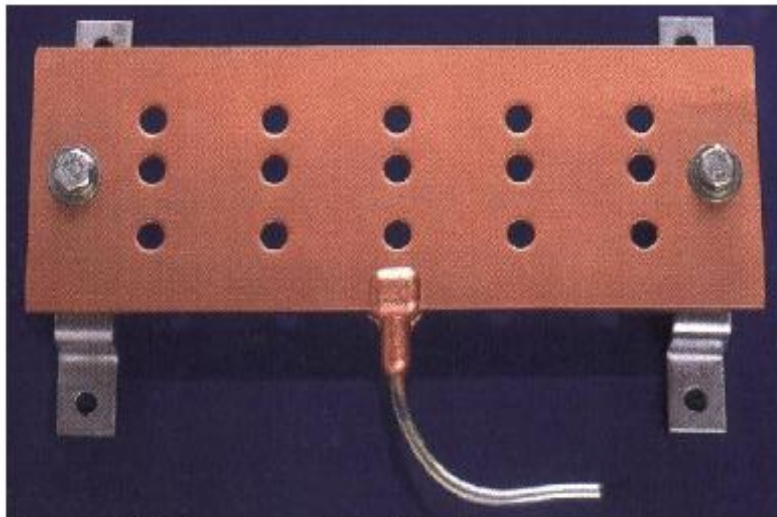


FIGURE 6-11 EXTERNAL GROUND BUS BAR



FIGURE 6-12 INTEGRATED CABLE ENTRY PORT WITH GROUND STRAPS

TOWER GROUND BUS BAR



Vertical Mount



Horizontal Mount

FIGURE 6-13 TYPICAL TOWER GROUND BUS BARS

METALLIC OBJECTS REQUIRING BONDING

- Internal Master Ground Bar (MGB) , Metallic entry points, Ice bridge
- Building ice shields, Antenna tower, Tower guy wires
- Transmission lines, Piping, Air conditioner
- Solid metal siding on buildings, Vent covers
- Generator and support skids, Storage tanks
- Anchors and skids on prefabricated buildings
- Satellite masts and mounts
- GPS masts, CCTV masts, Conduits or raceways
- External light fixtures or support masts, Fences
- Main electrical service grounding electrode system
- Main telephone company ground point
- Metal roofing and truss systems
- Metallic structures on the building roof or rain gutter systems

FENCES AND GATES

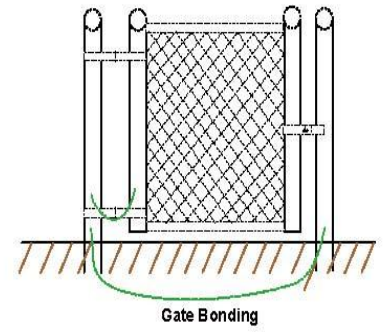
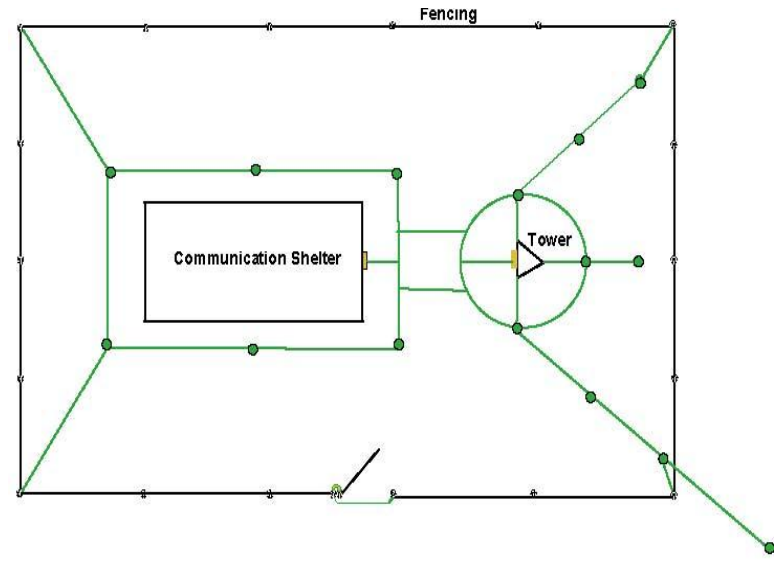
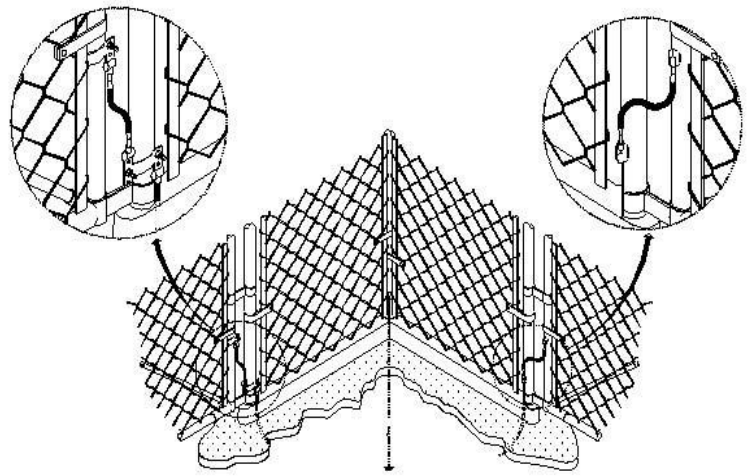


FIGURE 6-16 FENCE AND GATE GROUNDING METHOD

CABLE RUNWAYS & ICE BRIDGES

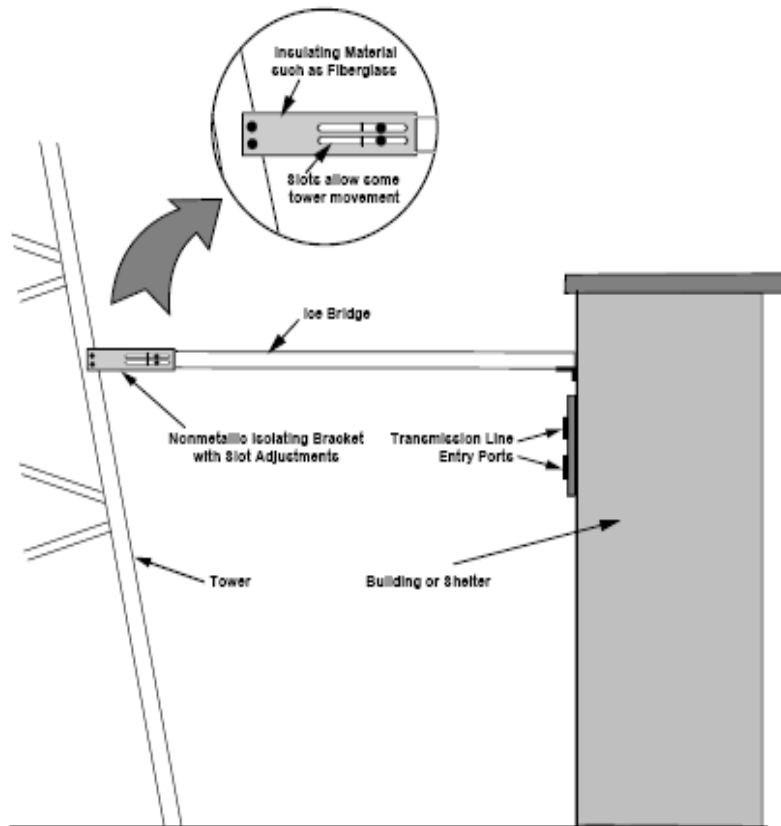


FIGURE 6-18 ELECTRICALLY ISOLATING THE ICE BRIDGE FROM THE TOWER

SELF-SUPPORTING TOWERS



GUYED LATTICE TOWERS



Guy Wire
Grounding
Conductor



FIGURE 6-24 EXAMPLE OF TOWER GUY WIRE GROUNDING

GUYED LATTICE TOWERS



GUYED LATTICE TOWERS



GUYED LATTICE TOWERS



GUYED LATTICE TOWERS



MONOPOLE TOWERS

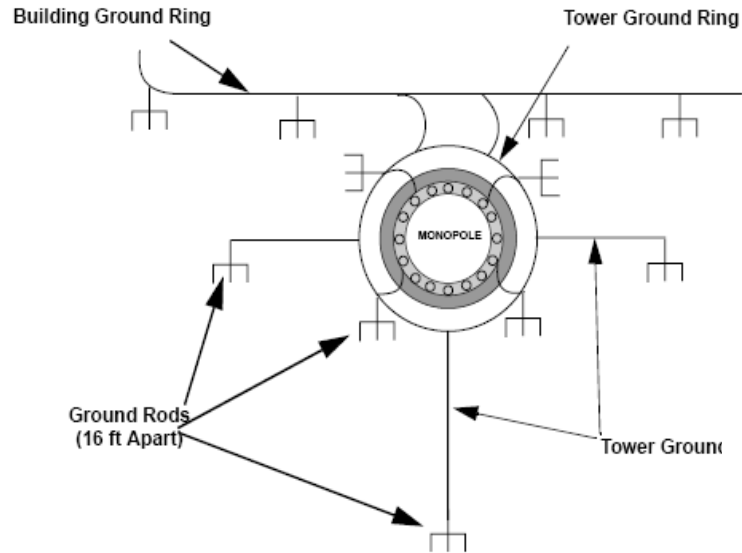


FIGURE 6-25 MONOPOLE TOWER GROUNDING



FIGURE 6-26 EXAMPLE OF MONOPOLE TOWER GROUND CONDUCTOR

ROOFTOP MOUNTED TOWERS

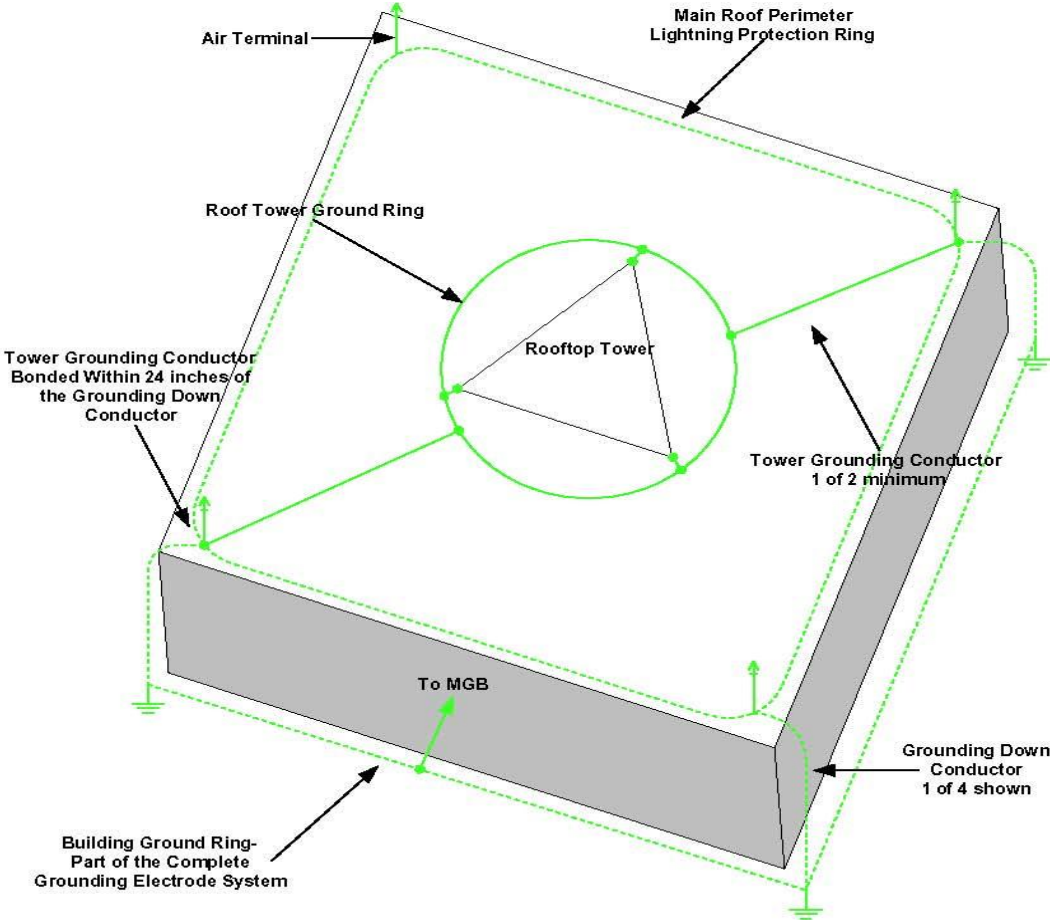


FIGURE 6-27 TYPICAL ROOFTOP TOWER GROUNDING RING

RF TRANSMISSION LINES

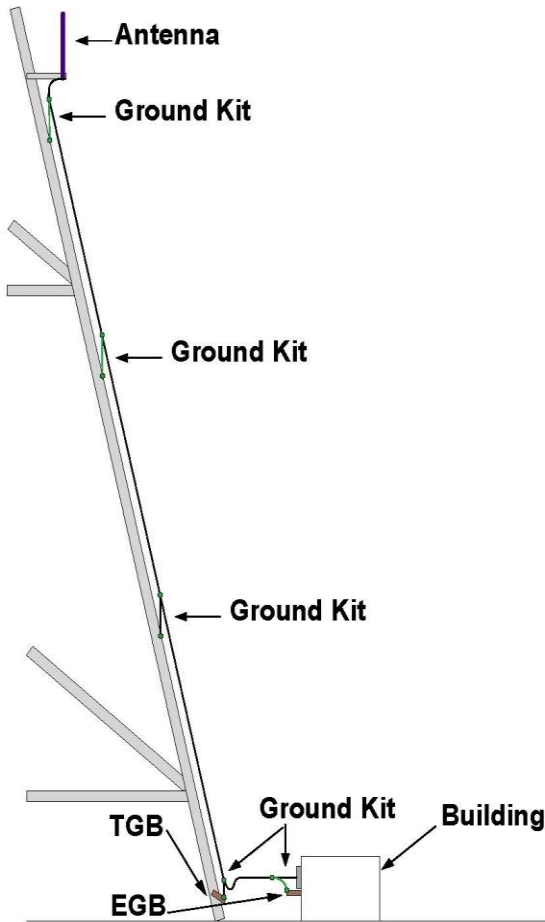


FIGURE 6-28 LOCATION OF TRANSMISSION LINE GROUNDING KITS

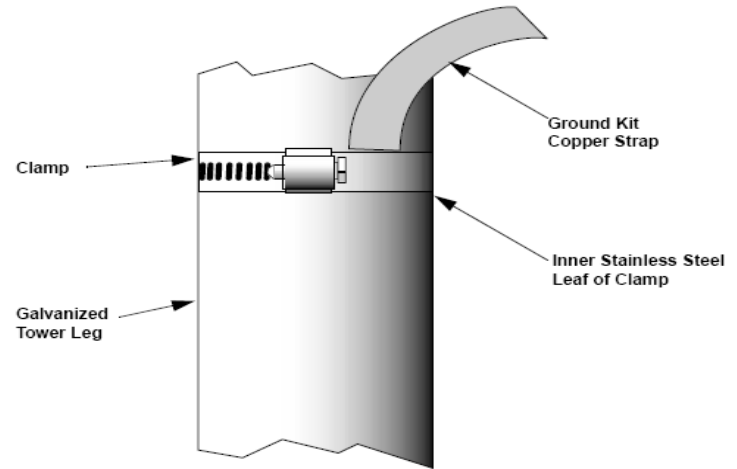


FIGURE 6-30 GROUNDING TRANSMISSION LINE TOP AND MIDDLE (TUBULAR TOWER)

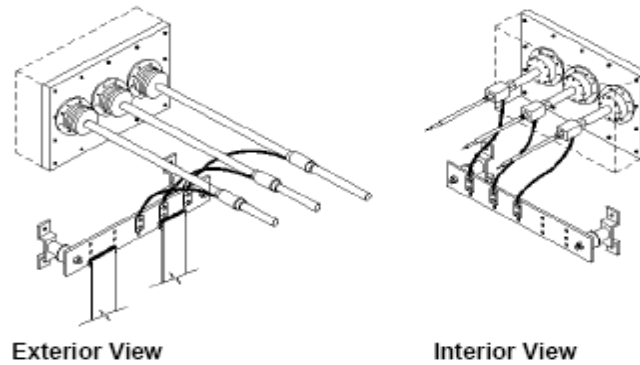
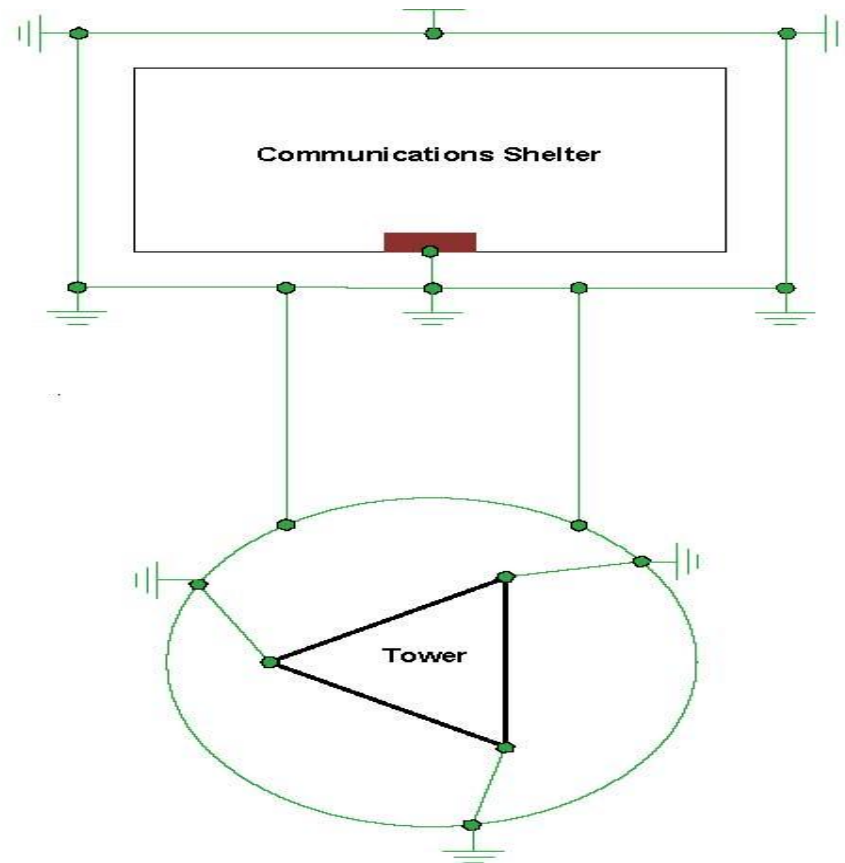


FIGURE 6-33 TRANSMISSION LINE GROUNDING AT BUILDING ENTRY POINT

DEDICATED COMMUNICATIONS SITE BUILDING



N.
4.

FIGURE 6-34 SITE GROUNDING ELECTRODE SYSTEM

GENERATORS EXTERNAL TO THE BUILDING

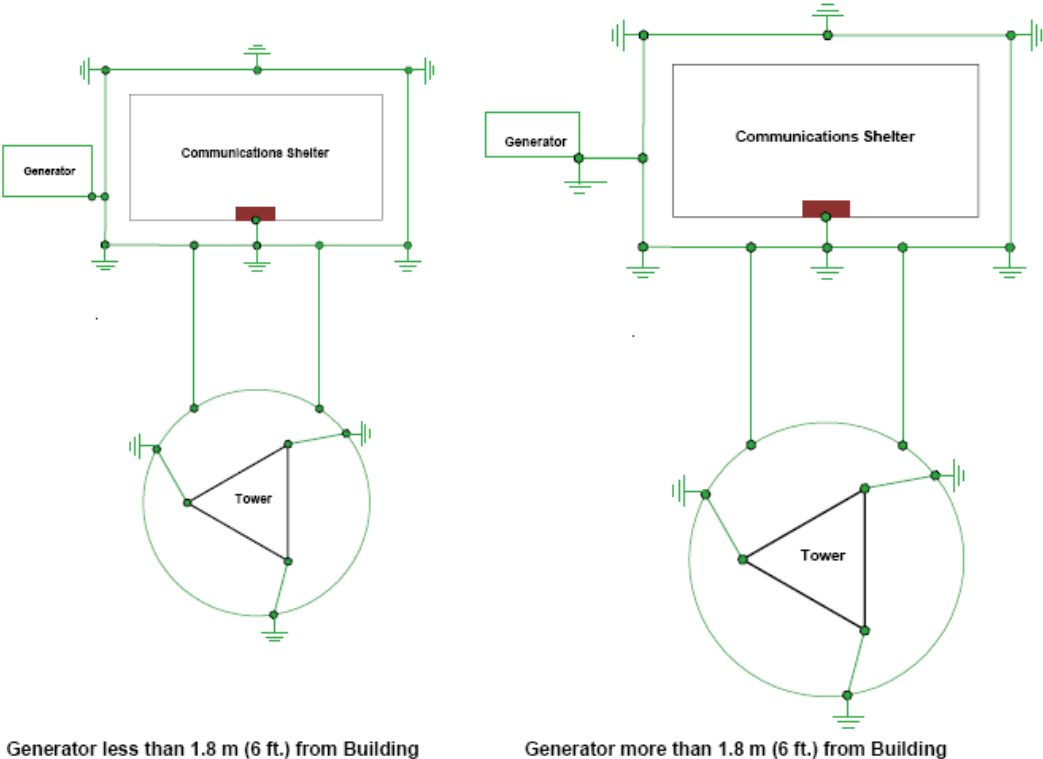


FIGURE 6-35 GENERATOR GROUNDING

SPECIAL GROUNDING SITUATIONS

- **ROOF-TOP AND INTEGRATED COMMUNICATIONS SITES**
- **METAL SHIPPING CONTAINERS USED AS COMMUNICATIONS BUILDINGS**
- **SITES WITH LIMITED SPACE FOR THE GROUNDING ELECTRODE SYSTEM**
- **TOWERS WITH LIMITED SPACE FOR A GROUND RING**
- **STONE MOUNTAIN TOPS**
- **SAND, CORAL, OR LIMESTONE ENVIRONMENTS**
- **SHALLOW TOPSOIL ENVIRONMENTS**

BONDING TO THE EXTERNAL GROUNDING ELECTRODE SYSTEM

REQUIREMENTS

- Single point grounding systems inside equipment shelters are bonded to the external GES and to the existing electrical service GES.
- All below-grade grounding connections are joined using exothermic welding or high-compression fittings compressed to a minimum of 12 tons of pressure.
- All above grade grounding connections are joined using exothermic welding, UL listed lugs, UL listed pressure connectors, and UL listed clamps.
- All copper connectors should maintain a minimum 88% conductivity rating.
- Do not use Aluminum for connection purposes.

BONDING TO THE EXTERNAL GROUNDING ELECTRODE SYSTEM

All bonding is performed so that a suitable and reliable connection exists.

- Remove from threads and surface areas where connections are made, all paint, enamel, lacquer and other nonconductive coatings to ensure a good electrical continuity .
- After bonding to a painted or galvanized structure, the area is primed and painted.
- Two-hole lugs secured with fasteners in both holes should be used to prevent movement of the lug. However, exothermic welding is the preferred method for bonding connections to the external GES.
- If exothermic welding is not used, irreversible compression fittings compressed with a compression tool with a minimum of 12 tons of pressure is to be used.
- When connecting ground lugs or compression terminals to ancillary equipment such as air conditioners and vent hoods, use a lock washer on the nut side. Don't use sheet metal screws and self-tapping screws.

BONDING TO THE EXTERNAL GROUNDING ELECTRODE SYSTEM



FIGURE 6-48 EXOTHERMIC WELDING MOLD (LEFT) AND PROCESS (RIGHT)



FIGURE 6-49 COMPLETED EXOTHERMIC WELDS IN TRENCH AND ON TOWER

BONDING TO THE EXTERNAL GROUNDING ELECTRODE SYSTEM

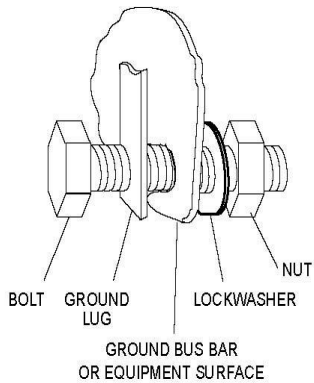
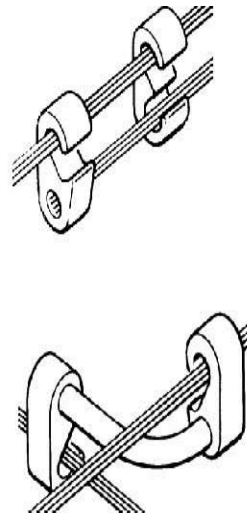


FIGURE 6-47 PROPER LOCATION OF WASHER WHEN CONNECTING GROUND LUG



Mechanical



Hydraulic



Battery-Powered

FIGURE 6-50 HIGH-COMPRESSION CONNECTORS AND TYPICAL CRIMPING TOOLS