

National Electrical Installation Standard (NEIS™)

NECA 331-2xxx



*Standard for Installing*  
**Building and Service Entrance Grounding**

Recirculation Ballot Draft

## TABLE OF CONTENTS

<b>1. SCOPE</b> .....	<b>1</b>
1.1 EQUIPMENT AND SYSTEMS INCLUDED .....	1
1.2 EQUIPMENT AND SYSTEMS EXCLUDED .....	1
1.3 REGULATORY AND OTHER REQUIREMENTS .....	1
1.4 MANDATORY REQUIREMENTS, PERMISSIVE REQUIREMENTS, QUALITY AND PERFORMANCE RECOMMENDATIONS, EXPLANATORY MATERIAL, AND INFORMATIVE ANNEXES .....	2
1.5 INTRODUCTION.....	3
<b>2. GROUNDING AND BONDING OVERVIEW</b> .....	<b>3</b>
2.1 PLANNING AND EXECUTION OF PROJECT.....	3
2.2 GROUNDING AND BONDING CONDUCTORS OVERVIEW .....	6
2.2.1 <i>Equipment Grounding Conductor (EGC)</i> .....	7
2.2.2 <i>Installing Equipment Grounding Conductors</i> .....	8
2.2.3 <i>Grounding Electrode Conductor (GEC)</i> .....	10
2.2.4 <i>Grounding Electrode Conductor (GEC) Size</i> .....	10
2.2.5 <i>Grounding Electrode Conductor Installation Protection</i> .....	11
2.2.6 <i>Repair or Splices in Grounding Electrode Conductors</i> .....	11
<b>3. SERVICE ENTRANCE AND BUILDING GROUNDING</b> .....	<b>13</b>
3.1 GENERAL REQUIREMENTS .....	13
3.2 GROUNDING ELECTRODES.....	15
3.2.1 <i>Metal Underground Water Pipe</i> .....	16
3.2.2 <i>Metal In Ground Support Structure Electrodes</i> .....	18
3.2.3 <i>Concrete-Encased Electrodes (Ufer Grounds)</i> .....	19
3.2.4 <i>Ground Ring</i> .....	25
3.2.5 <i>Rod, Pipe, or Plate Electrodes</i> .....	26
3.2.6 <i>Other listed Grounding Electrodes</i> .....	31
3.2.7 <i>Ground Enhancement Materials and Chemical Rods</i> .....	33
3.2.8 <i>Lightning Protection Ground Terminals</i> .....	34
<b>4. BUILDING EXTERIOR GROUNDING</b> .....	<b>34</b>

4.1	PERIMETER GROUNDING.....	35
4.1.1	<i>Triple Ground Rods.....</i>	36
4.1.2	<i>Waterstops for Foundation Penetrations.....</i>	36
4.1.3	<i>Inspection Wells.....</i>	37
4.1.4	<i>Fabricated Wire Mesh.....</i>	38
4.2	FENCE GROUNDING.....	39
4.3	GROUNDING OF OTHER EXTERIOR ITEMS.....	42
4.4	SINGLE GROUNDING ELECTRODE SYSTEM.....	44
4.5	GROUNDING ELECTRODES FOR SEPARATE BUILDINGS OR STRUCTURES.....	45
4.6	ADDITIONAL EQUIPMENT INSTALLED OUTSIDE A BUILDING.....	46
	<b>BUILDING INTERIOR BONDING AND GROUNDING.....</b>	<b>47</b>
5.1	BONDING.....	47
5.1.1	<i>Service Equipment Bonding.....</i>	47
5.1.2	<i>Intersystem Bonding.....</i>	48
5.1.3	<i>Bonding Other Enclosures.....</i>	50
5.1.4	<i>Bonding for Circuits Over 250 Volts.....</i>	51
5.1.5	<i>Bonding of Piping Systems and Exposed Structural Steel.....</i>	51
5.1.6	<i>Building Interior Bonding.....</i>	52
5.2	EQUIPMENT GROUNDING AND BONDING.....	61
5.2.1	<i>Equipment Fastened in Place.....</i>	61
5.2.2	<i>Specific Equipment Fastened in Place.....</i>	61
5.2.2	<i>Equipment Bonding.....</i>	62
5.2.3	<i>Receptacle Grounding.....</i>	65
5.2.4	<i>Isolated Ground (IG) Receptacles.....</i>	65
5.3	GROUNDING BUS AND GROUNDING TERMINAL BARS.....	66
6.	<b>BONDING AND GROUNDING OF ELECTRONIC SYSTEMS.....</b>	<b>68</b>
6.1	PERFORMANCE BONDING AND GROUNDING.....	68
6.2	SIGNAL REFERENCE GROUNDING GRID.....	69
6.3	GROUND CURRENT INTERFERENCE WITH CATHODE RAY TUBE (CRT) BASED EQUIPMENT.....	72
6.4	NETWORKED WORKSTATION EQUIPMENT.....	72

<b>7. INSPECTIONS .....</b>	<b>73</b>
7.1 FINAL REVIEW AND INSPECTION BEFORE ENERGIZING .....	73
7.2 PERIODIC INSPECTIONS AND MAINTENANCE .....	73
<b>ANNEX A: REFERENCES.....</b>	<b>A1</b>

## 1. SCOPE

This standard describes installation procedures for building and service entrance grounding as well as building interior bonding and grounding. The information provided in this standard is intended to define what is meant by installing equipment in a “neat and workmanlike manner” as required by the National Electrical Code® (ANSI/NFPA 70) (NEC), Section 110.12, and in accordance with “accepted good practice” as required by National Electrical Safety Code® (ANSI/IEEE C2) (NESC), Rule 012.C. The installations described in this standard should be performed by qualified persons. The term “qualified person” is defined in Article 100 of the NEC.

### 1.1 Equipment and Systems Included

The following are included in this publication:

- Electrical service and system grounding
- Building exterior grounds
- Building interior bonding
- Equipment grounding and bonding

### 1.2 Equipment and Systems Excluded

Lightning protection systems are specifically excluded from this publication. Interconnections between lightning protection systems and other grounding and bonding systems are necessary and briefly described in Section 3.2.8 of this standard.

### 1.3 Regulatory and Other Requirements

All information in this standard is intended to conform to the NEC and NESC. Installers should always follow the NEC®, NESC®, any applicable amendments in state and local codes, manufacturer’s instructions, listing agency requirements, and project specifications when installing grounding and bonding systems for buildings or structures.

Only qualified persons familiar with the construction of grounding and bonding of electrical systems should perform the work described in this publication.

Administrative functions such as receiving, handling, and storing required in Section 4, and other tasks may be performed under the supervision of a qualified person. All work shall be performed in accordance with NFPA 70E, *Standard for Electrical Safety in the Workplace*.

General requirements for installing electrical products and systems are described in NECA 1, Standard Practices for Good Workmanship in Electrical Construction (ANSI). Other NEIS provide additional guidance for installing particular types of electrical products and systems. A complete list of NEIS standards are provided in Annex A.

#### **1.4 Mandatory Requirements, Permissive Requirements, Quality and Performance Recommendations, Explanatory Material, and Informative Annexes**

**Mandatory Requirements.** Mandatory requirements in manufacturer instructions, or of Codes or other mandatory Standards that may or may not be adopted into law, are those that identify actions that are specifically required or prohibited and are characterized by the use of the terms must or must not, shall or shall not, or may not, or are not permitted, or are required, or by the use of positive phrasing of mandatory requirements. Examples of mandatory requirements may equally take the form of, “equipment must be protected . . .,” “equipment shall be protected . . .,” or “protect equipment . . .,” with the latter interpreted (understood) as “(it is necessary to, or, it is required to) protect equipment . . .”

**Permissive Requirements.** Permissive requirements of manufacturer instructions, or of Codes or other mandatory Standards that may or may not be adopted into law, are those that identify actions that that are allowed but not required or are normally used to describe options or alternative means and methods and are characterized in this Standard by the use of the terms “may”, or “are permitted”, or “are not required”.

**Quality and Performance Recommendations.** Quality and performance recommendations identify actions that are recommended or not recommended to improve the overall quality or performance of the installation and are characterized by the use of the term “should” or “should not”.

**Explanatory Material.** Explanatory material, such as references to other Codes, Standards, or documents, references to related sections of this Standard, information related to another Code, Standard, or document, and supplemental application and design information and data, is included throughout this Standard to expand the understanding of mandatory requirements, permissive requirements, and quality and performance recommendations. Such explanatory material is included for information only and is identified by the use of the term “NOTE,” or by the use of italicized text.

**Informative Annexes.** Non-mandatory information and other reference standards or documents relative to the application and use of materials, equipment, and systems covered by this Standard are provided in informative annexes. Informative annexes are not part of the enforceable requirements of this Standard but are included for information purposes only.

## **1.5 Introduction**

This standard has been developed to provide additional explanation and some “best practices” so that the requirements of the NEC are met and help define better what is meant by a “neat and workman like manner”. The installation guidance provided in this standard should not be considered all-inclusive and it is recognized there are many ways to complete a compliant installation.

This standard is intended to be used in concert with the NEC, the listing requirements from the listing agencies, and the manufacturer’s installation instructions for the equipment utilized to make the installation. This standard does not provide specific code text and it is expected the qualified user is familiar with the applicable NEC Articles and Sections as well as other general industry information and practices. The grounding and bonding terminology used in this standard will utilize the definitions from the NEC. Where the term is not defined in the NEC, then the definition can be found in Webster’s dictionary.

All information in this standard is intended to provide at least minimal conformance to the NEC and NESC. Installers should always follow the NEC®, NESC®, any applicable amendments in state and local codes, manufacturer’s instructions, listing agency requirements, and project specifications when installing grounding and bonding systems for buildings or structures. To mitigate conflicts from all these sources, an order of precedence should be established at the beginning of the project if not already established by the Authority Having Jurisdiction. It should be remembered the NEC is considered the minimum electrical safety standard so any design, specifications or installation that appears to not meet this minimum should be questioned.

## **2. GROUNDING and BONDING OVERVIEW**

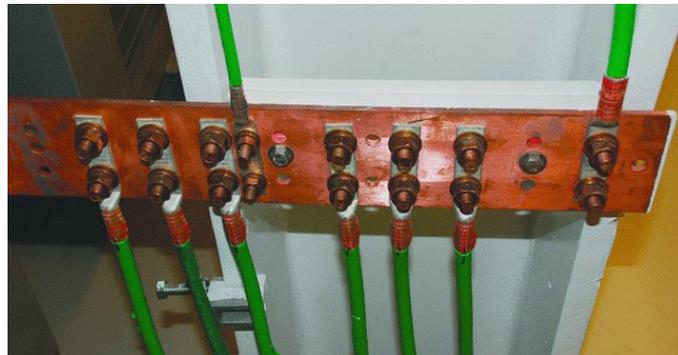
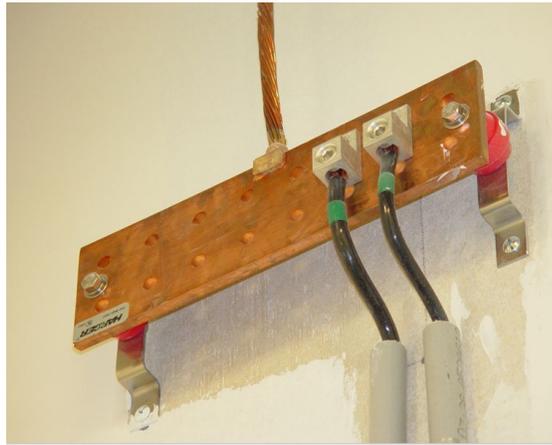
### **2.1 Planning and Execution of Project**

The beginning of any project needs to start with a sufficient level of planning to ensure a smooth installation and approval from the owner and Authority Having Jurisdiction. The complexity of the project will dictate the necessary level of planning that is needed. Clearly, planning the grounding electrode system and overall grounding and bonding for a single-family dwelling is less complex than a multi-tenant commercial building, health care facility, industrial plant or data center. But even with the less complex projects, there needs to be some planning done to avoid problems. Some considerations for projects may include the items below. While all the below items can help with the less complex dwelling unit, many of these are more suited for the complex commercial, institutional and industrial locations.

- (a) What are the geology and soil conditions of the building site? An effective grounding electrode needs to be in suitable earth with a level of moisture to keep conductivity. Knowing the composition of the earth as well as the frost line, for those areas subject to ground freezing, and where the permanent moisture level is located all help to determine which type of electrode can be most effective. While the NEC sets some minimum depths for driven electrodes or buried electrodes, site conditions may require deeper depths to be effective. This is to be in adequately moist earth and below any frost line. Obtaining the geotechnical report, if one is available, can be very informative in this planning. If no report is available, obtaining typical site information for the area from the building department is another resource.
- (b) Also, to help in the grounding electrode selections and installation, the specifications for the building construction need to be known. What is the plan for the water supply piping to the building? Is it uncoated metal pipe or is it a non-metallic pipe or coated that separates the pipe surface from earth contact? Are there structural metal pilings, casings or the like that would be an in-ground support structure electrode? What is the design for the foundation footing(s)? If rebar is being installed for structural and/or seismic reasons and the concrete will be in direct contact with the earth, arrangements need to be made to either have a rebar stub-up provided near the service equipment or to make a grounding electrode conductor connection before the concrete is poured. Rebar should never be exposed to contact with the soil and enter into the foundation or footing. Remember the metal water pipe, metal structural support members and the rebar in the footing or foundation are covered by other codes, such as the building code, and installed by other trades so it will require some level of coordination efforts on the part of the electrical and general contractors.
- (c) Do the specifications call for a ground ring, or grounding grid?
- (d) If the building is very large with more than one service at different locations, what will be the plan to interconnect the grounding electrode systems together?
- (e) What equipment will be installed in the building that may need additional grounding? Is there sensitive data processing equipment that might need a signal reference grounding mat in the room or area and provisions for a single point reference grounding bar to be installed? Does any of the equipment need an auxiliary electrode or a direct connection to the grounding electrode system.
- (f) Are there separately derived systems (transformers, generators, UPS systems, inverters, etc.) to be installed? Is there a plan or specification for the grounding of these separately derived systems? If not, what will be the plan for the installation for location and components needed.
- (g) With the advent in many areas installing or requiring alternate energy systems such as photovoltaic, wind, fuel cells, what is the grounding and interconnection

plan? How is that system to interface with the grid and how are the grounding and bonding needs being met?

- (h) If the building is to have multiple tenants that may change over time, is there a plan to install a common grounding busbar in the main electrical room and electrical rooms on each floor of a multi-story building. These busbars provide a convenient means to bring all the grounding electrodes together to a common bonding point. This then allows each tenant service to have the grounding electrode conductor installed to this common bus. Additionally, a single bond of metallic water and structural metal could be made rather than each service installer having to do it separately. Lastly, the main busbar can be the starting point for a common grounding electrode conductor riser to each floor or around the building on a single floor where it is attached to one or more grounding busbar(s) to serve separately derived systems or other grounding needs. This planning and initial installation can save much time and expense for tenant improvements and any future remodeling.



[insert one photograph similar to these examples]

Photo 2.1 – Example Grounding Busbar

- (i) Is a lightning protection system planned for the buildings or structures? Although it may not be part of the electrical installation by the electrical contractor, what will be the plan for the bonding of the building grounding electrode system to the

lightning protection ground terminals and grounding system as required by the NEC?

## 2.2 Grounding and Bonding Conductors Overview

Grounding and bonding systems serve three primary functions:

- a) Personnel safety - shock hazards and secondarily fire that result from ground faults
- b) Equipment and building protection - fires
- c) Electrical noise reduction – performance not necessarily safety related

Electrical ground faults, short circuits, lightning, and transient events can occur in any premises electrical distribution system. System grounding and equipment grounding are intended to establish a reference to ground (the earth) through a grounding electrode or system of grounding electrodes. System grounding provides the earth reference for electrical system voltage stability from the service or any grounded separately derived system. Effective ground-fault current paths are intentionally constructed in electrical systems to clear faults in the quickest possible manner by providing a low-impedance path returning the fault current to the supply source. The NEC refers to this as establishing an “effective ground-fault current path.” The equipment grounding conductors also provide the main path back to earth so non-current carrying metal enclosures, raceways and the like are maintained at or close to earth potential. The overall effectiveness of any grounding and bonding system is determined both by the components selected, and the manner in which these components are connected. While poor workmanship may not be evident until there is a fault, ensuring a safe and effective installation requires at least the same level of diligence and quality workmanship as any other part of the electrical installation.

In addition to grounding and bonding for safety reasons as required by the NEC, effective and compliant electrical grounding and bonding contributes to the proper functioning and performance of electronic equipment and systems. This subject is discussed in Section 6 Grounding and Bonding of Electronic Systems. With more and more building management and security systems being installed integrated with computers and operating with both wired and wireless communications, “electronic noise” can not only be a nuisance but become a safety hazard when system performance is necessary.

In addition to establishing a good earth connection with the grounding electrode or grounding electrode system, there are two key conductors used for grounding of systems and equipment:

- Grounding electrode conductors, and
- Equipment grounding conductors.

These conductor names are defined in Article 100 of the NEC. It is very important to understand which conductor is being installed or inspected to properly apply the correct installation requirements. Both of these conductors are conductive paths that extend the ground connection as defined in the NEC. These two defined conductors each serve different functions and are discussed in the next two sections. Finally, what is needed then is a “good” earth connection (grounding electrode or grounding electrode system), suitable connection from the grounding electrode to the equipment and system as applicable, (grounding electrode conductor) and also an effective (intentionally constructed, low impedance, electrically conductive) path back to the supply source from any point on the system where a ground fault could occur (equipment grounding conductor).

### 2.2.1 Equipment Grounding Conductor (EGC)

The EGC is the electrically conductive path purposefully installed to connect normally non-current-carrying metal parts of equipment together and to the system grounded conductor or to the grounding electrode conductor, or both. The equipment grounding conductor performs three essential functions in electrical system as follows:

1. The EGC provides a connection through a conductive path to ground (earth) from equipment.
2. The EGC performs bonding functions making the electrical connection of all non-current carrying metal enclosures, raceways and the like
3. The EGC performs as an effective ground-fault current path to facilitate overcurrent device operation.

The following components are those identified for use as the EGC for both branch circuits and feeders, under the conditions described in Article 250 of the NEC. In addition to the information in the grounding and bonding section of the NEC, the raceway, and related types of equipment grounding conductors have installation requirements found in their respective code sections.

- a) A wire type conductor manufactured from copper, aluminum, or copper-clad aluminum conductor
- b) Rigid metal conduit (RMC)
- c) Intermediate metal conduit (IMC)
- d) Electrical metallic tubing (EMT)
- e) Listed flexible metal conduit (FMC) in accordance with conditions stated in the NEC

- f) Listed liquid-tight flexible metal conduit (LFMC) in accordance with conditions stated in the NEC
- g) Armor of Type AC cable
- h) The copper sheath of mineral-insulated, metal-sheathed cable, Type MI
- i) The metal sheath or the combined metallic sheath and grounding /bonding conductors of Type MC cable
- j) Metal cable trays
- k) Cablebus framework
- l) Other electrically continuous metal raceways and listed auxiliary gutters
- m) Surface metal raceways listed for grounding

### 2.2.2 Installing Equipment Grounding Conductors

For best performance of the EGC function, all conductors of an electric circuit, including the EGC, must be contained in the same raceway, cable tray, trench, cable, or cord. The closer the EGC is aligned with the ungrounded conductor(s) the lower the overall impedance of the return ground fault path. It is noted that there are specific allowances in the NEC for installing EGCs separate from the circuit conductors in existing installations where no equipment grounding means exists in the outlet for a switch or receptacle. These allowances are there to provide a path that is better than nothing, but it is understood that the installation is not ideal. If using one of the allowed options extra care should be taken to minimize the impedance impact created by separation of the equipment grounding conductor from the circuit conductors.

- a) The EGC shall be installed in accordance with the applicable NEC provisions for the type of EGC selected. This generally applies where the EGC is a raceway, wireway, etc.
- b) When a metallic raceway system is used as an EGC, with or without a separate wire-type EGC installed, the entire raceway run is required to perform as effective ground-fault current path. For this reason, any fittings and terminations at boxes must be made up wrenchtight to ensure a low-impedance, effective path for ground-fault current.
- c) Additional bonding methods may be necessary and sometimes required around concentric, eccentric, or oversized knockouts in electrical enclosures. Metallic boxes with concentric or eccentric knockouts are listed for grounding and bonding for circuits over 250 volts. The listed metallic boxes as used in this part are device type boxes with a total volume of 100 cubic inches or less.

- d) All wire type EGC connections shall be made using listed equipment, fittings and attachment methods identified in NEC 250.8. This applies to all connections including the wire terminal and the wire terminal mounting hardware.
- e) If ungrounded conductors are increased in size for any reason (i.e. voltage drop, ampacity adjustment, conductor availability, etc.) the EGC shall be increased in size proportionately to the ungrounded conductors in accordance with the applicable NEC requirements.
- f) For motor circuits using an instantaneous circuit breaker (also known by a trade name as a Motor Circuit Protector (MCP)) or a Motor Short Circuit Protector, the EGC is allowed to be sized as if the motor short circuit and ground fault protective device is a dual element time delay fuse. This dual element time delay fuse would be sized based on NEC requirements for sizing the motor short circuit and grounding fault protective device including the exception.
- g) When the EGC is a separate (wire-type) conductor, its size is determined by the rating or setting of the overcurrent protective device (fuse or circuit breaker) installed for the circuit.
- h) In parallel installations, each EGC where of the wire type, must be installed in accordance with the NEC provisions for parallel circuit conductors. This will depend on if there is a single raceway or enclosure or if there are parallel conduits. The size of the wire type equipment grounding conductor in the single raceway or in each of the parallel raceways is based on the ampere rating of the overcurrent device using NEC Table 250.122.
- i) When the circuit conductors are installed in parallel and routed in multiple raceways or cable assemblies, the equipment grounding conductors must also be installed in parallel and in each raceway. The size in each cable or raceway is full size based on the NEC Table 250.122.
- j) Cable assemblies installed in parallel shall contain an equipment grounding conductor sized according to NEC 250.122 but it does not have to be larger than the circuit conductors. In parallel runs the circuit conductor is the total of all conductors in parallel that are installed to create one conductive path, not the individual conductors in each cable installed in the parallel arrangement. For multiconductor cables installed in parallel in multiple raceways, gutters, wireways or in cable tray that qualifies as an equipment grounding conductor, then the size of the EGC within the cable is permitted to be the standard size where the raceways, gutters, wireways or cable tray will provide the EGC function. The EGCs within each cable still need to be bonded at each end and connected to the same point electrically as the raceway, gutter, wireway or cable tray.

### 2.2.3 Grounding Electrode Conductor (GEC)

The grounding electrode conductor is the conductive path (conductor) installed to connect the system grounded conductor or the equipment to a grounding electrode or to a point on the grounding electrode system. Grounding electrode conductors are permitted to be copper, aluminum, or copper-clad aluminum, solid, stranded, insulated, covered, or bare.

The provision to install a GEC from the equipment to a grounding electrode or point on the grounding electrode system is an important consideration. This allows the bonding of several of the grounding electrodes together and then have the correctly sized GEC connect to one of the electrodes or to some other point on the interconnected network. This common connection point can be a minimum 1/4 x 2-inch copper or aluminum busbar or to one of the bonding jumpers. When going to a bonding jumper, the one consideration required is that all the bonding jumpers from the connection point are properly sized for the GEC that is required for the service or separately derived system.

### 2.2.4 Grounding Electrode Conductor (GEC) Size

- a) The minimum size of the GEC is determined based on:
1. the largest ungrounded service-entrance conductor that supplied the building or structure, or
  2. based on the largest ungrounded derived phase conductor of a separately derived system.
  3. The largest feeder or branch circuit conductor for buildings or structures served by feeder(s) or branch circuit(s)

The GEC is never required to be larger than a 3/0 AWG copper or 250 kcmil aluminum or copper-clad aluminum conductor. This is because the GEC is unable to dissipate any more current into the earth than can be carried by the conductors. Note, that the GEC is not intended to be a fault current carrying conductor.

- b) The common grounding electrode conductor for multiple service disconnection means in separate enclosures is based on the size of the largest ungrounded service entrance conductor supplying all the two or more services.
- c) For multiple separately derived systems the common grounding electrode conductor is required to be at least a 3/0 AWG copper or 250kcmil aluminum. The common grounding electrode conductor can also be structural metal forming the frame of the building or metallic water piping that meet the requirements set for the ability to use these structural

components as a conductor. For wire type common grounding electrode conductors, many project specifications require a larger conductor where certain performance considerations are implemented.

### 2.2.5 Grounding Electrode Conductor Installation Protection

Grounding electrode conductors shall be protected from physical damage wherever they are accessible. .

- a. The use of aluminum or copper-clad aluminum GECs is prohibited where the bare conductor is installed in direct contact or within 18 inches of the earth, masonry, or where subject to other corrosive conditions.
- b. Installation of aluminum conductors in outdoor rated equipment, including open bottom switchgear or switchboards on concrete pads is not exposing the bare aluminum conductor at the termination to the corrosive conditions of the "earth". Unless there are other corrosive environmental aspects present, installations made within 18 inches of the bottom is acceptable.
- c. The GEC can be installed directly on a building or structure, if 6 AWG or larger, and not subject to physical damage. If the GEC is subject to physical damage, it shall be installed in a metallic raceway (RMC, IMC or EMT) or cable armor for protection. Another acceptable alternative is to use metal raceway that is nonferrous (such as aluminum conduit or aluminum EMT), or nonmetallic raceways (such as Schedule 80 PVC or RTRC-XW conduit) that provide adequate protection from physical damage.
- d. Any ferrous metallic enclosures or raceways containing grounding electrode conductors shall be electrically continuous from the electrical equipment to the grounding electrode to ensure that current flow is not impeded by the inductive element of the circuit. Bonding can be accomplished by connecting each end of the GEC enclosure or raceway to the electrical equipment enclosure and the electrode itself.
- e. The size of the bonding jumper for ferrous metal raceways or enclosures containing a grounding electrode conductor must be the same size or larger than the enclosed grounding electrode conductor.

### 2.2.6 Repair or Splices in Grounding Electrode Conductors

Grounding electrode conductors can be damaged during construction where it emerges from the concrete. Repair splicing methods and products are available for both horizontal and vertical applications. A minimum amount of

concrete may need to be chipped away to make the appropriate splice repair. If this is done, suitable repair of the concrete needs to be accomplished.

Where GECs need to be extended to a new service or derived system location or for modifications to the electrical distribution system, the GEC must be spliced by means of exothermic welding or irreversible compression connections listed for this purpose.. Note that connections of grounding electrode conductors to the grounding electrodes are required to be accessible if installed above grade level and not encased in concrete or covered with fire coating material such as on structural steel.

- a. In general, wire type GECs installed for services, separately derived systems, or buildings served by feeder(s) or branch circuit(s) is required to be run in one continuous length, without splices or joints. However, wire type GECs can be spliced by means of exothermic welding, or irreversible compression connectors listed as grounding and bonding equipment, (*Photo 2.2.6 Typical Irreversible Compression Connectors Listed as Grounding and Bonding Equipment*)



*Photo 2.2.6* Photo provided by NEMA

- b. If busbar is used as the GEC, then specific NEC provisions in allow for joining the lengths of busbar together with mechanical means (bolts) to make it continuous. This provision does not give permission to splice wire type grounding electrode conductors using a busbar with wire type mechanical pressure connectors. Also, where metal water piping or structural metal is used to extend the ground connection as provided in the NEC requirement for continuity has provisions for the joining of the water pipe or structural metal segments together to meet the continuity requirements.
- c. The NEC and this standard do not include specifics on installation of lightning protection systems. The only requirement in the NEC is that the grounding electrode system for the premises wiring be connected (bonded) to the ground terminals of the lightning protection system. Further information on the design and installation of lightning protection

systems can be found in NFPA 780, Standard for the Installation of Lightning Protection System, and from the Lightning Protection Institute.

### **3. SERVICE ENTRANCE AND BUILDING GROUNDING**

A grounding electrode is defined in the NEC as a conducting object through which a direct connection to earth is established. While this definition opens up many possibilities, the NEC provides a list of grounding electrodes that are permitted for use in electrical installations. The grounding electrodes permitted by the NEC are further described in Part III of Article 250 and discussed in section 3.2.

#### **3.1 General Requirements**

- a. All electrical systems shall have at each service, separately derived system, or building served by a feeder(s) or branch circuit(s) a grounding electrode conductor connected to a grounding electrode system. One exception is a building served by a single branch circuit including a multi-wire branch circuit that includes an equipment grounding conductor is not required to have a grounding electrode installed. While this is allowed and meets the minimum NEC, consideration should be made for buildings that may be separated by a significant distance. The concern would be possible potential differences of the earth (ground) at the building being served from the earth reference from the equipment grounding conductor of the building providing the branch circuit. For most dwelling applications, this is not typically a concern, but for farms, buildings in a campus arrangement, or otherwise separated buildings by some distance should be reviewed.
- b. Two or more grounding electrodes, of the same type or different types, bonded together form a grounding electrode system.
- c. For a grounded system, the grounding electrode conductor shall also be connected to the grounded service conductor, or the grounded conductor for the separately derived system and in both cases the metal equipment enclosure.
- d. For ungrounded systems, the grounding electrode conductor shall be connected to the metal enclosure of the service or a separately derived system.
- e. For services this connection shall be permitted to occur at any accessible point from the load end of the service drop or service lateral to the grounded conductor (neutral) termination (bus, terminal block, or other terminal typically supported in insulation from the enclosure) in the service disconnecting means enclosure. The enclosure is prohibited from ever being used as a current path for the grounded circuit (neutral) conductor.

- f. For a separately derived system the grounding electrode conductor can be connected to any point from the source of the separately derived system up to the point of the enclosure with the first disconnecting means. This will also be the same location where the system bonding jumper will be required to be installed.
- g. If a separately derived system is outside of the building or structure being served, the connection of the grounding electrode conductor is required at the source outside. The main reason for this is in the event of lightning, it is not desired to have lightning induced current travel on the neutral conductor into the building to find the connection to earth.
- h. One additional consideration is where there are multiple sources of a separately derived system connected in parallel creating one system. This occurs with engine-generators that are paralleled together in a paralleling switchboard, or photovoltaic systems with many inverters with the AC output paralleled together. In these cases, the multiple sources that are paralleled should be considered as one separately derived system and the grounding may be best completed in the paralleling switchgear or common connection point.
- i. The grounded conductor (usually a neutral) is generally connected to ground at only one point on each service or separately derived system. (*Fig. 3.1(a) Grounding of AC Power System*).

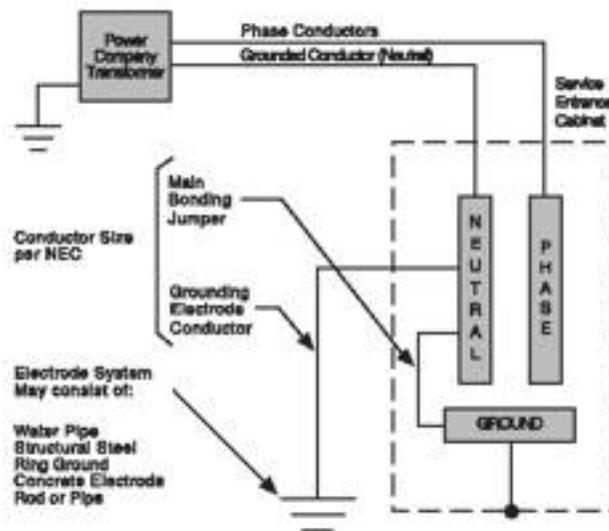
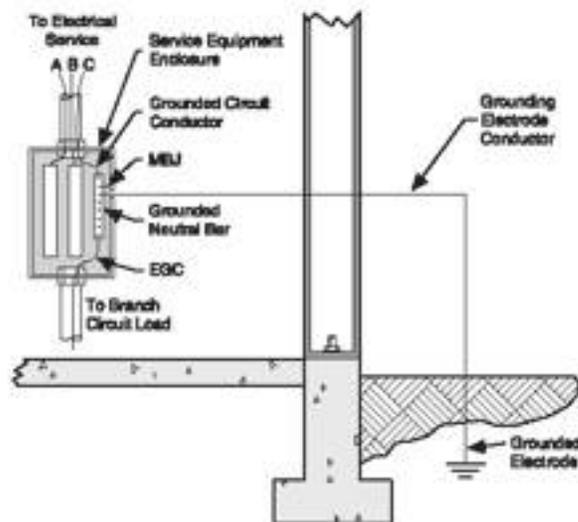


Fig 3.1(a) Illustration by ERICO Corporation International

- j. The service disconnecting means is frequently the point at which the required grounding connections are made (*Fig. 3.1(b) Service Equipment Grounding Connections*).
- k. The connection of the grounding electrode conductor to the metal frame of the building or structure of fire rated buildings (type IA or IIA) can be made by two methods.
  1. First, exothermic welding the grounding electrode conductor to the structural metal.
  2. Secondly, installing an irreversible compression type connection listed for grounding and bonding and attaching the lug part to the structural metal by mechanical means such as bolts.

After installation is completed by either method and inspected, then the building structural metal can be covered or recovered with the appropriate fire proofing material.



*Fig 3.1(b)* Illustration by ERICO Corporation International

### 3.2 Grounding Electrodes

All grounding electrodes that are present at the building or structure served are required to be bonded together to form the grounding electrode system. The following types of grounding electrodes are discussed in the Sections listed below:

- Metal Underground Water Piping
- Metal Building Frame
- Concrete-Encased Electrodes

- Ground Ring
- Installed Electrodes (such as rods, pipes, or plates)
- Other listed Grounding Electrodes
- Other buried metal structures such as well casings, tanks, etc.

The first three electrodes listed are part of the building construction and generally installed by other trades, plumber, steel erection, or foundation contractor respectfully. The other electrodes listed, except the last item, are installed for the purpose of being a grounding electrode and are generally installed by the electrical installer.

There are conductive materials that should never be used as grounding electrodes as follows:

- a. Underground gas piping (although gas piping must be bonded to the system).
- b. Aluminum material
- c. The steel reinforcing shell or metal support structure for an in-ground swimming pool.

### 3.2.1 Metal Underground Water Pipe

- a. Metal water piping that is in direct contact with the earth for 3.0 m (10 ft) or more shall be part of the grounding electrode system. The metal water pipe must be bare metal or if coated the coating material electrically conductive, such as galvanizing with zinc.
- b. When connecting the grounding electrode conductor to the metal water pipe, a listed clamp or other listed means shall be used to make the connection. If the clamp is to be buried in the earth then the clamp must be listed for grounding and bonding and be listed and identified as suitable for direct burial. This is many times indicated by the letters “DB” stamped into the clamp body.
- c. Ground clamps shall be listed for the materials of which the metal water pipe is constructed as well as the conductor material of the grounding electrode conductor.
- d. Not more than one grounding electrode conductor shall be connected to each clamp unless the clamp is listed for multiple connections (*Fig. 3.2.1(d)(1) Ground Clamp on Water Pipe Photo 3.2.1(d)(1) Mechanical Grounding/Bonding Clamp for Water Pipe*).



*Fig 3.2.1(d)(1) Photo of typical water pipe grounding clamp*



*Photo 3.2.1(d)(1) Photo provided by NEMA*

- e. The point of connection shall be located anywhere on the pipe in the earth or up to the first 1.52 m (5 ft) from the point of entrance of the metal water pipe into the building.
- f. Following the definition of a grounding electrode being in the earth, metal water piping beyond the first 1.52 m (5 ft) into the building is not considered as part of the grounding electrode system.
- g. Unless the water pipe meets the provisions in the NEC for use beyond the first 5 feet, the metal water pipe shall not be used as a conductor to interconnect parts of the grounding electrode system. The exception in the NEC only applies to commercial, institutional, and industrial occupancies.
- h. The metal water pipe electrode is required to be supplemented by an additional electrode which cannot be another metal water pipe. This is to ensure when the metal water pipe is replaced or repaired, typically with non-metallic pipe, which then negates its ability to be a grounding

electrode, there is still another suitable electrode in the earth for the building or structure power system.

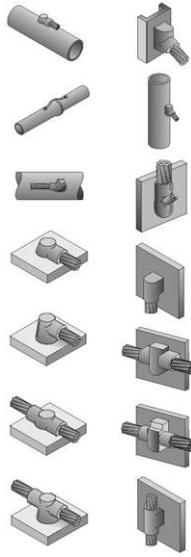
- i. For the supplementing of the metal water pipe, if the in ground support structure electrode, concrete-encased electrode, or any of the other electrodes identified in the NEC are not present for use, an electrode from the acceptable list will need to be installed to supplement the metal water piping; see Section 3.6 of this standard.
- j. If the supplemental electrode is a rod, pipe or plate, there must be two of them installed in any combination unless the single rod, pipe, or plate has a resistance to ground of 25 ohms or less. That ground resistance may be required to be proven by test with documentation available to the Authority Having Jurisdiction.

### 3.2.2 Metal In Ground Support Structure Electrodes

- a. If the metal in-ground support structure of the building qualifies as a grounding electrode in accordance with the NEC, it shall be bonded to the grounding electrode system. The metal in-ground support structure is structural metal, such as I-beams, driven into the earth with or without concrete encasement. These items are driven into the earth to a solid base (bedrock) to provide support to the building where the soil conditions cannot provide that support. Other examples of metal in-ground support structures are casings, concrete pilings with rebar inside.
- b. Any of the metal in-ground support structure that is exposed above the finish grade is generally suitable to use as a conductor to connect to the electrode portion that is in the earth. The wire type grounding electrode conductor or grounding electrode bonding jumpers can be connected to this above grade part of the structure.
- c. The connection of the grounding electrode conductor to the structural metal frame electrode shall be accomplished by the use of exothermic welding, listed lugs, listed pressure connectors, listed clamps or other listed means. (*Figure 3.3(b) Mechanical Connection to Building Metal Framing*).
- d. If the in-ground support structure is a concrete piling with rebar encased, then the concrete would need to be removed sufficient to expose the rebar. The grounding electrode conductor or electrode bonding jumper would be connected to this rebar similar to what is done with a concrete encased electrode.
- e. Where the grounding electrode conductor is to be attached, dirt or non-conductive coatings such as paint, lacquer and enamel, have to be

removed from the contact surfaces of the metal frame to ensure good electrical continuity.

- f. Wire type conductor connections to steel or cast iron that meet any installation requirements are available (Fig. 3.2.2(d)(1) Cable to Steel or Cast-Iron Connections using exothermic welds and Photo 3.2.2(d)(1) Irreversible Compression Connector for Connection Cable to Steel).



*Fig 3.2.2(d)(1) Illustration by ERICO Corporation International*



*Photo 3.2.2(d)(1) Photo provided by NEMA*

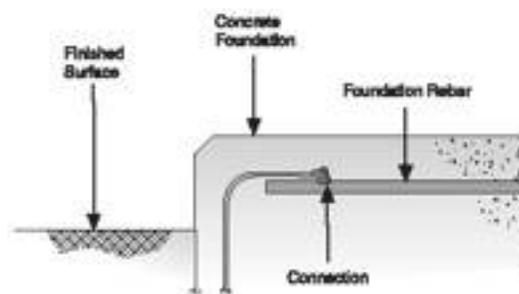
### 3.2.3 Concrete-Encased Electrodes (Ufer Grounds)

The structural steel within the concrete foundation or footing is usually referred to as “rebar,” which is short for reinforcing bar (*Fig. 3.2.3(a)*)

*Foundation Rebar Ground Connection and Fig. 3.2.3(b) Foundation Rebar Ground Connection*). The rebar with encasement can be used as the concrete encased electrode if the installation meets the several requirements stated in the NEC. Alternatively, the NEC allows for a 4 AWG bare copper conductor to be installed at the base of the foundation or footing and encased by a minimum of 2 inches of concrete. If the rebar is being used, then connections to the rebar within the building footing or foundation must be accomplished before the concrete is poured in place. The NEC also allows for a section of rebar to be bent and installed so that the bottom has the correct overlap in accordance with the building code and the vertical portion is above the concrete in a dry non-corrosive environment as shown in photo 3.2.3(a). Typically, this rebar extension or “stub-up” is in the area of the service and may be inside a wall space where the connection of the grounding electrode conductor can be completed. Rebar cannot penetrate from the concrete in such a way that it is exposed to the earth.

For remodel or building additions, it is not required to disturb concrete footings or foundations of existing buildings or structures to establish a concrete-encased electrode.

Where plastic sheeting (vapor barriers) or other insulating materials are installed under footings or otherwise separate the concrete from the earth there is not a concreted encased electrode available. *Note: Where there is isolation/insulation between the concrete footing or foundation and the direct connection to earth is compromised, the concrete no longer qualifies as a grounding electrode.*



*Fig 3.2.3(a) Illustration by ERICO Corporation International*

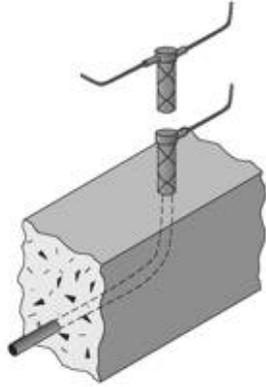


Fig 3.2.3(b) Illustration by ERICO Corporation International



Photo 3.2.3(a) Rebar Stub Up with GEC to Panelboard

- a. Rebars are required to be electrically continuous (wire ties connecting crossed rebar at a minimum). This can be done using wire ties, welding, or other means to secure the rebar together. The installation is generally done by the concrete (foundation) contractor and details of how to arrange and connect rebar sections together are under the adopted building code. (Fig. 3.2.3(c) "UFER" Ground Detail).

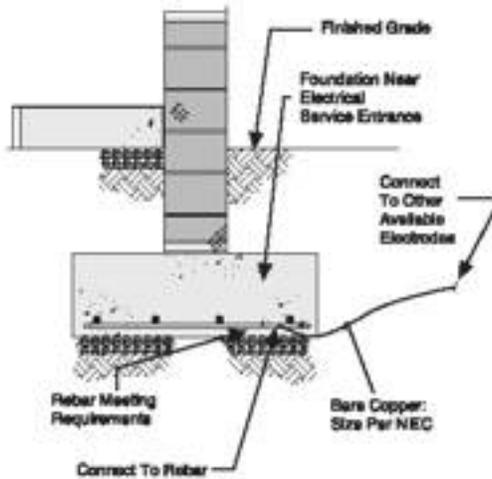


Fig 3.2.3(c) Illustration by ERICO Corporation International

- b. The concrete-encased electrode must be covered on all sides by at least 50 mm (2 in.) of concrete and consist of at least 6.0 m (20 ft) of reinforcing bars of not less than 13 mm (1/2 in.) in diameter (No. 4 rebar) located near the bottom of a concrete footing or foundation. The concrete-encased electrode shall be permitted in a horizontal or vertical arrangement as long as 6.0 m (20 ft) is encased in the concrete. The electrode is the combination of 20 feet or more of concrete in contact with the earth that encases the rebar. The rebar is the means to make an electrical connection to the concrete that is in contact with the earth.
- c. Rebar covered with a non-conductive coating, such as epoxy, is not suitable for use as concrete-encased electrodes.
- d. Concrete slabs on grade are not suitable for use as concrete-encased electrodes. The electrode must be in the foundation or footing. What constitutes a foundation or footing is best defined in the adopted building code.
- e. Plastic vapor barriers or the use of insulation block forms that remain in place significantly impede and often isolate the connection between the concrete and the earth thereby making the assembly not suitable as a concrete encased electrode.
- f. An alternative method of providing a concrete-encased electrode is to embed at least 20 feet of bare copper conductor, not smaller than 4 AWG in the concrete at the base of the foundation or footing. The wire acts in place of the rebar as described above. (Fig. 3.2.3(d) *Copper Wire as Concrete Encased Electrode*).

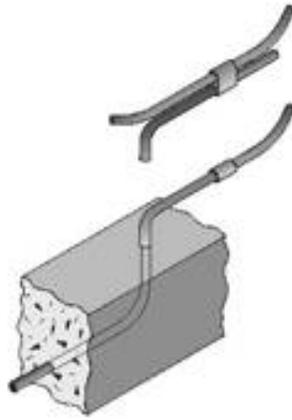


Fig 3.2.3(d) Illustration by ERICO Corporation International

- g. Where the grounding electrode conductor is connected to a buried or encased electrode, the device used must be listed for direct soil *burial* (Fig. 3.2.3(e) *Welded Connections for Direct Soil Burial*). Options for these connections include exothermic welding, irreversible compression connectors, or mechanical connectors that are listed for grounding and bonding and all being suitable for direct burial application. See photo 3.2.3(b) for examples of mechanical clamps that can be used for connection to rebar.

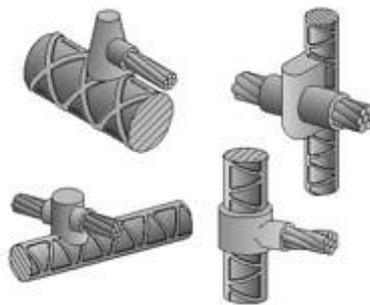


Fig 3.4(e) Illustration by ERICO Corporation International



Photo 3.2.3(b) – Rebar Clamp for GEC

- h. For welded connections, it is recommended to locate the weld away from areas of maximum tensile stress, such as near the free end of the bar in a lap splice.

If a foundation with rebar is used as part of the grounding electrode system and to be connected to the structural steel columns, bond the anchor bolts for structural metal columns to the main rebars (*Fig. 3.2.3(f) Bonding of Anchor Bolts to Rebar*). It is also acceptable to install a wire type bonding jumper by exothermically welding or mechanical means as discussed for the metal in-ground support structure to the steel member (column) anchored by the bolts in lieu of connecting the anchor bolts themselves to the concrete encased rebar.

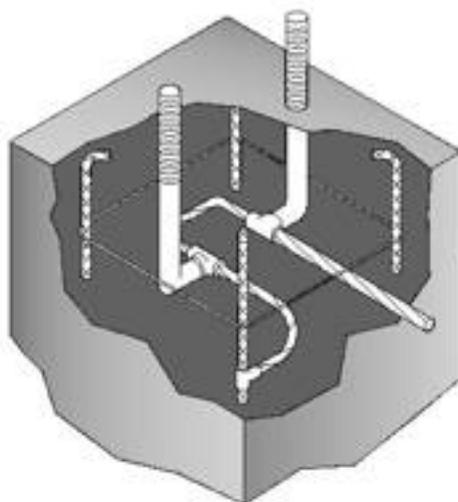
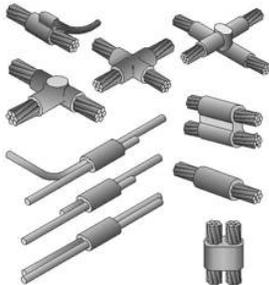


Fig 3.2.3(f) Illustration by ERICO Corporation International

### 3.2.4 Ground Ring

As stated earlier, the metal water pipe, in-ground support structure, and concrete encased electrodes are part of the building construction and generally installed by other trades. The ground ring and several electrodes in following sections are installed specifically to act as a grounding electrode and generally are installed by the electrical installer.

- a. A ground ring is required to consist of at least 6.0 m (20 ft) of 2 AWG bare copper or larger wire that completely encircles the building. Refer to Section 4.1 for expanded recommendations for perimeter grounding using a ring, which exceeds minimum NEC requirements.
- b. The ground ring should be in direct contact with the earth at a depth below the earth surface of at least 750 mm (30 in.). This is the minimum depth and the installation may be required to be deeper where soil conditions or frost levels would dictate.
- c. If the connection to the ground ring is a direct burial connection, the ground clamps or fittings must be listed for direct soil burial or exothermic welding must be chosen (*Fig. 3.2.4) Cable Connection to Ground Ring and Photo 3.5(c) Mechanical Cable Connection to Ground Ring*).
- d. Install the ground ring and any associated rod, pipe or plate electrodes and interconnecting conductors 450 mm (18 in.) beyond the roof drip line. This may provide additional moisture to reduce resistance.



*Fig 3.2.4()* Illustration by ERICO Corporation International



*Photo 3.2.4* Photo provided by NEMA

### 3.2.5 Rod, Pipe, or Plate Electrodes

The NEC has provisions for grounding electrodes that have to be installed such as rod, pipe, plate, or other listed electrodes. These grounding electrodes are usually installed when the grounding electrodes inherent to building construction are not present for use in forming a grounding electrode system. These electrodes such as rod, pipe, or plate electrodes in many cases can improve the effectiveness of the overall grounding electrode system. For example, it is common to install ground rods at corners and along the perimeter along with a ground ring.

The most commonly installed electrodes consist of one or more rod(s), pipe(s) or plate(s) as discussed in the following sections.

#### 5.1 Ground Rods

Common selection criteria for ground rods include but are not limited to:

- a. Ground rods shall be stainless steel or have be manufactured from iron or steel and shall be at least 15.87 mm (5/8 in.) in diameter. Typically, the iron or steel forms a core with the outer surface galvanized, clad with copper, or otherwise metal-coated for protection..
- b. Stainless steel and copper or zinc coated ground rods that are not less than 12.70 mm (1/2 in.) are acceptable if they are listed.
- c. A copper-bonded iron or steel ground rod shall have a copper thickness at least 10 mils
- d. A galvanized iron or steel ground rods shall have a galvanized coating at least 3.9 mils
- e. Rods are available with a factory-welded pigtail (*Fig. 3.2.5(a) Grounding Rods with Wire Pigtails*). Pigtails could be added in

the field by using mechanical, compression, or exothermic products that are listed and suitable for the application



Fig 3.2.5(a) Illustration by ERICO Corporation International

## 5.2 Installing Ground Rods

Follow these procedures when installing ground rods:

- a. Ground rods must be installed (driven) such that at least 2.44 m (8 ft) of length is in contact with the earth. Ideally, the earth should not be overly rocky so there is good contact made with the driven ground rod all along the surface of the rod. The rod should be installed so that it penetrates below the permanent moisture level.
- b. If rock is encountered when being driven vertically, the ground rod can be driven at an angle, not to exceed 45° from vertical. If driving at an angle encounters rock, then it is permitted to bury the rod in a trench which is at least 30 inches below the earth.
- c. The point of connection of the grounding electrode conductor shall be below or flush with grade unless it is suitably protected against physical damage. The connector for use below grade must be listed for grounding and bonding and also as suitable for direct burial.
- d. Where the rod is above the finish grade the required protection can be by a box or other suitable means made from concrete, metal, wood or other material suitable to provide physical protection for the connection. Examples are in figures 3.2.5(b), 3.2.5(c) and 3.2.5(d)

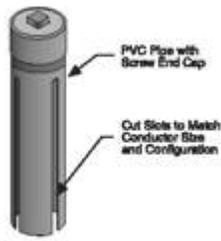


Fig 3.2.5(b)

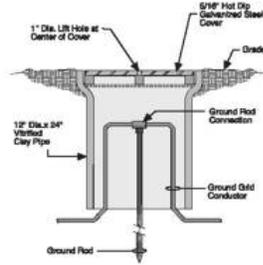


Fig 3.2.5(c)



Fig 3.2.5(d)

Illustrations 3.2.5(b), (c), and (d) by ERICO Corporation International

- e. The basic requirement is to install two rods, pipes or plates in any combination unless the ground resistance of a single rod, single pipe or single plate electrode is 25 ohms or less.
- f. Unless the surface layer of soil 2.44 m (8 ft) to 3.0 m (10 ft) is of a relatively low resistivity, the use of multiple rods may not be effective. Either the rod or rods will need to go deeper or another type of electrode should to be considered.
- g. The NEC requires a minimum separation of 1.83 m (6 ft) between rod, pipe or plate electrodes. Spacing at distances equal to or greater than the length of the rod or pipe can reduce the effects of overlapping spheres of influence.
- h. If ground rods are being buried in a trench as indicated above, the 6 feet of spacing still applies so the trench would need to be a minimum of 22 feet to accommodate two 8-foot ground rods and have 6 feet of spacing between the ends.
- i. Sometimes it is necessary to drive ground rods to a depth of 30 m (100 ft) to 45 m (150 ft) to reach a low resistivity layer. Since a continuous rod cannot be installed, rod sections must be spliced. The methods available are threaded couplers, compression (threadless) type and welding (*Fig 3.2.5(e) Splice Methods for Ground Rods*).

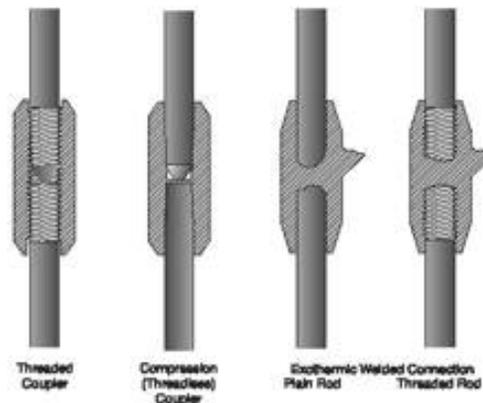


Fig 3.2.5(e) Illustration by ERICO Corporation International

- j. Ground rods may also be spliced using a combination of a screw coupling and a welded coupling. After the screw coupling is installed, two exothermic welded connections can be made to weld the coupling to both the top and bottom rods (Fig. 3.2.5(f) *Screw/Welded Coupling for Ground Rod*).

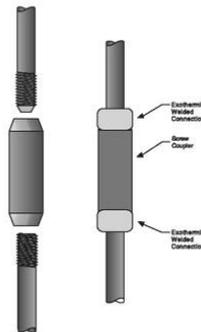
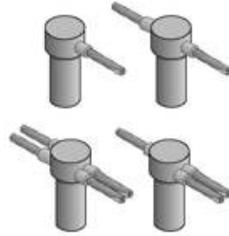


Fig 3.2.5(f) Illustration by ERICO Corporation International

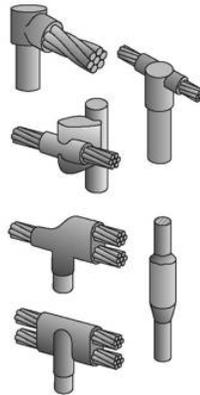
### 5.3 Connections Between Ground Rods and Conductors

The connection between the ground rod and the conductor is critical to maintaining the integrity of the grounding system. Clamps or fittings listed for grounding and bonding are permitted as well as exothermic welding. The marketplace offers a complete line of conductor-to-ground rod connections. They are used for both plain or threaded copper-bonded, galvanized, or stainless-steel rods (Fig. 3.2.5(g) *Examples of Exothermic Welded Connections Made with*

*Single-Use Molds and Fig. 3.2.5(h) Examples of Exothermic Welded Connections Made with Multi-Use Molds*). The NEC identifies several types of connectors for grounding applications but remember when connecting to a grounding electrode the connector needs to be listed for grounding and bonding.



*Fig 3.2.5(g) Illustration by ERICO Corporation International*



*Fig 3.2.5(h) Illustration by ERICO Corporation International*

#### 5.4 Pipe Grounding Electrodes

Pipe electrodes are no very common but recent industry feedback indicates that pipe electrodes are still used in parts of the United States.

Pipe electrodes shall be metric designator 22 or 3/4-inch trade size or larger and shall have their outer surface galvanized or another metal

coating for corrosion protection. Typically, 10-foot lengths of ¾ inch rigid metal conduit are used.

- a. Pipe electrodes must be installed (driven) such that at least 2.44 m (8 ft) of length is in contact with the earth. Ideally, the earth should not be overly rocky so there is good contact made with the driven pipe all along the surface of the rod. The pipe should be installed so that it penetrates below the permanent moisture level.
- b. If rock is encountered when being driven vertically, the pipe can be driven at an angle, not to exceed 45° from vertical. If driving at an angle encounters rock, then it is permitted to bury the pipe in a trench which is at least 30 inches below the earth.

## 5.5 Plate Electrodes

Plate electrodes are another type of electrode permitted by the NEC.

- a. The plate must have at least 1.186 m<sup>2</sup> (2 ft<sup>2</sup>) of surface area in contact with the earth. A plate that is 12 x 12 inches meets the 2 square feet of surface area by counting the top and the bottom surface areas that are exposed to the earth.
- b. The plate may be constructed of iron or steel of at least 6.4 mm (¼ in.) thick or other nonferrous materials of at least 1.5 mm (0.06 in.) thick.
- c. Plate electrodes shall be installed not less than 750 mm (30 in.) below the surface of the earth.
- d. Wherever possible, install plates below the permanent moisture or frost line.
- e. Horizontal and vertical steel surface connections can be used to connect the grounding electrode conductor to the plate electrodes.
- f. As with all electrode connections, any non-conductive coatings such as grease or paint shall be removed before making the connection.

### 3.2.6 Other listed Grounding Electrodes

There are several varieties of grounding electrodes that are listed to applicable product safety standards, specifically UL 467 *Standard for Grounding and Bonding Equipment*. The NEC recognizes listed electrodes in general as permitted for use individually or as part of the grounding electrode system. These listed electrodes are often unique in physical characteristics and are intended for installation in vertical orientations or horizontal

applications. The installation requirements for listed grounding electrodes that are not specifically addressed in the Code must be followed. The most common of these “other listed electrodes” are the chemical type grounding electrodes.

- a. Chemical-Type Grounding Electrodes consist of a copper tube filled with salts. Moisture entering the tube slowly dissolves the salts, which then leach into the surrounding earth through holes in the tube (*Fig. 3.2.6 Chemical Rod*). This lowers *the earth resistivity in the area around the electrode*, which reduces the electrode resistance.

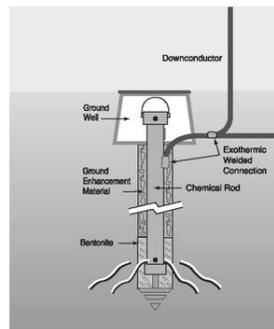


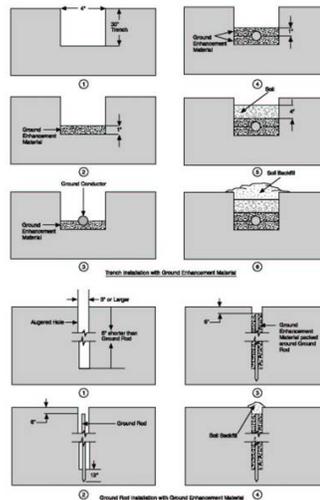
Fig 3.2.6 Illustration by ERICO Corporation International

- b. For maximum efficiency, back-filling *the electrode with ground enhancement material to the level marked on the electrode* is recommended. Chemical electrodes are available in both vertical and horizontal configurations; some of them are provided with a pigtail welded to the electrode. Standard pigtail sizes include 4/0 AWG and 2 AWG tinned solid copper conductors.
- c. These electrodes do require periodic maintenance. If local conditions are right, the breather cap will allow humid air to enter the tubing. As the temperature varies to a cooler temperature in the tube, condensation will form and keeps the chemical salts wetted to leach out into the surrounding soil. Ideally adding water should not be required, but in some cases, it may be necessary to charge the electrode with water from time to time. At the end of life further salts may be required to be replenished in the electrode to keep it active

### 3.2.7 Ground Enhancement Materials and Chemical Rods

Several materials are available to improve the ground resistance. They are below along with their approximate resistivity values;

- Concrete: 3000 to 9000 ohm-cm (30 -90 ohm-meter)
  - Bentonite (clay): 250 ohm-cm. (2.5 ohm-meter)
  - Ground enhancement material: 12 ohm-cm (0.12 ohm-meter)
- a. Unusual soil conditions demand additional considerations, e.g., ground enhancement material or other influences including use of additional electrodes which can reduce earth resistance. Unusual soil conditions as used in this section relates to inconsistent or variable soil resistivity due to multiple factors such as seasonal conditions, climate, or geographical locations
- b. Ground enhancement materials often are used in situations where reducing earth resistance and maintaining low resistance permanently is required. It reduces the resistance of the electrode to the earth and performs in all soil conditions (*Fig. 3.2.7(a) Trench Installation with Ground Enhancement Material*). It can be used around ground rods in an augured hole or installed in a trench (*Fig. 3.2.7(b) Ground Rod Installation with Ground Enhancement Material*)



Figs 3.2.7(a) and 3.2.7(b) Illustration by ERICO Corporation International

### 3.2.8 Lightning Protection Ground Terminals

Grounding electrodes installed for lightning protection systems are known as ground terminals. These electrodes are not allowed to be used as the grounding electrodes for the electrical system supplying a building or structure.

The NEC requires that the ground (earth) terminals of a lightning protection system be bonded to the electrical service or system grounding electrode or grounding electrode system. Ideally this should be completed outside the building or structure and at the earth level from electrode system to electrode system. Lightning protection for buildings or structures is beyond the scope of the NEC but is covered in NFPA 780 *Standard for the Installation of Lightning Protection Systems*.

## 4. BUILDING EXTERIOR GROUNDING

The NEC specifies minimum electrical installation requirements with the focus on the safe use of electricity as provided in the scope of the NEC. For many types of installations, optimal grounding performance goes beyond minimal safety and requires the use of additional grounding components and installing grounding systems that are designed above the minimum requirements in the Code. Figure 4.1 shows many typical grounding and bonding applications and methods associated with a building or structure including outside applications. Figure 4.1 is provided as an example of typical grounding and bonding connections that are either required by the NEC or installed by specification because of a design consideration.

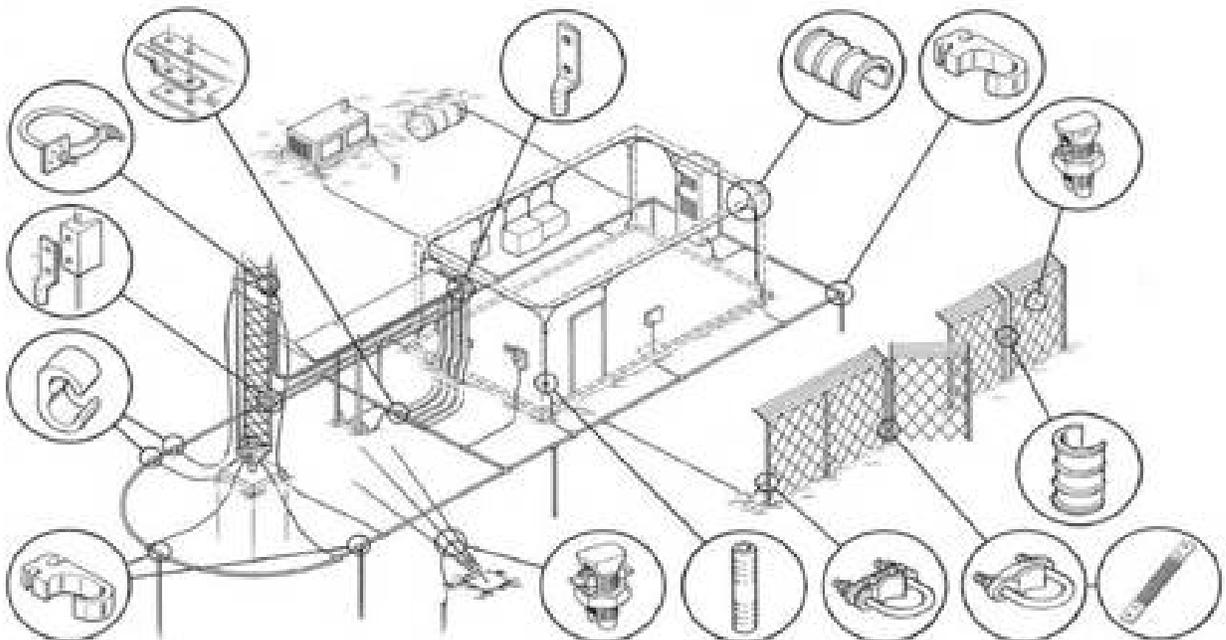


Figure 4.1 Typical building and outside grounding and bonding applications and methods - Illustration provided by NEMA

#### 4.1 Perimeter Grounding

- a. One of the most common methods to provide a grounding electrode for large buildings is a copper ground ring that is directly buried in the earth and installed around the perimeter of the building. One consideration for the size of the ground ring is the size of the electrical service. While the minimum size is 2 AWG copper, but many designs and specifications require 1/0 AWG copper or larger conductors. Again, these specifications are driven more by performance needs that go beyond meeting minimum safety requirements.
- b. The advantage of this method when grounding large buildings, and facilities with multiple buildings, is that perimeter grounding provides an equipotential ground for all the buildings and equipment within each building that are bonded to the perimeter ground. Also, the larger footprint of the ground rings and interconnected perimeter grounding will assist in lowering the resistance to earth of the grounding electrode system.
- c. The ground rings are often installed with ground rods at the corners and at intervals along the ring. The rod is often installed so the top is at the bottom of the trench for the ground ring and connected to the ring by exothermic welding or irreversible crimp connectors. Section 4.1.1 below provides further discussion of this installation.
- d. Note, that the NEC minimum is a grounding electrode or grounding electrode system at each building or structure. There is no NEC requirement that the grounding electrodes or grounding electrode systems for multiple buildings or structures be bonded together. The electrode systems are electrically connected where there are feeders or branch circuits installed with equipment grounding conductors that would connect to the grounding electrode system as each building.
- e. Another means of effective grounding for a large building with steel structural framing is to connect perimeter building steel columns to a ground ring, the concrete encased electrode in the support footing, or the rod electrodes installed around the perimeter of the building or structure (*Fig. 4.1(a) Bonding of Building Columns*). This is often a design specification. The interconnection of the columns and the electrodes installed in the earth is the steel frame of the building as permitted in the NEC.
- f. The installation of the specific grounding electrode, ring, concrete encased electrode or rods is discussed in sections 3.2.2, 3.2.3 and 3.2.5 of this standard.

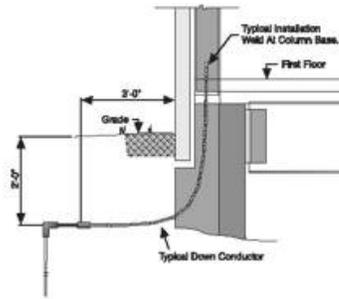


Fig 4.1(a) Illustration by ERICO Corporation International

#### 4.1.1 Triple Ground Rods

Ground rods are sometimes installed in a triangular configuration. These “triad ground rods” are typically located at the corners of buildings or structures. (Fig. 4.1.1 Triad Ground Rod Details).

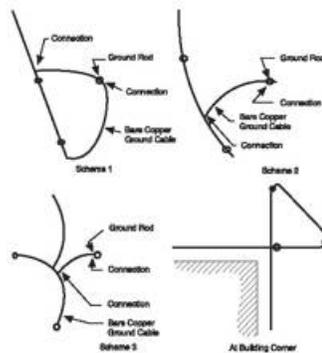


Fig 4.1.1 Illustration by ERICO Corporation International

- a. Spacing between the ground rods in a triad arrangement should be equal to or greater than the individual ground rod length.
- b. Three rods installed in a straight line may be more efficient and result in lower overall system impedance depending on soil conditions. Spacing between ground rods should be equal to or greater than the individual ground rod length.

#### 4.1.2 Waterstops for Foundation Penetrations

Each grounding electrode conductor of electrode bonding conductor that passes through a foundation wall must be provided with a “water stop”. This is especially important when the conductor passes through the foundation

wall at a point that is or may become below the water table (*Fig. 4.1.2 Waterstop*).

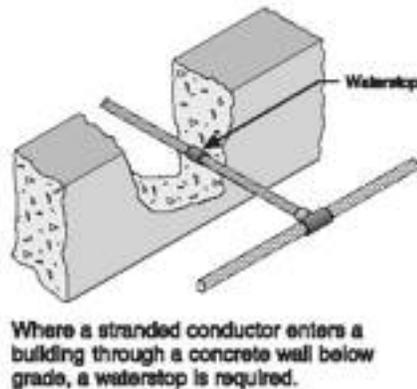


Fig 4.1.2 Illustration by ERICO Corporation International

### 4.1.3 Inspection Wells

For ready access to inspect or test ground rod, ring or other buried electrodes, inspection wells may be placed over a ground rod, or exposed connections. Several methods can be used.

- a. A plastic pipe, a clay pipe, or a commercial box can be placed over the rod (*Fig. 4.1.3(a) Plastic Pipe for Inspection Well, Fig. 4.1.3(b) Clay Pipe for Inspection Well, Fig. 4.1.3(c) Commercial Box for Inspection Well*). Plastic pipe can be custom-fabricated in the field to be installed over an existing connection.

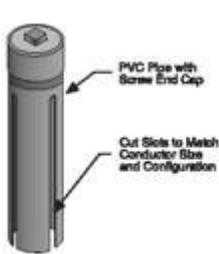


Fig 4.1.3(a)

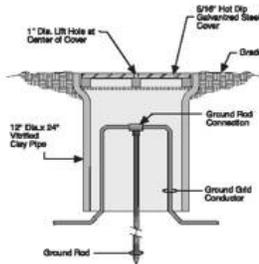


Fig 4.1.3(b)



Fig 4.1.3(c)

Illustrations 4.1.3(a), (b), and (c) by ERICO Corporation International

- b. If the conductors are planned to be removed from the rod to enable resistance measurements to be made, either a bolted connector or lug may be used (*Fig. 4.1.3(d) Disconnect with Lugs*).
- c. A good practice would be to have a connection plate or bus exothermically welded to the top of the ground rod. Then the grounding electrode conductor

or bonding conductor can be mechanically connected to this plate. The use of irreversible crimp spade lugs listed for grounding and bonding and direct burial along with stainless steel hardware will minimize corrosion of these connections and facilitate removal and reinstallation.

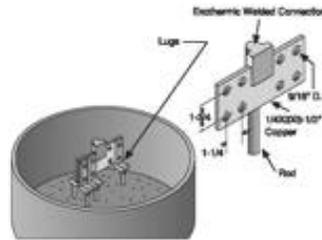


Fig 4.1.3(d) Illustration by ERICO Corporation International

#### 4.1.4 Fabricated Wire Mesh

Prefabricated wire mesh is not one of the electrodes recognized by the NEC but could be a supplement to any of the recognized electrodes as allowed under “other local metal underground systems or structures”. A possible use of prefabricated wire mesh is to mitigate step and touch potentials where indoor or outdoor electrical switchgear, especially medium or high voltage systems, is installed.

- a. When the required resistance is not achieved using the usual grounding layouts and electrodes available, prefabricated wire mesh can be added to lower the overall grounding impedance (*Fig. 4.1.4 Prefabricated Wire Mesh*). Typically, prefabricated wire mesh products are available in conductor sizes ranging from 6 to 12 AWG solid.
- b. Prefabricated ground mesh is a convenient, efficient and economical means of improving grounding systems at facilities with high voltage installations and wherever large area grounds are required.
- c. Equipotential mesh reduces step potentials at power plants and substations, and effectively minimizes ground plane fluctuations at communications antenna sites. Wire mesh is also an excellent ground screen, reflector and electronic shield for large facilities.
- d. Prefabricated wire mesh should be buried in the earth where needed to improve grounding or laid on top of the earth to be covered with crushed rock to assist with step and touch potentials. The final application and specifics for installation are generally part of the engineered design.

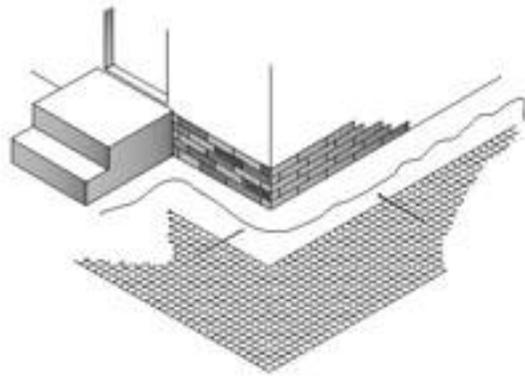


Fig 4.1.4 Illustration by ERICO Corporation International

## 4.2 Fence Grounding

The National Electrical Safety Code (NESC) recommends that where fences must be grounded, such grounding shall be designed to limit touch, step and transferred voltages in accordance with industry practice. The NEC in Part X of Article 250 has similar requirements with prescriptive text for substations with exposed electrical conductors.

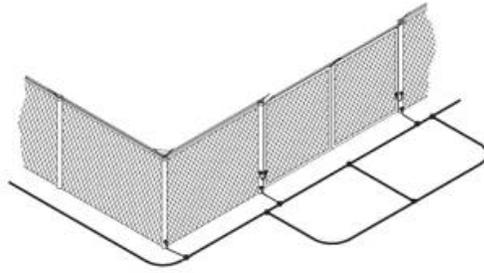
In accordance with the NESC, the grounding connection must be made either to the grounding system of the enclosed equipment or to a separate ground. There are six separate requirements for fences when the NESC requires grounding or bonding:

1. Where gates or other openings are installed, the fence shall be grounded at each side of the gate or similar opening.
2. If a conducting gate is used, the gate shall be bonded to the station grounding electrode system, grounding electrode, or fixed posts of the fence. (*Fig. 4.2(a) Grounding of Gates*).



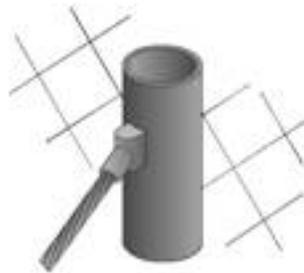
Fig 4.2(a) Illustration by ERICO Corporation International

3. Where conductive gates are installed, they shall be bonded by a buried bonding jumper across the opening. (*Fig. 4.2(b)*)



*Fig 4.2(b)* Illustration by ERICO Corporation International

4. If the fence contains sections of barbed wire, the barbed wire must also be bonded to the fence, grounding conductor or other bonding jumper.



*Fig 4.2(c)* Illustration by ERICO Corporation International



Photo 4.2 Photo provided by NEMA

5. If the fence posts consist of a conducting material, a grounding electrode or bonding conductor must be connected to the fence posts with a suitable connecting means (*Figure 4.2(c)* and *Photo 4.2* are two examples of suitable methods for bonding fence sections).

- If the fence posts consist of a non-conducting material, a bonding connection shall be made to the fence mesh strands and barbed wire strands at each grounding electrode conductor point (*Fig. 4.2(d) Split Bolt Connectors*).

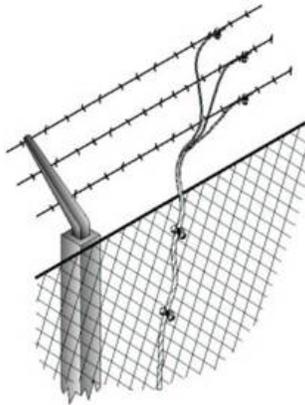


Fig 4.2(d) Illustration by ERICO Corporation International

Any fence around a substation on the property should be grounded and tied into the substation ground system. When the substation grounding system is some distance away, generally more than 6 feet, then the fence should be grounded to a separate grounding electrode system. Where the grounding grid is close to the fence, substation grounding grids will typically extend beyond the fence line for 3 feet or more.

If a facility fence meets the substation fence, the two fences should be electrically isolated from one another to prevent a fault in the substation from transferred throughout the facility using fences as conductors (*Fig. 4.2(e) Typical Perimeter Fence Isolation Section*). This is done in the safest way by installing a non-conductive portion of fence at least 1.83 m (6 f long at the junction, if possible).

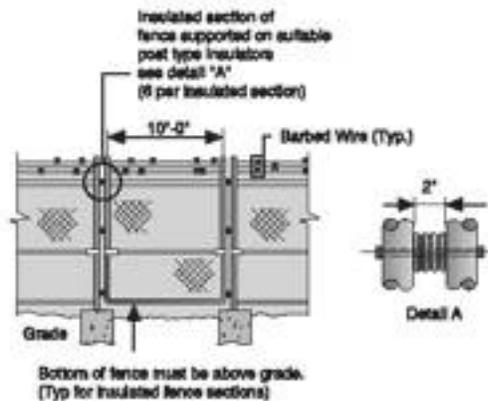


Fig 4.2(e) Illustration by ERICO Corporation International

The NEC add some other grounding connection points for consideration.

- Bonding jumpers shall be installed at each fence corner and at a maximum 50 m (160 feet) intervals.

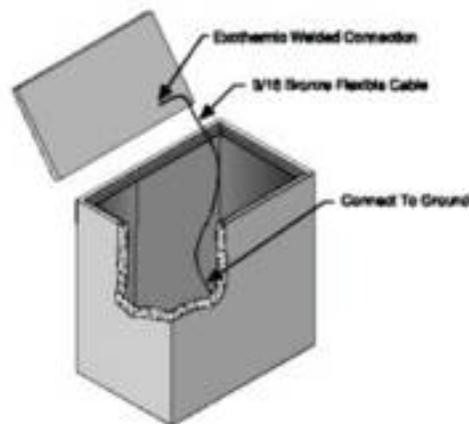
2. Where overhead conductors cross the fence line, bonding jumpers shall be installed on each side of the crossing.
3. The grounding grid or grounding electrode system shall extend to cover the swing of all gates.

### 4.3 Grounding of Other Exterior Items

The term “Grounded (Grounding) implies that a conductive object is connected to ground (earth) or to a conductive body that is an extension of the ground connection (grounding electrode). Equipment grounding conductors (EGCs) and grounding electrode conductors (GECs) are conductive bodies that extend the ground connection.

When auxiliary grounding electrodes are installed for equipment, one should always be sure that the equipment grounding conductor of the circuit supplying the equipment is connected to the equipment in addition to any grounding conductor from an auxiliary electrode.

- a. Handhole, maintenance hole and pull box covers, if conductive, should be bonded to the grounding system using a flexible equipment grounding or bonding conductor (*Fig. 4.3(a) Pull Box Cover Grounding*).
- b. The NEC requires that metal covers and other exposed conductive surfaces shall be bonded in accordance with the same bonding requirements for service raceways if the conductors in the handhole are service conductors, or in accordance with the requirements for bonding other enclosures if the conductors in the handhole are feeder or branch-circuit conductors.

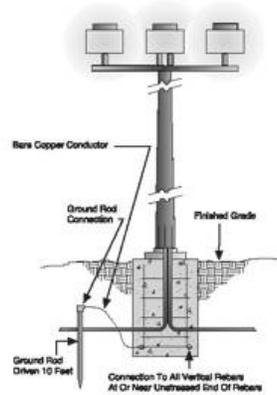


**Pull Box Cover Grounding**

*Fig 4.3(a)* Illustration by ERICO Corporation International

- c. A means must be provided in each metal box for the connection of an equipment-grounding conductor (EGC) or a supply side bonding jumper.

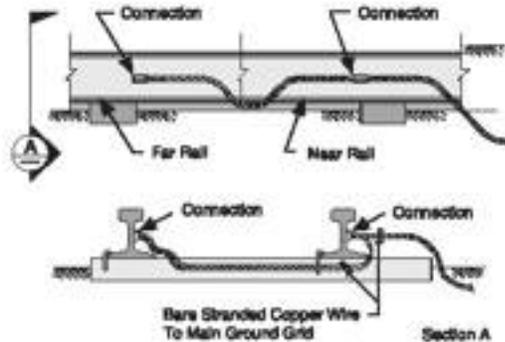
- d. Metal covers for pull boxes, junction boxes or conduit bodies shall also be grounded (connected to an equipment grounding conductor, or supply side bonding jumper) if they are exposed and likely to become energized.
- e. When hinged metal poles, less than 6.0 m (20 ft) in height, are installed, both parts of the hinged base shall be bonded to ensure the required low impedance connection.
- f. Lighting standards in parking lots and other areas where the public may come in contact with them should be grounded (connected to an auxiliary electrode and the equipment grounding conductor) (*Fig. 4.3(b) Lighting Pole Grounding*). The auxiliary electrode may be a ground rod installed in the excavation for the lighting standard foundation, or it may be the rebar cage assembly if that qualifies as a concrete encased electrode as discussed in section 3.2.3 of this standard. The auxiliary grounding electrode, equipment grounding conductor of the branch circuit, and the metal pole are required to be connected together. The earth cannot serve as an effective ground-fault current path (equipment grounding conductor).



*Fig 4.3(b)* Illustration by ERICO Corporation International

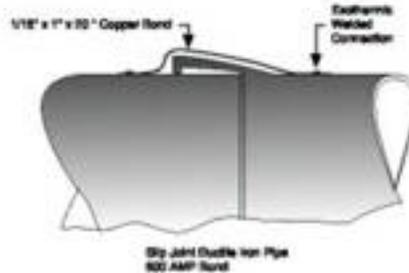
- g. Electric signs on poles and mounted on buildings are required to be grounded as specified in Article 600 of the NEC.
- h. Lighting standards and electric signs on poles, which are grounded by the use of a separate auxiliary ground rod or other grounding electrode, must also be connected to an equipment-grounding conductor of the supply branch circuit to ensure that the overcurrent protective device will operate in ground fault conditions. The in-ground support structural member for a sign may qualify as the grounding electrode if it meets the NEC requirements for that electrode (section 3.2.2 of this standard) or is connected to a concrete encased electrode (section 3.3.3 of this standard).
- i. Rails or sidings into hazardous locations such as grain storage facilities, ammunition supply depots, etc., should also be properly bonded and

grounded (*Fig. 4.3(c) Rail Siding Grounding*). Distant lightning strikes can travel through the rails for many miles.



*Fig 4.3(c) Illustration by ERICO Corporation International*

- j. In northern climates suitable bonding jumpers should be connected across slip joints on water pipes to enable thawing currents to be applied without burning the joint gasket (*Fig. 4.3(d) Water Pipe Bonding*).



*Fig 4.3(d) Illustration by ERICO Corporation International*

Other items located on the outside of the building that should be grounded in addition to lighting standards, pull box covers, may include hand rails and railings and similar conductive parts when the possibility they could become energized exists.

#### **4.4 Single Grounding Electrode System**

All of the components (electrodes) discussed in Section 3 comprise the grounding electrode system for a building or structure. However, not all of these electrodes or components will be present or installed at every building or structure. All components that are present or installed must be bonded together to form a single grounding system; multiple separate grounding electrode systems are not permitted within the same building or structure. If a building or structure is supplied by two or more services, the grounding electrodes for the two services shall be bonded

together. Two or more grounding electrodes that are bonded together are considered a single grounding system.

The bonding together of separate grounding electrodes or grounding electrode systems can be accomplished using any one or combination of any of the following.

- a. Wire type bonding jumpers
- b. Ground ring
- c. Structural metal interconnected to form the building frame
- d. Metallic water piping system in commercial, institutional or industrial facilities where it meets the NEC allowance for use more than 5 feet from the entrance to the building.

#### **4.5 Grounding Electrodes for Separate Buildings or Structures**

Buildings or structures supplied by a feeder(s) or branch circuit(s) are required to have a grounding electrode or grounding electrode system in accordance with Part III of Article 250. At least one of the grounding electrodes in Section 3.1 shall be used if present or another one of the identified electrode(s) shall be installed at a separate building or structure supplied by a feeder or branch-circuit.. Examples of building or structures that require grounding electrodes are:

- Detached garages
- Storage buildings
- Agricultural barns
- Billboard or other informational signs
- Traffic signal controllers
- Buildings served by feeder from a central utilities building or other service point for multiple buildings in a campus arrangement such as schools, medical centers, and industrial complexes.
- Any other similar type buildings structures.

These buildings and structures are typically supplied from another building or structure where the utility service power is located. There are some cases where the separate buildings or structures have their own service and in those cases the grounding electrode and bonding requirements for a service apply. Note, that the service may be at the utilization voltage (typical) but is often provided at medium or high voltage. In the cases of medium or high voltage the supplies to buildings from the service are still feeders.

Where a single branch circuit or a multi-wire circuit is the only electrical power system to the building or structure and the circuit includes an EGC, the grounding electrode is not required to be installed.

#### **4.6 Additional Equipment Installed Outside a Building**

Under the definition for a structure to no longer include equipment, there are situations where equipment installed outside a building should have consideration to install a grounding electrode or grounding electrode system.

The main purpose of this grounding is to provide a local earth reference the metal enclosures or other exposed metal non-current carrying parts. This earth reference is there to minimize any potential difference that could arise from the use of the equipment and to mitigate possible shock hazards for operators or service personnel that are standing on the earth and contacting the metal enclosure or other metal parts.

Examples of such equipment could include but would not be limited to:

- a. Generators installed with a weather enclosure outside, especially larger units with a base tank and enclosure designed for personnel to enter.
- b. Large all metal prefabricated cooling tower assemblies installed separate from the building in its own basin of water.
- c. Prefabricated electrical buildings designed for personnel to enter and containing switchgear, lighting, HVAC and other electrical equipment.



**Photo 4.6** – Prefabricated Electrical Building

## BUILDING INTERIOR BONDING AND GROUNDING

### 5.1 Bonding

#### 5.1.1 Service Equipment Bonding

Service equipment is any equipment necessary for the main control and means of deenergizing the supply of electricity to a building or structure. Specifically, the following service equipment that contain service conductors must be effectively bonded together:

- a. service raceways
- b. cable trays
- c. service cable armor/sheath
- d. grounded conductor
- e. cable bus framework
- f. service equipment enclosures
- g. Enclosures for other than service equipment installed ahead of the service equipment enclosure such as metering enclosures, current transformer enclosures, junction and pull boxes.

In addition to the service raceways, and enclosures any ferrous metal raceways which contain a grounding electrode conductor shall be bonded to the same requirements.

There are several permissible methods to bond the service equipment together:

1. Use the grounded service conductor. On the line side of the service equipment there is no separate equipment-grounding conductor or equipment bonding conductor by definition of these terms. The grounded conductor assumes this role as well as generally that of the supply side bonding jumper between enclosures on the line side of the service. Permissible means for any connection made to the grounded conductor include exothermic welded connections, listed pressure connectors, listed clamps, and other listed means.

As discussed in section 4.5 of this standard a feeder to another building or structure with both a neutral and an equipment grounding conductor, the equipment grounding conductor is used for bonding. This feeder

does not result in a service at the building served so these requirements do not apply.

2. Use threaded raceway connections. This includes threaded couplings, bosses, or hubs. It is important that these connections be installed wrenchtight to ensure a low-impedance connection and to maintain mechanical integrity when carrying a fault current.
3. Use threadless couplings or connectors. These fittings are available for rigid metal conduit (RMC), intermediate metal conduit (IMC), and EMT. Again, it is important that the connections be made up wrenchtight. With RMC or IMC, the use of standard locknuts, even if a double arrangement is used, (one on the inside and one on the outside) or a locknut and bushing is specifically prohibited, to achieve the bonding required.

For EMT, if used, outside or in a wet location, be sure all fittings are listed raintight.

4. Use other listed devices. This would include fittings such as bonding-type locknuts and grounding bushings with bonding jumpers, and grounding wedges. Remember that raceways require good mechanical assembly as well as electrical conductivity. If threaded conduit or nipples are being installed with bonding bushings, be sure that either both locknuts are installed, one inside and one outside, then install the bushing wrench tight for bonding. Alternatively, if the bonding bushing is to provide the mechanical joining inside the enclosure then thread the outside locknut as far as it will go and after inserting the conduit install the bushing until it is on wrench tight. Then tighten the outside locknut to complete the installation on the outside.

### 5.1.2 Intersystem Bonding

Installers of the service equipment generally must provide a means for interconnecting the grounding/bonding systems of communication circuits, radio and television equipment and CATV circuits. An intersystem bonding termination device for connecting grounding and bonding conductors of other systems must be installed external to service equipment and at the disconnecting means for separate buildings or structures. Interservice bonding terminations are not required on services or feeders to out buildings or structures not likely to have communication circuits or equipment installed. Examples include services to irrigation pivots or pumps, well pump equipment, accessory buildings used for storage and the like.

The intersystem bonding termination must have provisions (listed terminals) for terminating a minimum of three intersystem bonding or grounding

electrode conductors. The intersystem bonding termination equipment must be installed so as not to interfere with enclosure access covers or doors.

The following are acceptable intersystem bonding terminations:

- a. A set of terminals securely mounted to the meter enclosure and electrically connected to the meter enclosure. The terminals must be listed as grounding and bonding equipment.
- b. A bonding bar near the service equipment enclosure, meter enclosure, or raceway for service conductors. The bonding bar shall be connected with a minimum 6 AWG copper conductor to an equipment grounding conductor(s) in the service equipment enclosure, meter enclosure, or exposed nonflexible metallic raceway. See photo 5.1.2(a) for example of listed intersystem bonding bar.
- c. A grounding/bonding terminal bar near the grounding electrode conductor. The grounding/bonding terminal bar must be connected to the grounding electrode conductor with a minimum 6 AWG copper conductor.



Photo 5.1.2(a) Intersystem Bonding Termination

- d. An alternative more suited to commercial, institutional, and industrial installations is to provide the minimum  $\frac{1}{4}$  x 2-inch copper or aluminum grounding busbar by whatever length is needed. This busbar can serve many functions including being used to bond the several grounding electrodes present together as permitted by the NEC, connection as or to a common grounding electrode conductor to serve separately derived systems, or multiple services. As long as the minimum three terminals (lugs) are provided for the interservice bonding of the communication systems, it can also serve this purpose. Labeling of these terminals may be beneficial to ensure they are not inadvertently used for other

grounding or bonding purposes. See photo 5.1.2(b) for example of grounding bar.



Photo 5.1.2(b) Grounding Bar

For existing buildings or structures where the service equipment is already in place and operational, there are three options to facilitate the interconnection of these limited energy system grounding electrode and bonding conductors:

- a. Use the exposed metallic service raceways;
- b. Connect directly to the exposed grounding electrode conductor ;
- c. Bond a copper or other corrosion-resistant conductor of at least a 6 AWG copper, to the service raceway or equipment and leave exposed to access with three terminals for the connection of the communications grounding electrode or bonding conductors.

### 5.1.3 Bonding Other Enclosures

In addition to the service equipment enclosures, other noncurrent-carrying enclosures shall be bonded if they are to serve as equipment grounding conductors:

- a. metal raceways
- b. cable trays
- c. cable armor
- d. cable sheaths
- e. enclosures for wiring system such as wireways, gutters, pull and junction boxes
- f. equipment enclosures
- g. frames
- h. fittings

- i. any other metal noncurrent-carrying parts

This requirement applies regardless of whether a wire type equipment-grounding conductor is installed. Any conductor installed to act as an equipment grounding conductor shall meet all the applicable NEC requirements regardless if there is another equipment grounding conductor already present.

#### 5.1.4 Bonding for Circuits Over 250 Volts

- a. Metallic raceways and cables with metal sheaths containing electrical circuits operating at over 250 volts to ground are required to be bonded to ensure electrical continuity of metal raceways or cable armors or sheaths. The permissible methods are the same as those used for service equipment with the exception of the grounded conductor, which is generally not permitted for bonding in locations on the load side of the service disconnecting means.
- b. When enclosures other than listed metallic device boxes with oversized concentric or eccentric knockouts are used with circuits over 250-volts, one of the methods listed in section 5.1.1 of this standard must be utilized to achieve the required bonding. Listed outlet or device boxes are boxes with a volume maximum of 100 cubic inches. Any of the following methods may be used with listed metallic boxes that have concentric or eccentric knockouts:
  - a. Threadless couplings and connectors for metal sheath cables
  - b. Double locknut installations for RMC, and IMC
  - c. Fittings with shoulders, which seat firmly against the enclosure such as for EMT, Flexible metal conduit (FMC), liquid tight flexible metal conduit, and cable connectors,
  - d. Other listed fittings.

#### 5.1.5 Bonding of Piping Systems and Exposed Structural Steel

Any interior piping systems, such as potable water, or any piping which contains a liquid or a gas, and “may become energized,” shall be bonded. The permissible bonding locations are to the

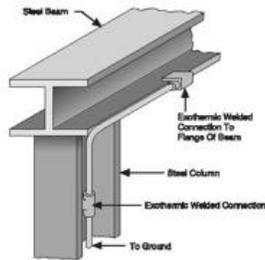
- a. Service equipment enclosure
- b. Grounding electrode conductor where of sufficient size
- c. Service grounded conductor

- d. One or more grounding electrodes that comprise the grounding electrode system.

### 5.1.6 Building Interior Bonding

Any exposed structural metal, which is interconnected to form a building frame and is not intentionally grounded, shall be bonded to the service and to any separately derived system serving the area where the structural metal is exposed. (*Fig. 5.1.6(a) Building Steel Bonding*) The connections can be made using irreversible compression connector, mechanical connectors, or exothermic welding processes.

- a. Structural metal that has its joints welded, connected by bolts, rivets, or other similar devices that form a metal to metal contact are suitable for interconnecting the columns and beams. If the junctions have not joined to be electrically continuous such as gaps or expansion joints, the interior columns and beams could require positive bonding of beams to columns to provide long term low-resistance connections for electrical continuity throughout the building (*Fig. 5.1.6(a) Building Steel Bonding*).



*Fig 5/1/6(a)* Illustration by ERICO Corporation International

- b. On building where there is exposed steel structure, welding or otherwise bonding a grounding/bonding terminal busbar to the column provides for future attachment points for other grounding electrode or bonding conductors (*Fig. 5.1.6(b) Grounding Bar Welded to Column*).

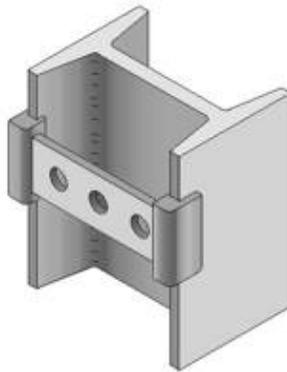


Fig 5.1.6(b) Illustration by ERICO Corporation International

- c. At building expansion joints, a flexible conductor bonds the columns or beams on each side of the joint (Fig. 5.1.6(c) *Expansion Joint Bonding Detail*). The connection of the flexible conductor can be by exothermic welding, irreversible crimp connectors, or irreversible crimp lugs to the bonding conductor with the lug connected to the column or beam with bolts.

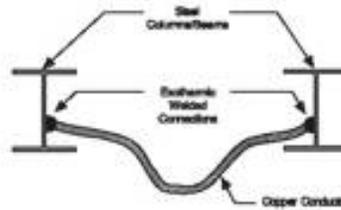


Fig 5.1.6(c) Illustration by ERICO Corporation International

- d. The bottom chord of a bar joist can be easily bonded (Fig. 5.1.6(d)(1) and (d)(2) *Bonding of Bar Joist*). The connection of the flexible conductor can be by exothermic welding, irreversible crimp connectors, or irreversible crimp lugs to the bonding conductor with the lug connected to the column or beam with bolts.

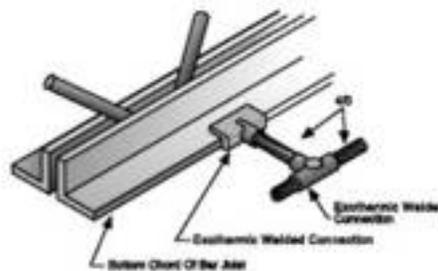


Fig 5.1.6(d)(1) Illustration by ERICO Corporation International

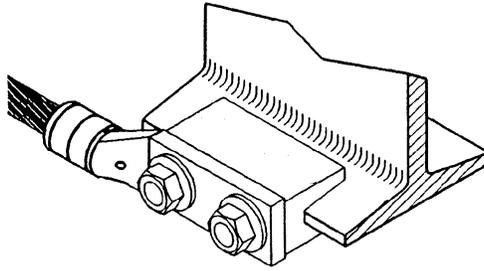


Fig 5.1.6(d)(2) Illustration provided by NEMA

- e. Bond steel columns within the building to the footer with the conductor extending to the main ground grid (Fig. 5.1.6(e) *Structural Footer Bonding*)

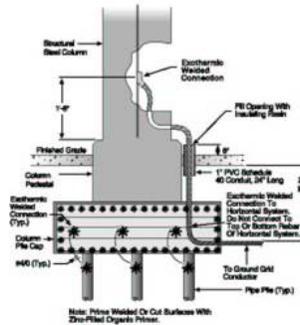


Fig 5.1.6(e) Illustration by ERICO Corporation International On multi-floor buildings, the common grounding electrode conductor shall extend to each floor (Fig. 5.1.6(f) *Grounding System Routing*). The common grounding electrode conductor can be the structural metal connected together to form the frame of the building, a wire type conductor with a minimum 3/0 copper or 250 kcmil aluminum or a metal water pipe system meeting the NEC requirements to extend beyond the first 5 feet of entry into the building. The water pipe system would have to meet the following provisions.

1. Shall be in a commercial, institutional, or industrial building with proper maintenance and supervision to ensure continuity of the metal water piping system
2. Water piping system visible without disturbing or having to remove building structure or finish except for floor and wall penetrations. Removal of drop ceiling tiles and the like is acceptable
3. Floor or wall penetrations are to be perpendicular to the floor or wall

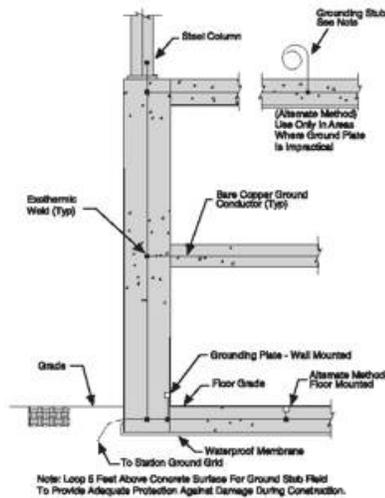


Fig 5.1.6(f) Illustration by ERICO Corporation International

- f. To provide accessible grounding connection points at each floor, a good practice would be install a minimum ¼ x 2-inch copper or aluminum grounding busbar. The busbar length should be sufficient to attach the number of wire lugs anticipated and considering future needs. This busbar would provide for terminations for grounding electrode conductors for separately derived systems or other items needing grounding or bonding. (see 4.3 and Fig. 5.1.6(g) *Grounding/Bonding Terminal Bar Placement*).

Any wire type common grounding electrode conductor must remain unspliced or if spliced, then it must be by exothermic welding or irreversible crimp. Any mechanical connection for continuity of the common grounding electrode conductor is not allowed. Grounding electrode conductors from separately derived systems and bonding conductors connecting to the busbar can use any listed wire connector including mechanical lugs bolted to the busbar. Connection directly to the wire type common grounding electrode conductor can be by exothermic welding, irreversible crimp connector, or mechanical means such split bolt connectors listed for grounding and bonding.

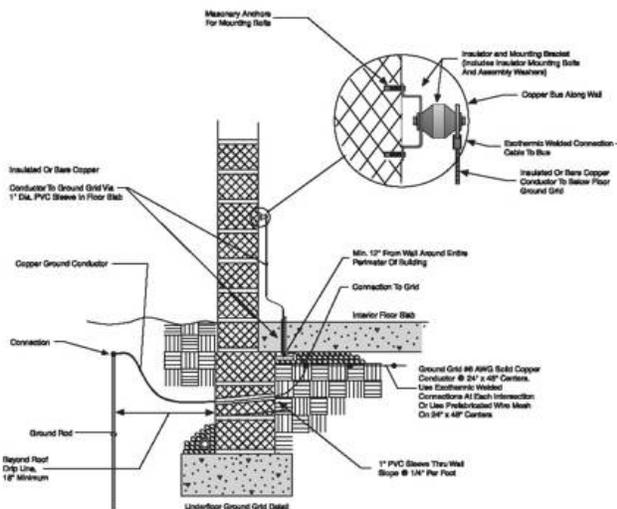


Fig. 5.1.6(g) Illustration by ERICO Corporation International

- g. Cast copper alloy grounding plates can be embedded in concrete structures for attachment of future equipment grounding, or grounding electrode conductors (Fig. 5.1.6(h)(1) *Flush Floor Grounding Plate* and Fig. 5.1.6(h)(2) *Equipment Grounding Plate at Concrete Column*). The plates are provided with drilled and tapped holes for lug attachment. Another alternative is using a compression floor grounding plate (Photo 5.1.6(h)(3))

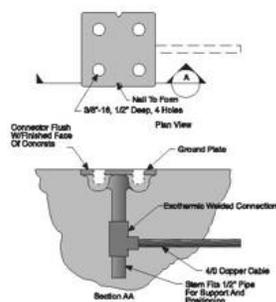


Fig 5.1.6(h)(1) Illustration by ERICO Corporation International

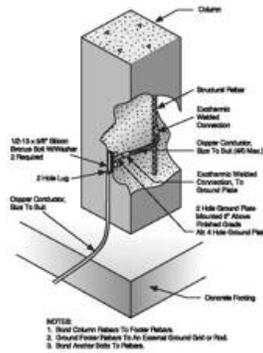


Fig 5.1.6(h)(2) Illustration by ERICO Corporation International



Photo 5.1.6 Photo provided by NEMA

- h. These plates are also available with a pigtail already attached from the factory (*Fig. 5.1.6(i) Pre-Fab Grounding Plates*).

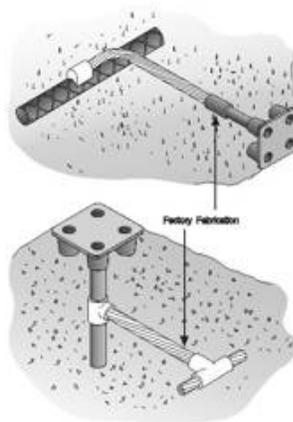


Fig 5.1.6(i) Illustration by ERICO Corporation International

- i. Where columns are fire-proofed, an alternative connection for the structural metal is to exothermically weld grounding plates to steel columns as shown in *Fig. 5.1.6(j) Grounding Plate on Stem Welded to*

*Column*) or attach a terminal connection means (lug) to the surface as allowed by the NEC.

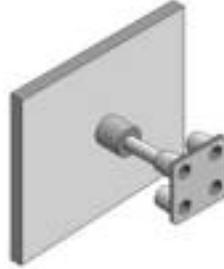


Fig 5.1.6(j) Illustration by ERICO Corporation International

- j. Light duty grounding points, such as those used for grounding conductive floors for static concerns, can be made in office columns (Fig. 5.1.6(k) *Light-Duty Grounding Provisions*).

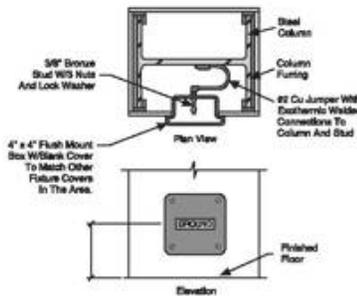


Fig 5.1.6(k) Illustration by ERICO Corporation International

- k. In areas where a conductive floor is used, such as a data processing equipment room, it is bonded to the ground system as shown in Fig. 5.1.6(l) *Detail – Conductive Floor Ground*.

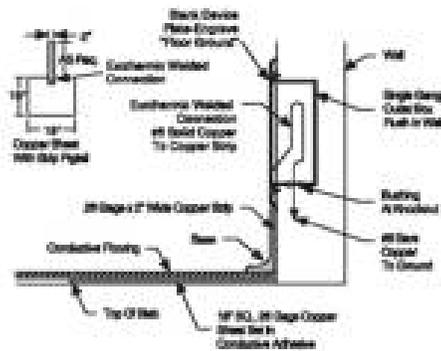


Fig 5.1.6(l) Illustration by ERICO Corporation International

- I. In areas where static electricity must be controlled, bond metal doors and frames (Fig. 5.1.6(m) *Bonding of Metal Doors and Frames*).

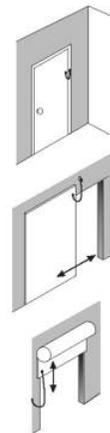


Fig 5.1.6(m) Illustration by ERICO Corporation International

- m. At large facilities having multiple buildings with underground utilities, one means of grounding cable racks in maintenance manholes is shown in Fig. 5.1.6(n)(1) *Cable Rack Grounding*. Alternative means includes crimp lugs on bonding conductors bolted to the rack.

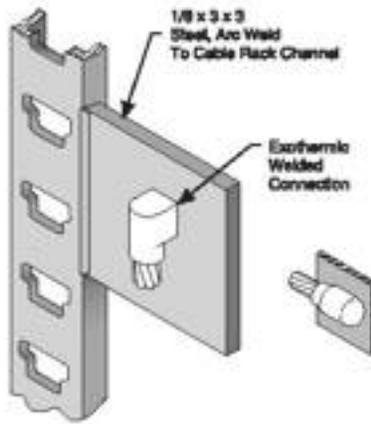


Fig 5.1.6(n)(1) Illustration by ERICO Corporation International

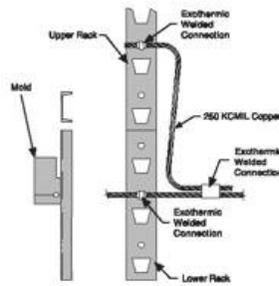


Fig 5.1.6(n)(2) Illustration by ERICO Corporation International

- n. Metal handrails that could become energized should be grounded. A good practice is to use cast copper alloy grounding plates embedded in the concrete at frequent intervals (*Fig. 5.1.6(o) Metal Handrail Grounding*).

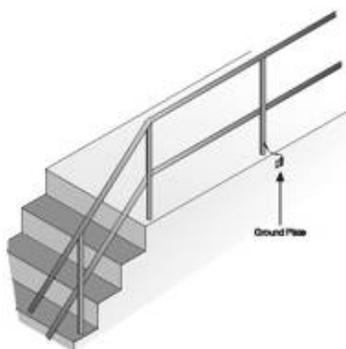


Fig 5.1.6(o) Illustration by ERICO Corporation International

## 5.2 Equipment Grounding and Bonding

### 5.2.1 Equipment Fastened in Place

There are six general conditions under which exposed noncurrent-carrying metal parts of fixed equipment likely to be energized must be connected to an equipment grounding conductor:

- a. Whenever such metal parts are located within a zone that extends within 2.44 m (8 ft) vertically and 1.52 m (5 ft) horizontally of ground or any grounded objects which may be contacted by persons. This establishes a “reach or touch zone” that ensures protection if persons standing on the ground or a grounded surface could come in contact with such objects.
- b. Exposed metal parts installed in wet or damp locations and are not isolated.
- c. Metal parts when in electrical contact with metal.
- d. In hazardous (classified) locations.
- e. Exposed noncurrent-carrying metal parts of fixed equipment must be connected to the equipment grounding conductor anytime such equipment is supplied by metal-clad or metal-sheathed cables, metal raceways, or any other wiring method which functions as an equipment grounding conductor.
- f. Where fixed equipment operates with any terminal at over 150 volts to ground, any exposed noncurrent-carrying parts of such equipment must be grounded.

### 5.2.2 Specific Equipment Fastened in Place

In general, any exposed noncurrent-carrying metal parts which are likely to become energized associated with any of the following equipment/locations shall be connected to an equipment grounding conductor:

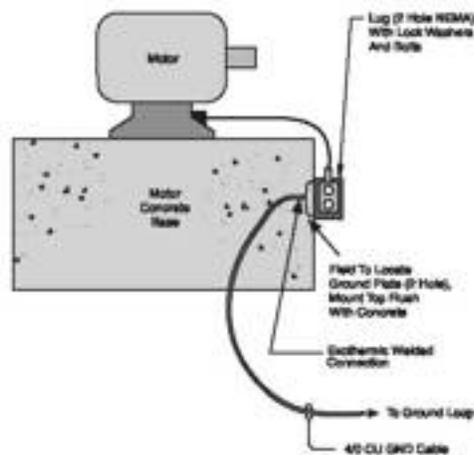
- a. Switchgear and switchboard frames and structure unless the system is 2 wire DC and the frame is effectively isolated from ground
- b. The generator and motor frames for electric pipe organs
- c. Motor frames
- d. Enclosures for motor controllers
- e. Elevators and cranes
- f. Commercial garages

- g. Theaters and motion picture studios except pendant lampholders supplied at less than 150 volts to ground
- h. Electric signs outline lighting and associated equipment
- i. Motion picture projection equipment,
- j. Equipment supplied by Class 1 circuits unless the voltage is less than 50 volts to ground. Class 1, Class 2 and Class 3 power-limited remote-control, signaling and fire alarm circuits where system grounding is required.
- k. Luminaires
- l. Motor-operated water pumps including the submersible type
- m. Metal well casings where submersible pump installed

### 5.2.2 Equipment Bonding

In general, any exposed non-current-carrying metal parts which are likely to become energized associated with electrically-powered equipment/locations should be bonded to the facility grounding system. This is generally accomplished with the equipment grounding conductor installed with the circuit supplying the equipment. This can also be supplemented by installing an auxiliary grounding electrode that is connected to the equipment grounding conductor of the circuit.

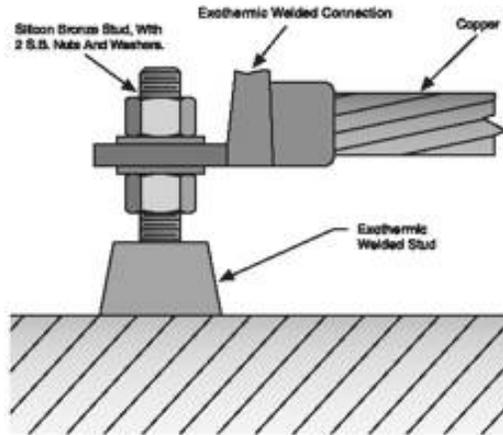
- a. Ground motorized equipment as shown in Fig. 5.2.2(a) Large Motor Grounding Detail.



*Fig 5.2.2(a) Illustration by ERICO Corporation International*

- b. Installing grounding plates as discussed in section 5.1.6 provides accessible grounding points throughout the building

- c. When removable grounds are required near a grounded column or beam, a stud can be welded to the steel and the bonding jumper can be attached using a lug (*Fig. 5.2.2(b) Removable Ground Detail*). Providing mechanical protection to the stud is recommended. Alternatively, the grounded column or beam can have a grounding bus installed that is bonded to the column or beam through the installation (welding), as described in section 5.1.6(b) of this standard, or by a bonding jumper installed from the steel to the bus.



*Fig 5.2.2(b) Illustration by ERICO Corporation International*

- d. In metallic cable tray installations, bolted joints do not always provide the required low resistance. Metallic cable tray systems that are not classified by a recognized testing laboratory have not been evaluated for suitability as an equipment grounding conductor. Classified metallic cable tray installed with all the parts and hardware supplied by the manufacturer and in accordance with the manufacturer's installation instructions can be used as an equipment grounding conductor. Where cable tray sections are discontinuous, bonding of the sections together is completed to provide the equipment grounding path. If the cable tray is not suitable as an equipment grounding conductor or if it is to be supplemented, a separate wire type equipment grounding conductor can be installed the length of the tray, bonded to each tray section and as needed to adjacent steel columns, or optionally, jumpers can be used across each joint. The cable can be connected to the steel cable tray by exothermic welding or by listed connection devices (*Fig. 5.2.2(c) Bonding Steel Cable Tray*) bolted to the tray. Aluminum cable tray connection will be made by bolting the conductor terminal to the aluminum tray. (*Fig. 5.2.2(d) Bonding Aluminum Cable Tray*).



*Fig 5.2.2(c)* Illustration by ERICO Corporation International



*Fig 5.2.2(d)* Illustration by ERICO Corporation International

- e. Metal parts of electric signs and outline lighting systems that may become energized are required to be grounded. Grounding and bonding requirements for signs and outline lighting systems are included in Article 600 of the NEC. For high-voltage secondary circuits of neon signs and outline lighting installations, bonding separate metal parts of the system is required and the bonding conductor is required to be installed external to the raceway containing the high voltage secondary conductor. If a non-metallic raceway is installed, the external bonding conductor must be spaced a minimum of 1 ½ inches from the conduit, if the circuit is operating at 100 Hz or less, and 1 ¾ inches when the circuit is operating at over 100 Hz.
- f. Metal parts of buildings or structures are not permitted as a bonding means for metal parts of signs or outline lighting installations.

### 5.2.3 Receptacle Grounding

- a. Generally, all grounding-type receptacles should be installed with a consistent orientation. For the vertical orientation it is up to the owner, engineer or the installer to determine if the equipment grounding conductor pin at the top or the bottom. If the horizontal orientation is used, again it is up to the owner, engineer or the installer to determine if the neutral conductor slot at the top or the bottom. Whatever the determination all receptacles should be installed in a consistent orientation unless there is a specific meaning to using the alternative orientation, such as signifying something such as a switched receptacle.

**Ginger, Can we remove the border on this figure? Thanks**

- b. The equipment-grounding conductors should be terminated on the receptacle in a manner such that the disconnection of the receptacle will not interrupt the continuity of the equipment-grounding conductor. Equipment grounding conductors run with branch circuit conductor should be spliced together and a “pigtail” or pigtails are run to the receptacle as well as to any metal device box.
- c. Non-grounding type receptacles shall be replaced with another non-grounding type receptacle or with a GFCI type receptacle marked “No Equipment Ground”.
- d. Non-grounding type receptacles are permitted to be replaced with grounding-type receptacles supplied though a GFCI protected circuit and are required to be marked “GFCI protected, No Equipment Ground”.
- e. Where an equipment grounding means exists in an enclosure or the receptacle is connected to an equipment grounding conductor located in the area as provided in the NEC a non-grounding type receptacle is permitted to be replaced by a grounding-type receptacle.
- f. All metal faceplates of receptacles and switches must be grounded by connection to the equipment grounding conductor.

### 5.2.4 Isolated Ground (IG) Receptacles

IG (isolated ground) receptacles are frequently used for electronic/data processing equipment applications. The main purpose is to provide isolation from parts of the equipment grounding circuits that could be generating or transmitting electrical “noise” that may affect performance of sensitive electronic equipment. The use of the IG receptacle does not negate the requirement to have an effective ground fault current path for any ground faults that may occur in equipment plugged into the IG receptacle.

- a. The NEC requires that IG receptacles be identified by an orange triangle located on the face of the receptacle.

- b. The receptacle grounding terminal must be grounded by an insulated equipment-grounding conductor run with the circuit conductors.
- c. A recommended practice is to identify the isolated equipment grounding conductor as green with one or more yellow stripes. For conductors 4 AWG or larger that are permitted to be identified at terminations, the identification of the isolated equipment grounding conductor can be accomplished by wrapping a portion of the conductor with green phase tape and then applying a single width wrap with yellow phase tape.
- d. If the isolated grounding receptacle is installed in the patient care space, but outside the patient care vicinity, the NEC requires the isolated equipment grounding conductor to be identified with the green and yellow stripe.
- e. The isolated equipment-grounding conductor is permitted, but not required, to be installed through one or more panelboards, boxes, wireways, or other enclosures provided it terminates within the same building to the equipment-grounding conductor terminal for the applicable derived system or service. The isolated equipment grounding conductor is required to terminate to the main equipment grounding conductor at some point. That point is anywhere from the receptacle up to the system supply. In no case is the isolated equipment grounding conductor permitted to go beyond the service, or separately derived system supplying the branch circuit. Where installed in a building supplied by a feeder or branch circuit, the isolated equipment ground is not permitted to be installed beyond the main disconnecting means for that building.
- f. The isolated equipment-grounding conductor must be in addition to the regular equipment-grounding conductor for the branch circuit.

### **5.3 Grounding Bus and Grounding Terminal Bars**

A grounding bus installed around the inside walls of a room, provides a convenient grounding connection means for multiple pieces of equipment or bonding/equipment grounding conductors. Grounding bus bars of this type are often installed in data processing, telecommunications or radio/TV facilities. As has been discussed in several sections of this standard, planning and installation of an external accessible grounding bus in the electrical rooms, service area and other locations can be very advantageous for initial construction and for future tenant improvements or remodel.

As a case example, consider a multi-occupancy commercial building with several different tenant/businesses. The initial shell contractor installs a grounding bus in the main electrical room and uses it to bond all the grounding electrodes together. The contractor also uses it to bond the main building metallic water system and the building structural metal. When the contractor installs the “house service” the

grounding electrode conductor for that service is routed from the service equipment to this grounding bar. If this building has many floors, a minimum 3/0 copper or 250 kcmil aluminum wire type common grounding electrode conductor can be installed in the electrical riser with a grounding bar installed in the electrical room on each floor. Installation of the common grounding electrode conductor must ensure it is not spliced or if so the splicing is done with exothermic welding or irreversible crimp. For this riser installation, laying type lugs would be an alternative to install without splicing. As each new tenant service is installed that tenant electrical contractor can install that tenant service grounding electrode conductor to the provided grounding busbar and will already have the metallic water and structural metal bonding completed. In the future as any service change is needed all that is disturbed to complete the remodel is the service and the grounding electrode conductor for that tenant while all other services remain undisturbed.

- a. Grounding bus is normally mounted using stand-off brackets with insulators. (Fig. 5.3 Wall-Mounted Ground Bus and 5.3(a) Floor-Mounted Ground Bus. The busbar can be attached to the wall, but this mounting away from the wall permits the installation of wire terminals using bolts and nuts making a much easier installation and for any future changes. The busbar is commercially available from several sources but the contractor can manufacturer their own as long as the busbar is a minimum 1/4 x 2 inches with length determined by the need.

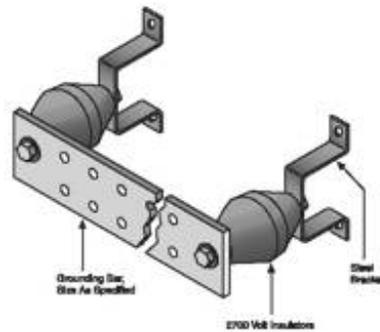
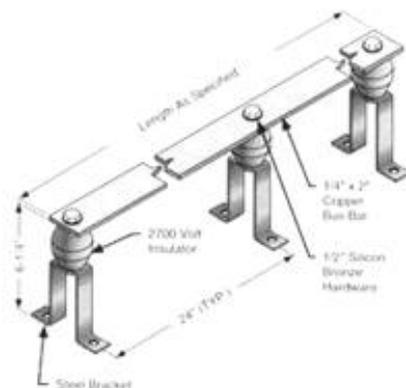
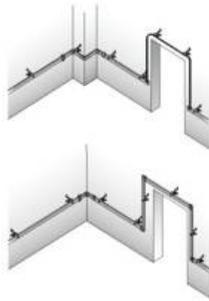


Fig 5.3 Illustration by ERICO Corporation International

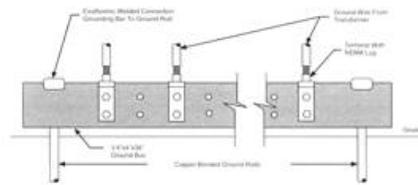


*Fig 5.3(a)* Illustration by ERICO Corporation International

- b. A grounding bus can be installed around doors using busbars or jumpers, as shown in Fig 5.3(b) Grounding Installed Around Doorways and Fig. 5.3(c) Grounding Bar Wall-Mounted and Photo 5.3(c) Grounding Bar Wall-Mounted.



*Fig 5.3(b)* Illustration by ERICO Corporation International



*Fig 5.3(c)* Illustration by ERICO Corporation International In installations with raised floors, such as information technology equipment (ITE) rooms, the bus may be mounted above the raised floor, or mounted between the structural floor and the raised floor.

## 6. BONDING AND GROUNDING OF ELECTRONIC SYSTEMS

### 6.1 Performance Bonding and Grounding

Over and above “Safety Bonding and Grounding” practices described in Section 5, electronic systems often require “Performance Bonding and Grounding”. What makes electronic systems different is the sensitivity of their circuit components to relatively small transient currents and voltages as well as low level signals at high frequencies. It is also inherent in the nature of electronic devices to operate as very fast speeds also known as “clock speed”; so, they are affected by equally “fast” electrical disturbances.

There is no conflict between the “Safety Bonding and Grounding” and the more specialized grounding and bonding practices described in this section, which are intended to enhance the reliability of electronic systems.

- a. Field-installed electrical grounding/bonding conductors routed between the metal frame or enclosures of separate units of electronic equipment should be connected to the EGC at both ends.
- b. Sometimes two bonding jumpers of different lengths are required in connecting equipment together or to a signal reference grid (discussed in the next section) so the bonding will perform at a wide range of frequencies.
- c. Bonding jumpers may need to use fine stranded conductors or even flat braided conductors. Again, this is not necessarily for current carrying capability but the ability to carry high frequencies which travel on the surface or “skin” of the conductor.
- d. Isolation transformers with electrostatic shielding between the windings may be required to supply panelboard(s) used to serve branch circuit power to the electronic equipment.
- e. Do not create an “isolated” ground (this is different than using an isolated grounding receptacle) for any equipment which is not connected to the facility electrical distribution grounding system. A common installation error which can create serious safety consequences is to disconnect the branch circuit equipment grounding conductor and to install a direct connection to a separate grounding electrode. This attempt to create a separate “clean” ground reference is dangerous, and typically does not improve electronic equipment performance.

## **6.2 Signal Reference Grounding Grid**

The focus for grounding and bonding in most installations is at the power system frequency, which in the US is 60 Hz and other parts of the world 50 Hz. For the power parts of electronic equipment this still holds true, but for the internal functioning and communication aspects of electronic equipment, especially anything with a micro-processor in it, electrical trades persons have to also understand what is going in the kilo-hertz, mega-hertz and even giga-hertz frequency ranges. Some considerations to mitigate problems are:

- a. Cables between electronic enclosures in equipment rooms should be routed close to the structural floor below the raised floor or platform.
- b. The best results are obtained when these cables are laid in close proximity to a specially installed signal reference grid under a raised floor normally used in an information technology (computer) room.
- c. If wireways are used to route cables, they should be metal, continuously grounded and bonded, and have a tight cover fastened by screws.
- d. Additional bonding connections should be made at several points along the entire length of the metal raceway, wireway or tray.

- e. If cables are routed in a cable tray or wireway, random lay is preferred rather than “neat” bundling. Random lay decreases the coupling of noise from one adjacent conductor into the other.
- f. Another way to achieve a random lay is the use of specifically designed cable supports attached to fasteners in the ceiling or under the raised floor. The sequence of “close” bundling inside the support (e.g., a J-hook) and “open” bundle in the 1.22 m (48 in.) to 1.52 m (60 in.) between supports virtually guarantees that no two cables run parallel in close proximity for more than a few feet.
- g. Telecommunications cables should be separated from power cables and conduits as far as possible; crossovers should be made at right angles or as close to right angles as possible.
- h. In addition to being well grounded/bonded to the equipment at the ends of the run, the metal raceway, wireway or tray should also be bonded to any nearby structural steel along the run.
- i. All metallic piping, ducting, conduit/raceway, wireway and cable tray located within 6 feet (horizontal or vertical) of any installed Signal Reference Grid (SRG) shall be bonded to the SRG. Fluids, including air, going through piping or ducts will create static charges that when discharged can cause damage to sensitive electronic equipment.
- j. One typical approach for making connections to the SRG is to embed a grounding plate at each intersection of the SRG conductors on a spacing of around .186 m (2 ft) x .186 m (2 ft) or 1.22 m (4 ft) x 1.22 m (4 ft) square.
- k. Another design for the signal reference grid is to use the pedestals and stringers for the raised floor, typically in a 2 ft. by 2 ft. grid and then have bonding of the pedestals with a minimum 6 AWG copper conductor on alternating rows of pedestals.
- l. In cases where connection points on 2-foot centers are not needed, a ground connection plate can be installed as shown in *Fig. 6.2(a) Ground Connection Plate in SRG*.

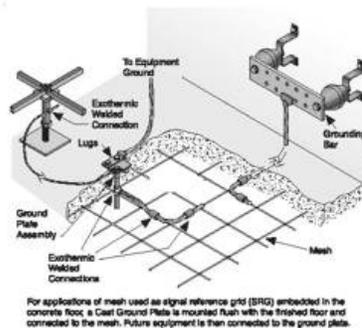


Fig 6.2(a) Illustration by ERICO Corporation International

- m. In addition, the neutral terminal, such as the XO terminal on a wye-secondary connected transformer of a separately derived system, or the neutral bus in the panelboard located in the room with the electronic equipment should be connected to the SRG and, as well as the grounding electrode system. The grounding electrode system connection point many times is a grounding busbar, as discussed in section 5.3 of this standard, installed in the room with the sensitive electronic equipment for this purpose. The signal reference ground is also connected to this busbar so there is a single point grounding reference for the room and area. This applies to power distribution units (PDUs) that supply information technology equipment in the vicinity of a SRG.
- n. The SRG should be bonded to any nearby accessible building steel so as to create many points of grounding/bonding. This is important to do along the SRG's perimeter and for any steel that penetrates the SRG's surface. In completing this bonding caution is advised to minimize creating ground loops with the SRG, bonding conductors and building steel.
- o. Listed electrical or electronic information technology equipment may provide additional or special grounding/bonding requirements. Follow the manufacturer's installation instructions including the need for two bonding conductors of different lengths.
- p. When a metallic mesh is embedded in the structural concrete subfloor, it can be used for an electronic signal reference grid.
- q. The concrete floor embedded SRG is often combined with the steel reinforcing bar system that is installed in the poured concrete. In some cases, where the reinforcing steel system is welded together, it can serve as the actual SRG, otherwise the reinforcing steel is simply periodically welded to the SRG at those points where the two structures have nearby or intersecting elements.

### **6.3 Ground Current Interference with Cathode Ray Tube (CRT) Based Equipment**

Low frequency magnetic fields, such as the power system's 60 Hz and its harmonics, will sometimes interfere with the electron beam being used to paint the image on CRT screens. This magnetic field interference is observed as a wavy or rippling display. This can be very evident if the CRT is backed up to the wall of the electrical room with the power switchgear or switchboard on the opposite side of that same wall. Below are a few measures that often solve the electromagnetic interference problems:

- a. Increasing the distance between the affected equipment and the source of the interfering magnetic field and reorientation of the equipment in regard to the lines of force of the magnetic field.
- b. Increasing the number and location of any grounding/bonding connections between grounded items. For instance, more bonding between cold water piping, building steel, and grounding electrode conductors.
- c. Metal shielding, mesh or solid, can be installed to cover the sides and gun of the CRT.
- d. Power cords supplying the CRT can be looped into a small coil and secured by cable ties.
- e. A common mode filter can be installed to minimize common mode noise in the grounding circuit.

### **6.4 Networked Workstation Equipment**

Workstations on a network need special attention concerning grounding so that common-mode noise will not be a significant problem. Here are some suggestions:

- a. Provide an externally applied supplementary equipment grounding conductor network that is connected to each item of the workstation and to the "green wire" of the branch circuit(s) serving the workstation.
- b. If there is any excess length in the ac power cords or data cables used to connect the work station, loop the excess into a small coil secured by cable ties or suitable tape.
- c. Observe bending radius limits of conductors.

Grounding of telecommunications systems, such as voice and data circuits, has become a well-defined area. If good workmanship practices are not followed, the systems will be more sensitive to noise disturbances. The proper installation of telecommunications circuits is beyond the scope of this standard, but some helpful references are provided in Annex A.

## 7. INSPECTIONS

### 7.1 Final Review and Inspection before Energizing

After the electrical installation is complete, a careful /review/inspection is needed to ensure safety and performance criteria have all been met. Regarding grounding, the following should be part of the inspection process:

- a. Verify all conductors and connections before energizing the circuits. Misidentification of conductors such as the grounded (neutral) and equipment grounding conductors often occurs. Mistakes of this kind are a serious code violation. Cross-connection between neutral and equipment grounding conductors can result in unwanted current flow in the equipment grounding system but will normally not cause an overcurrent protection device to operate.
- b. All metallic raceway, wireways, cable trays and metallic enclosures, must be well bonded along their length to ensure end to end continuity. Correct installation with threaded fittings made up wrench tight and, screw terminals proper torqued and lastly all wire terminal properly torqued with calibrated torqueing equipment.
- c. They should also be well grounded at multiple points along their length to building steel and SRGs within 6 feet to provide effective high frequency grounding.
- d. Any connection that is not a good electrical connection over the life of the installation is potential trouble. Such a poor connection can be a cause of noise or of a total interruption of the signal process or power continuity. Also, poor connections can fail when called upon to carry ground fault current. Either the connection is made properly, or it must be reworked to bring it within specifications.
- e. A common error is with grounding and bonding is terminating more than one, sometimes many, equipment grounding conductors in a terminal only listed for a single conductor of specified size range. Generally, one wire per terminal is a best practice unless there are clear markings or instructions that allow for more than one conductor. The lack of a marking means it is only suitable for one conductor. The markings or instructions will specify both the number and allowable size of conductors in a terminal when more than one is permitted.

### 7.2 Periodic Inspections and Maintenance

A good grounding system must receive periodic inspections and, if needed, maintenance, to retain its effectiveness. Adequate design, professional choice of materials, and proper installation techniques ensure that the grounding system resists deterioration or inadvertent destruction. Minimal repair is then required to

retain effectiveness throughout the life of the structure. Part of periodic maintenance of the grounding system may include:

- a. Periodic ground resistance testing of the grounding electrode system. Good practice is to do this on a sliding schedule, such as every 13 months, so seasonal variations can be documented. In addition to the test result, the recent weather and other conditions that can contribute to earth resistance should be noted.
- b. Verification of the adequacy of the equipment grounding system by low level current injection and measuring impedance or insulation resistance using a “megger” type tester. There are commercially available instruments that will plug into a receptacle or connect to the end of a branch circuit and measure the impedance. The results may identify loose or poor connections such as on wire nuts or other terminals.
- c. Measure the grounding continuity such as indicated in maintenance testing of patient care space receptacles and equipment in Health Care Facilities and found in NFPA 99. There is similar type testing in the Mine Safety and Health Administration (MSHA) for mine under MSHA oversight.

Figures without citations Ginger, we will not be using these figures in this edition of NECA 331. (remove)

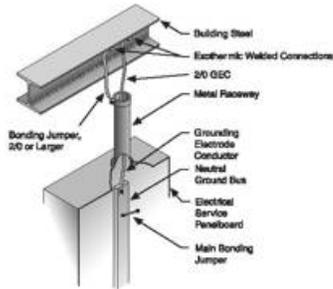


Fig 4.1.5(a)

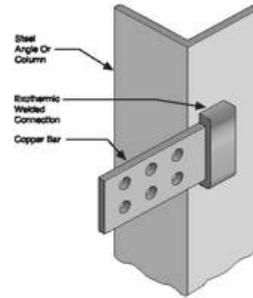


Fig 4.1.5(j)

## ANNEX A: REFERENCES

- ANSI/IEEE C2 -2017 National Electrical Safety Code (NESC)
- ANSI/IEEE Std. 81 Guide for Measuring Earth Resistivity, Ground Impedance and Earth Surface Potentials of a Grounding System
- ANSI/IEEE Std. 142 Recommended Practice for Grounding of Industrial and Commercial Power Systems
- ANSI/IEEE Std. 1100 Recommended Practice for Power and Grounding Sensitive Electronic Equipment
- Published by IEEE  
The Institute of Electrical and Electronics Engineers, Inc.  
445 Hoes Lane  
Piscataway, NJ 08855-1331  
(732) 981-0060 tel  
(732) 981-1721 fax  
[www.ieee.org](http://www.ieee.org)
- ANSI/NECA 1-2015 National Electrical Installation Standard (NEIS™);  
*Standard for Good Workmanship in Electrical Contracting*
- ANSI/NECA/BICSI 568-2006 National Electrical Installation Standard (NEIS™);  
*Standard for Installing Commercial Building Telecommunications Cabling*
- Published by NECA  
National Electrical Contractors Association  
3 Bethesda Metro Center, Suite 1100  
Bethesda, MD 20814  
(301) 215-4504 tel  
(301) 215-4500 fax  
[neis@necanet.org](mailto:neis@necanet.org)
- ANSI/NFPA 70-2017 National Electrical Code® (NEC®)
- Published by NFPA  
National Fire Protection Association  
One Batterymarch Park,  
Quincy, MA 02269-9101  
(800) 344-3555 tel  
(617) 770-3305 fax  
[www.nfpa.org](http://www.nfpa.org)

ANSI/TIA/EIA Standard 568	Commercial Building Telecommunications Cabling Standard
ANSI/TIA/EIA Standard 569	Commercial Building Standard for Telecommunications Pathways and Spaces
ANSI/TIA/EIA Standard 570	Residential Telecommunications Cabling Standard
ANSI/T/E-J-STD-607	Commercial Building Grounding (Earthing) and Bonding Requirements for Telecommunications

Published by TIA  
Telecommunications Industry Association  
2500 Wilson Blvd., Suite 300  
Arlington, VA 22201-3834  
(703) 907-7700 tel  
(703) 907-7727 fax  
[www.tiaonline.org](http://www.tiaonline.org)

The current editions of the above standards should be consulted.

Current National Electrical Installation Standards Published by NECA:

National Electrical Contractors Association  
3 Bethesda Metro Center Ste 1100  
Bethesda, MD 20814  
(301) 657-3110 tel.  
(301) 215-4500 fax  
[www.neca-neis.org](http://www.neca-neis.org)

NECA 1-2015	Standard Practices for Good Workmanship in Electrical Contracting (ANSI)
NECA 90-2004	Recommended Practice for Commissioning Building Electrical Systems (ANSI)
NECA 100-2006	Symbols for Electrical Construction Drawings (ANSI)
NECA 101-2006	Standard for Installing Steel Conduits (Rigid, IMC, EMT)
NECA 102-2004	Standard for Installing Aluminum Rigid Metal Conduit (ANSI)
NECA/AA 104-2006	Recommended Practice for Installing Aluminum Building Wire and Cable (ANSI)

NECA/NEMA 105-2007	Recommended Practice for Installing Metal Cable Tray Systems (ANSI)
NECA 111-2003	Standard for Installing Nonmetallic Raceways (RNC, ENT, LFNC) (ANSI)
NECA 120-2006	Standard for Installing Armored Clad (AC) and Metal-Clad Cable (MC) (ANSI)
NECA 121-2007	Standard for Installing Nonmetallic-Sheathed Cable (Type-NM-B) and Underground Feeder and Branch-Circuit Cable (Type UF) (ANSI)
NECA 200-2002	Recommended Practice for Installing and Maintaining Temporary Power at Construction Sites (ANSI)
NECA 202-2006	Recommended Practice for Installing and Maintaining Industrial Heat Tracing Systems (ANSI)
NECA 230-2003	Standard for Selecting, Installing, and Maintaining Electric Motors and Motor Controllers (ANSI)
NECA/FOA 301-20xx	Standard for Installing and Testing Fiber Optic Cables
NECA 303-2005	Installing Closed-Circuit Television (CCTV) Systems (ANSI)
NECA 305-2001	Standard for Fire Alarm System Job Practices (ANSI)
NECA 331-2004	Standard for Building and Service Grounding and Bonding (ANSI)
NECA 400-2007	Standard for Installing and Maintaining Switchboards (ANSI)
NECA 402-2007	Standard for Installing and Maintaining Motor Control Centers (ANSI)
NECA/EGSA 404-2007	Standard for Installing Generator Sets (ANSI)
NECA 405-2001	Recommended Practice for Installing and Commissioning Interconnected Generation Systems (ANSI)
NECA 406-2003	Standard for Installing Residential Generator Sets (ANSI)
NECA 407-2009	Recommended Practice for Installing and Maintaining Panelboards (ANSI)
NECA 408-2009	Standard for Installing and Maintaining Busways (ANSI)
NECA 409-2009	Standard for Installing and Maintaining Dry-Type Transformers (ANSI)
NECA 410-2005	Standard for Installing and Maintaining Liquid-Filled Transformers (ANSI)

NECA 411-2006	Standard for Installing and Maintaining Uninterruptable Power Supplies (ANSI)
NECA 420-2007	Standard for Fuse Applications (ANSI)
NECA 430-2006	Standard for Installing Medium Voltage Metal-Clad Switchgear (ANSI)
NECA/IESNA 500-2006	Standard for Installing Indoor Commercial Lighting Systems (ANSI)
NECA/IESNA 501-2006	Standard for Installing Exterior Lighting Systems (ANSI)
NECA/IESNA 502-2006	Standard for Installing Industrial Lighting Systems (ANSI)
NECA 503-2005	Standard for Installing Fiber Optic Lighting Systems (ANSI)
NECA/BICSI 568-2006	Standard for Installing Commercial Building Telecommunications Cabling (ANSI)
NECA 600-2003	Recommended Practice for Installing and Maintaining Medium-Voltage Cable (ANSI)
NECA/NEMA 603-2005	Recommended Practice for Installing Underground Nonmetallic Utility Duct (ANSI)
NECA 605-2005	Recommended Practice for Installing Underground Nonmetallic Utility Duct (ANSI)