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ET2 UNIT 4 (Volume 2): ELECTRONIC EQUIPMENT & CABLING

EPQ 5.D.03 Fault Protection, Lightning Protection, and Signal Reference Ground Subsystems

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ET2 UNIT 4 (VOLUME 2): ELECTRONIC EQUIPMENT & CABLING

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QUESTIONS ABOUT THIS TEXT SHOULD BE ADDRESSED TO THE SUBJECT MATTER SPECIALIST FOR THE ELECTRONICS TECHNICIAN RATING

TABLE OF CONTENTS

Acknowledgments and References

Acknowledgments

Material is included in this pamphlet through courtesy of the designated source. The Coast Guard appreciates permission of the source to use this material, which contributes greatly to the effectiveness of this course. No copies or reproductions of the material are authorized without permission of the appropriate source.

The Coast Guard wishes to thank the following individuals for their expertise and support in the development of this document:

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List of References

This pamphlet contains original material developed at the U. S. Coast Guard Training Center, Petaluma, California, and excerpts from the following technical publications:

- *Electronics Manual*, COMDTINST M10550.25 (series)
- *CMplus Job Aids 5.1*
- MLC Standard Operating Procedures
- System Integrated Logistics Support (SILS) Command Policy Manual, COMDTINST M4105.8 (series)

Notice to Students

Purpose

This pamphlet serves to provide you with knowledge of how to address certain administration and documentation tasks required of an ET2.

Important Note

This text has been compiled for TRAINING ONLY. It should NOT be used in place of official directives or publications. The test information is current according to the references listed. You should, however, remember that it is YOUR responsibility to keep up with the latest professional information available for your rating. Current information is available from the *Enlisted Performance Qualifications Manual*, COMDTINST M1414.8 (series).

Course Content

This course content is based on the requirements stated in the *Enlisted Performance Qualifications Manual*, COMDTINST M1414.8 (series).

Pamphlet Content

This pamphlet contains five lessons:

Lesson 1: Overview of the Facility Ground System

Lesson 2: Earth Electrode Subsystems and Shipboard Ground Planes

Lesson 3: Inspecting Fault Protection Subsystem

Lesson 4: Inspecting Lightning Protection Subsystem

Lesson 5: Inspecting Signal Reference Ground Subsystem

Performance Qualifications

This pamphlet covers the following enlisted performance qualification (EPQ) for ET2 from the *Enlisted Performance Qualifications Manual*, COMDTINST M1414.8 (series):

5.D.03 MAINTAIN fault protection, lightning protection, and signal reference ground subsystems per the Electronics Manual, COMDTINST M10550.25 (series); Standard Practice for Shipboard Bonding, Grounding, and other Techniques for Electro-Magnetic Compatibility and Safety, MIL-STD-1310G; Grounding, Bonding and Shielding for Common Long haul/Tactical Communications Systems Including Ground Based Communications-Electronics Facilities and Equipment, MIL-STD-188-124B; and Grounding, Bonding, & Shielding for Electronic Equipment & Facilities, MIL-HDBK-419A.

Continued on next page

Notice to Students (continued)

Learning Objectives

Read the learning objectives before you begin reading the text. The objectives will guide you through the text and help you answer the questions in the self-quiz at the end of each lesson.

Quizzes

Each lesson has a self-quiz and pamphlets may have a pamphlet review quiz. You will find answers to each quiz on the pages following the quiz. Included are reference pages for the answers.

These self-quizzes are meant to check your comprehension of the material you covered. If you have problems understanding a section, go through it again or ask someone for help. The pamphlet review quiz questions are samples of the type of questions you will find on the end-of-course-test.

SWE Study Suggestion

Servicewide exam questions for your rate and pay grade are based on the Professional and Military Requirements sections of the *Enlisted Performance Qualifications Manual*, COMDTINST M1414.8 (series).

If you use the references from this text and consult the *Enlisted Performance Qualifications Manual*, you should have good information for review when you prepare for your servicewide exam (SWE).

Glossary of Terms

A glossary of terms is included at the end of this pamphlet as Appendix C.

Lesson 1

THE FACILITY GROUND SYSTEM

Overview

Introduction

This lesson introduces you to the facility ground system. The facility ground system forms a direct path of known low impedance between earth and various power, telecommunications and other types of electronic equipment in order to effectively extend the ground reference throughout the electronics facility. When viewing the proper grounding of electronic equipment, it is important to look at the facility ground system from a total system viewpoint, which includes the various subsystems making up the total facility ground system.

Lesson Objectives

Upon completing this lesson, you will:

- **IDENTIFY** the three primary functions of the facility ground system.
- **LIST** the four subsystems comprising the facility ground system.

References

The following references were used for this lesson:

- "Grounding, Bonding, and Shielding," MIL-STD-188-124B
- "Standard Practice for Shipboard Bonding, Grounding, and other Techniques for Electro-Magnetic Compatibility and Safety," MIL-STD-1310
- *Grounding, Bonding, and Shielding for Electronic Equipment and Facilities* Vol. 1 and 2, Military Handbook MIL-HDBK-419A
- *National Electrical Code*

Functions and Components

Grounding Electronic Equipment

Electronic and telecommunications equipment are effectively grounded through capacitive coupling, accidental contact, or intentional connection.

Primary Functions

The facility ground system serves three primary functions:

1. Personnel safety through low-impedance grounding and bonding between equipment, metallic objects, piping, and other conductive objects, so that currents due to faults or lightning do not result in voltages high enough to cause shock hazards.
2. Equipment and facility protection through low-impedance grounding and bonding between electrical services, protective devices, equipment, and other conductive objects so that faults or lightning do not result in hazardous voltages within the facility.
3. Electrical noise reduction on communication circuits by ensuring that (1) minimum voltage potentials exist between electronics equipment, (2) impedance between signal ground points within the facility to earth are minimal, and (3) interference from noise sources is minimal.

Facility Ground System Components

The ***facility ground system*** is comprised of:

- An earth electrode subsystem or shipboard ground plane,
- A fault protection subsystem,
- A lightning protection subsystem, and
- A signal reference subsystem.

Each of these components will be discussed in greater detail in the following lessons.

Facility Ground System Site Surveys

Overview

Facility ground system inspections and site surveys are conducted:

- Initially, whenever a new facility is constructed
- After major changes to the facility, structure or equipment are made
- At least annually

Initial Inspections for New Facilities

Initial inspections and site surveys for new construction establish a baseline or starting point by which the condition of the facility ground system is measured for subsequent inspections. Subsequent inspections should be performed at least annually.

Inspections for Older Facilities

In an older facility, if there is no documentation showing prior inspections, an inspection should be performed to determine the general condition of facility ground system. Subsequent inspections should be performed at least annually.

Thorough inspections should be performed following any major changes or additions to the facility, structure, or equipment.

Site Survey Standards

Data gathered during the site survey consists of data collected IAW:

- MIL-STD-188-124B
- National Electrical Code (NEC)

Site Survey Data

For a complete list of site survey requirements, refer to MIL-HDBK-419A, Vol. II Section 1.4.9. The list below provides a brief example of the information gathered:

- Identification of the neutral conductor, to ensure that it is colored white, or natural gray, or is otherwise marked or tagged
- Identification of the grounding conductor, to ensure that it is colored green, or green with stripes, or is otherwise marked or tagged
- Verification that grounding (safety) conductors running through metal conduit are bonded to the conduit at both ends

Note: Information such as that listed above may have already been gathered and be a part of the facility's existing records. If so, the newly gathered information may be compared to the existing information to determine the present state of the facility ground system.

Practice Exercise

Exercise Instructions

This exercise is meant to check your comprehension of the material covered in this lesson. Read each question and write the answers in the spaces provided. Check your answers in the Feedback section following the exercise. If you are having difficulty understanding a section, go through it again or ask someone for help.

1. List the components that make up the facility ground system.

   ____

   ____

   ____

   ____

2. Facility ground system inspections and site surveys are conducted after major changes to the facility, structure or equipment are made. (Circle correct answer)

   True   False

3. List the primary functions of the facility ground system.

   ____

   ____

   ____

Practice Exercise Feedback

Exercise Answers and References

Question	Answer	Reference Page
1	The four components that make up the facility ground system are: 1. Earth electrode subsystem or shipboard ground plane 2. Fault protection subsystem 3. Lightning protection subsystem 4. Signal reference ground subsystem	1-2
2	True	1-3
3	The three primary functions of the facility ground system are: 1. Personnel safety through low impedance grounding and bonding between equipment. 2. Equipment and facility protection through low impedance grounding and bonding between electrical services, protective devices, equipment and other conductive objects. 3. Electrical noise reduction on communication circuits.	1-2
End		

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Lesson 2

EARTH ELECTRODE SUBSYSTEMS AND SHIPBOARD GROUND PLANES

Overview

Introduction

This lesson introduces you to the earth electrode subsystem and shipboard ground plane. The earth electrode subsystem and shipboard ground plane play a very important role in the overall performance of a C-E facility by providing a low-impedance connection to earth. While both the earth electrode subsystem and shipboard ground plane form the basis for all grounding of the remaining facility ground subsystems (fault protection, lightning protection and signal reference ground protection), they do so in very different ways.

Lesson Objectives

Upon completing this lesson, you will:

- **LIST** the components of the earth electrode subsystem
- **IDENTIFY** the bond categories and methods

References

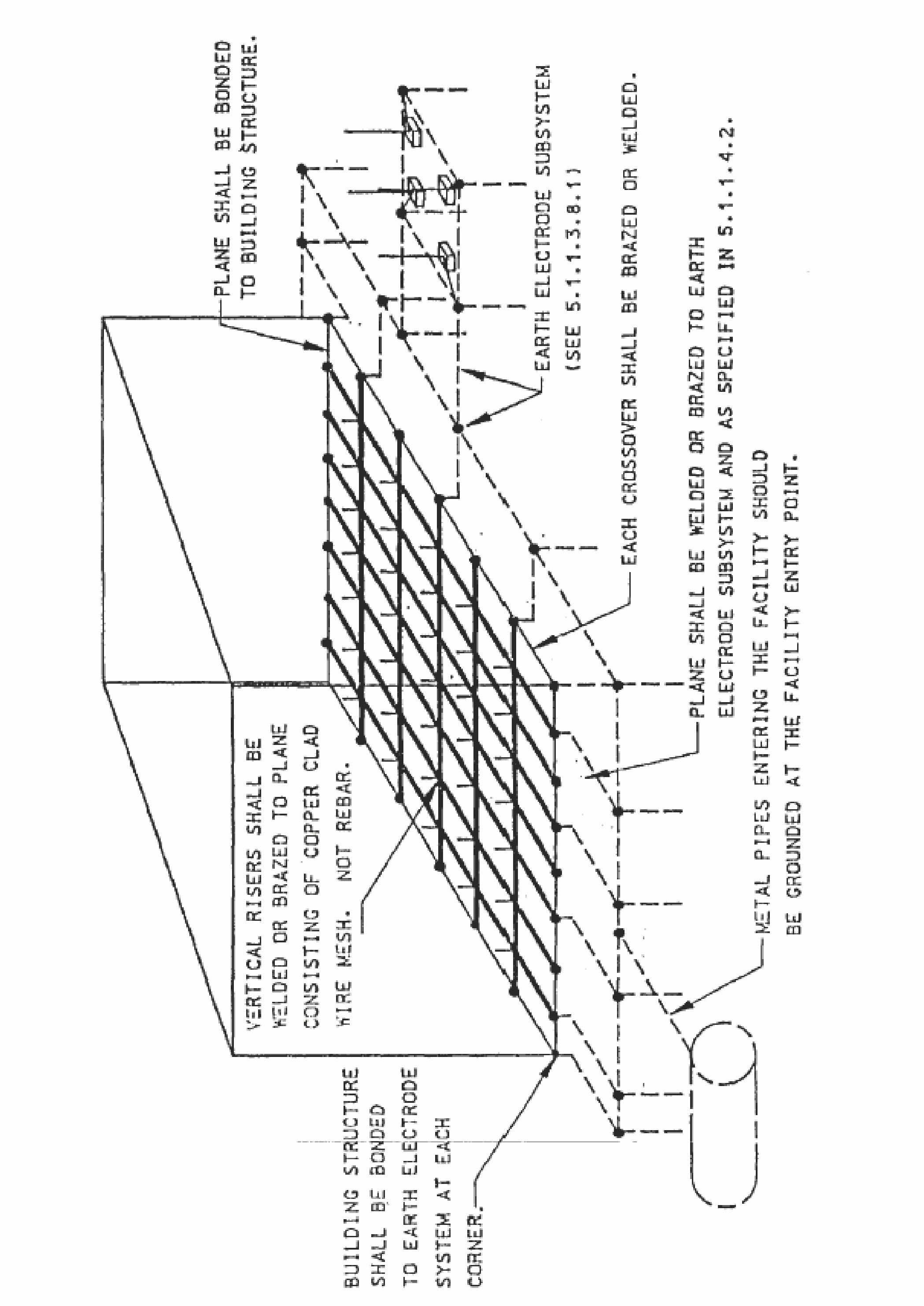
The following references were used for this lesson:

- Grounding, Bonding, and Shielding, MIL-STD-188-124B
- Standard Practice for Shipboard Bonding, Grounding, and other Techniques for Electro-Magnetic Compatibility and Safety, MIL-STD-1310
- Grounding, Bonding, and Shielding for Electronic Equipment and Facilities Vol. 1 and 2, Military Handbook MIL-HDBK-419A
- National Electrical Code

Earth Electrode Subsystem

Introduction

The earth electrode subsystem and its relationship to the other subsystems of the facility ground system can be seen in the graphic depiction below.



Earth Electrode Subsystem (Continued)

Earth Electrode Subsystem Components

The earth electrode subsystem consists of a network of earth electrode rods, plates, mats, or grids and their interconnecting conductors. Ground reference is established by electrodes in the earth at the site or installation. The earth electrode subsystem includes the following components:

- A system of buried, driven rods interconnected with bare wire that normally form a ring around the building, or
- Metallic pipe systems (e.g.,, water, gas, fuel, etc.) that have no insulation joints (these must not be used as the sole earth electrode subsystem), or
- A ground plane of horizontal buried wires

Note: Extensions from buried electrodes entering buildings often serve as the principal ground point for connections to equipment ground subsystems.

Ground Rods

The most common type of ground rods are those made of copper-clad steel. Copper-clad steel ground rods are used due to the steel core providing strength to withstand the driving force used to drive them into the earth and the copper provides compatibility with copper or copper-clad interconnecting cables and corrosion protection. For most applications, ground rods of 1.90 cm (3/4 inch) diameter, and length of 3.0 meters (10 feet), are used where bedrock is beyond a depth of three meters (10 feet).

Buried Horizontal Conductors

Buried horizontal conductors include:

- Strips of metal, solid wires or stranded cables where bedrock is near the surface of the earth. With low impedance being desirable for minimizing lightning surge voltages and length of the buried horizontal conductors affecting the impedance of the conductors, several wires, strips, or cables arranged in a star pattern, with the facility at the center, is preferable to one long length of conductor.
- Grid systems, consisting of copper cables buried in the ground and forming a network of squares, to provide equipotential areas throughout the facility area. These systems usually extend over an entire area with the spacing of the conductors varying according to requirements of the installation and bonded together at each crossover point.
- Rectangular or circular plate electrodes in contact with the soil. With a burial depth of five to eight feet, this system is considered very expensive for the value produced and generally not recommended.

Earth Electrode Subsystem (Continued)

Metal Framework

The metal framework of buildings may exhibit a resistance to earth of less than 10 ohms, depending upon the size of the building, the type of footing, and the type of subsoil at a particular location. Buildings that rest on steel pilings in particular may exhibit a very low resistance connection to earth. For this low resistance to be used advantageously, it is necessary that all elements of the framework be bonded together.

Water Pipes

Metal underground pipes have traditionally been used as a source for grounding electrodes. The resistance to earth provided by piping systems is usually quite low because of the extensive contact made with soil. Municipal water systems in particular establish contact with the soil over a wide area. For water pipes to be effective, any possible breaks in the continuity of the pipe must be bridged with bonding jumpers. The NEC requires that water metering equipment and service unions be bypassed with a jumper not less than that required for the grounding connector.

Shipboard Ground Plane

Introduction

The shipboard ground plane is used to provide a ground in both:

- Metallic hull ships
- Non-metallic hull ships

Metallic Hull Ships

In metallic hull ships, the metal hull, when in contact with sea water, establishes and is designated as ground potential for all electrical and electronic equipment.

Non-metallic Hull Ships

In non-metallic hull ships, ground plates are installed to provide an earth ground connection when in contact with sea water and are designated as ground potential for all electrical and electronic equipment. Ground plates are to be installed at the lowest point of the hull and as close as possible to the vertical mast.

Bond Categories and Methods

As defined in the previous lesson, bonds are the paths between two metallic surfaces and are created using a variety of methods. Bond categories and the methods used in creating bonds include:

Class A bond: Welding of metallic surfaces

Class B bond: Bolting or clamping of metallic surfaces

Class C bond: Bridging using a metallic (conductive) strap

Shipboard Ground Plane Requirements

Following are some of the requirements for the shipboard ground plane. For a complete listing of shipboard ground plane requirements, refer to MIL-STD-1310G (Navy).

- For metallic and non-metallic hull ships, all class A extensions to the ship’s ground potential shall be designated as the ship’s ground plane
- Items that are class B or class C bonded to the ground plane shall not be used as a tie point to ground potential for subsequent items
- Routing of all bond straps and grounding wires bonded to the ground plane shall be directly routed and kept as short as practical
- DC resistance across bonding and grounding junctions shall not exceed 0.1 ohms for electrical safety
- RF impedance across bonding and grounding junctions shall not exceed 25 ohms at 30 megahertz (MHz)

Inspection Procedures

Introduction

While not the responsibility of the Electronics Technician to inspect the earth electrode subsystem or the shipboard ground plane, the following sections list some (but not all) of the activities involved in performing a visual and electrical inspection of the earth electrode subsystem and shipboard ground plane. Refer to MIL-STD-188-124B and MIL-STD-1310G (Navy) for additional requirements.

Visual Inspection Procedures - Earth Electrode Subsystem

A visual inspection of the facility's earth electrode subsystem is used to determine if:

- The earth electrode subsystem shown in the facility's engineering drawing complies with MIL-STD-188-124B;
- The earth electrode subsystem consists of rods uniformly spaced around the facility, and outside the drip line of the facility;
- The grounding rods of the earth electrode subsystem are made of copper clad steel;
- The earth electrode subsystem rods are interconnected with No. 1/0 AWG, or larger, bare copper cable;
- The earth electrode subsystem interconnecting cables are brazed or welded to each ground rod;
- The earth electrode subsystem provides a complete loop that fully encloses the facility;
- Other structures (e.g., tower, etc.) are located within 6m (20 feet) of main facility and if one earth electrode subsystem encompasses all structures;
- The tower has an earth electrode subsystem connected to the earth electrode subsystem of the building;
- Other structures located greater than 6m (20 feet), are provided with a separate earth electrode subsystem;
- There is more than one earth electrode subsystem, and if so, if they are interconnected with two bare No.1/0 AWG copper cables that use independent routes.

Inspection Procedures (Continued)

Electrical Inspection Procedure - Earth Electrode Subsystem

An electrical inspection of the facility’s earth electrode subsystem includes, but is not limited to the following activities:

- Measure the resistance to earth every 12 months after the initial 12-month period of installation using the FALL-OF-POTENTIAL METHOD (including a diagram of the test procedure in the test data results).
- Determine if the resistance of the earth electrode subsystem to ground using the FALL-OF-POTENTIAL METHOD is less than 10 ohms.
- Determine if the wideband noise with respect to earth ground measures less than 100 mV p-p, with periodic noise burst not exceeding 0.5 V p-p, and occasional bursts up to 1.0 V p-p or greater.
- Measure the resistance to earth of all equipment, structures, fences and gates that are required to be bonded to ground and meets requirements of being less than 0.5 ohms.

Visual Inspection Procedures - Shipboard Ground Plane

Visual inspection procedures for the shipboard ground plane are performed to determine if:

- Metallic superstructure, equipment foundations and racks (not shock mounted), and mounting studs or brackets to which equipment is bolted for installation are class A bonded to ground potential.
- Equipment and hardware that is class B or class C bonded to the ship's ground plane is designated as grounded, but not as an element of the ground plane for grounding other items.
- Electrical and electronic equipment cases, cabinets or enclosures that may require routine removal for repair and replacement during the ship's life cycle are class B or class C bonded to ground.
- Shock-mounted equipment and equipment racks, and equipment mounted within them, are class B or class C bonded to ground.

Practice Exercise

Exercise Instructions

This exercise is meant to check your comprehension of the material covered in this lesson. Read each question and write the answers in the spaces provided. Check your answers in the Feedback section following the exercise. If you are having difficulty understanding a section, go through it again or ask someone for help.

1. List the components that make up the earth electrode subsystem.

   ____

   ____

   ____

Match the bonding classification on the right with the bonding method on the left.

2. ____	Bridging using a metallic (conductive) strap.	A.	Class A bond
3. ____	Welding of metallic surfaces.	B.	Class B bond
4. ____	Bolting or clamping of metallic surfaces.	C.	Class C bond

Practice Exercise Feedback

Exercise Answers and References

Question	Answer	Reference Page
1	• Buried, driven rods interconnected with bare wire that normally form a ring around the building • Metallic pipe systems, i.e., water, gas, fuel, etc., that have no insulation joints (these must not be used as the sole earth electrode subsystem) • A ground plane of horizontal buried wires	2-3
2	Bridging using a metallic (conductive) strap. C (Class C bond)	2-5
3	Welding of metallic surfaces. A (Class A bond)	2-5
4	Bolting or clamping of metallic surfaces. B (Class B bond)	2-5
End		

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Lesson 3

INSPECTING FAULT PROTECTION SUBSYSTEMS

Overview

Introduction

This lesson introduces you to the fault protection subsystem. The fault protection subsystem uses conductors and devices in order to provide personnel and equipment protection against power fault currents and static charge buildup.

Objectives

Upon completing this lesson, you will:

- IDENTIFY types of conductors used for fault protection
- DETERMINE sizes of conductors used for fault protection
- LIST the protective devices used for fault protection
- INSPECT the fault protection subsystem

References

The following references were used for this lesson:

- Electronics Manual, COMDTINST M10550.25(series)
- Grounding, Bonding, and Shielding, MIL-STD-188-124B
- Grounding, Bonding, and Shielding for Electronic Equipment and Facilities Vol. 1 and 2, Military Handbook MIL-HDBK-419A
- MLC Standard Operating Procedure (SOP)
- National Electrical Code

Fault Protection Subsystem

Introduction

Under conditions of current overload or excessive voltage, the fault protection subsystem ensures that:

- Personnel are protected from shock hazards.
- Equipment is protected from damage or destruction.

Providing Fault Protection

For fault protection, a low impedance path through the earth electrode subsystem will ensure that adequate fault current can flow in order to trip circuit breakers or open fuses.

The fault protection subsystem provides for the grounding of conduits containing signal conductors, all other structural metallic elements and cabinets or racks of equipment.

Fault Protection Subsystem Components

Components of the fault protection subsystem include:

- Fault protection conductors.
- Fault protection devices.

Fault Protection Conductors

Introduction

Fault protection conductors are provided throughout the power distribution system in order to allow electrical paths of sufficient current-carrying capacity to operate fuses and circuit breakers. Fault protection conductors include:

- Grounding electrode conductors
- Equipment grounding conductors
- Non-current carrying metal structures

Note: If at all possible, fault protection conductors should be physically separate from signal reference ground conductors except at where they connect to the earth electrode subsystem.

Interconnecting Fault Protection Conductors

The fault protection subsystem provides a low impedance path to ground by interconnecting all equipment to the facility's earth electrode subsystem using grounding conductors (green wires). Interconnecting all equipment at the earth electrode subsystem creates an equipotential plane that eliminates the difference of potential between individual equipments and from the equipment to ground. See Figure 3-1 below.

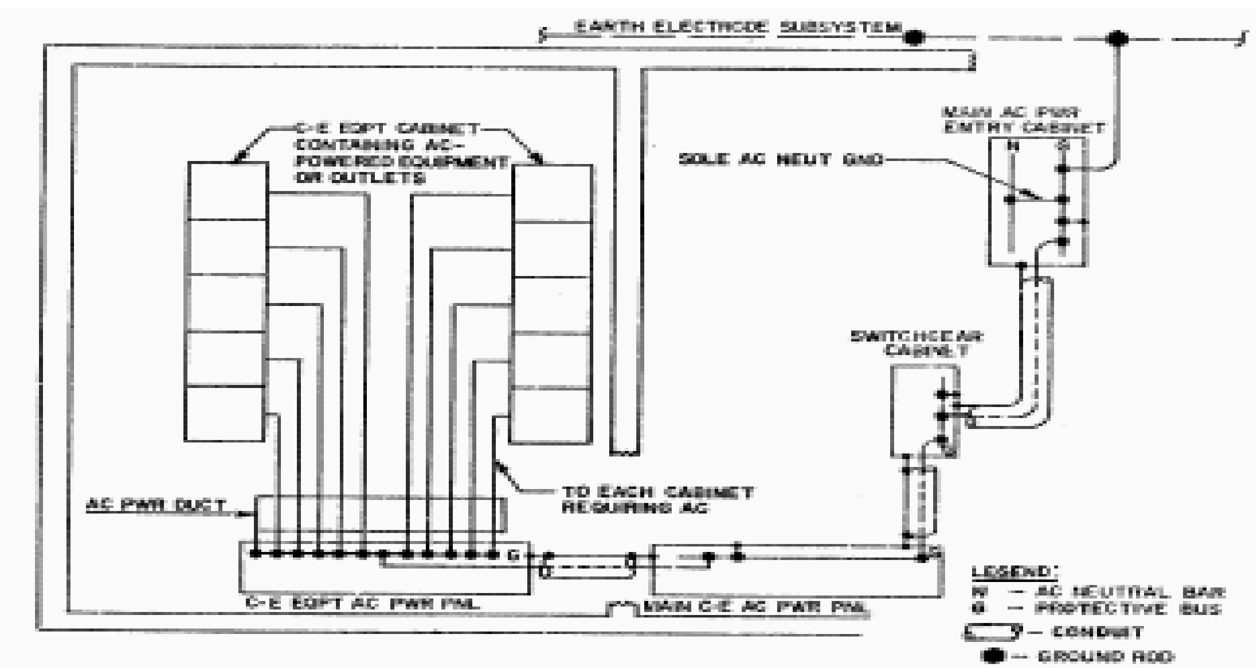


Figure 3-1

Note: The AC neutral and phase conductors are not shown for clarity.

The "G-Protective Bus" is the equipment-grounding conductor.

All grounding conductors that penetrate or cross a designated RF barrier or shield should be bonded to the barrier or shield.

Fault Protection Conductors (Continued)

Grounding Electrode Conductor Materials

Protective measures must be taken during installation and maintenance to prevent corrosion from taking place. The material selected should be resistant to any corrosive condition that may exist and may be made of:

- Copper
- Aluminum
- Copper-clad aluminum

Grounding Electrode Conductor Types

Grounding electrode conductors may be:

- Solid
- Stranded
- Insulated
- Covered
- Bare wires

Grounding Electrode Conductor Sizes

The size of the grounding electrode conductor is determined by the size of the largest entrance conductor. Refer to the table below to determine the correct size of the grounding electrode conductor.

Grounding Electrode Conductor for AC Systems			
Size of Largest Service-Entrance Conductor or Equivalent Area for Parallel Conductors		Size of Grounding Electrode Conductor	
Copper Wire No.	Aluminum or Copper-Clad Aluminum Wire No.	Copper Wire No.	Aluminum or Copper-Clad Aluminum Wire No.
2 or smaller	1/0 or smaller	8	6
1 or 1/0	2/0 or 3/0	6	4
2/0 or 3/0	4/0 or 250 kcmil	4	2
Over 3/0 thru 350 kcmil	Over 250 thru 500 kcmil	2	1/0
Over 350 thru 600 kcmil	Over 500 thru 900 kcmil	1/0	3/0
Over 600 thru 1100 kcmil	Over 900 thru 1750 kcmil	2/0	4/0
Over 1100 kcmil	Over 1750 kcmil	3/0	250 kcmil

Fault Protection Conductors (Continued)

Grounding Electrode Conductor Connectors

Grounding electrode conductors must be installed in one continuous length without splices or joints unless they are spliced by:

- An irreversible compression-type connector identified for splicing, ***or***
- Exothermic welding process

Grounding Electrode Conductor Placement

Grounding electrode conductors or their enclosures shall be securely fastened to the surface on which they are carried. Refer to the table below when inspecting for the placement of grounding electrode conductors.

<table>
<tr><th>If the grounding electrode is a:</th><th>And is:</th><th>Then the grounding electrode conductor:</th></tr>
<tr><td>No. 4 or larger copper or aluminum conductor,</td><td>Exposed to physical damage,</td><td>Must be protected.</td></tr>
<tr><td rowspan="2">No. 6 conductor,</td><td>Free from exposure to physical damage,</td><td>Is allowed to run along the surface of the building construction without metal covering or protection where it is secured to the building.</td></tr>
<tr><td>Exposed to physical damage,</td><td rowspan="2">Must be in rigid metal conduit, intermediate metal conduit, rigid nonmetallic conduit, electrical metallic tubing, or cable armor.</td></tr>
<tr><td colspan="2">Less than No. 6 conductor,</td></tr>
</table>

Ref: National Electrical Code, Ch. 2, Article 250, Par. 250-64(b)

Equipment Grounding Conductors

Grounding equipment conductors must be physically separate from signal reference grounds except at the earth electrode subsystem. The equipment fault protection subsystem provides grounding of conduits for signal conductors and all other structural metallic elements as well as racks or equipment cabinets.

Note: Metal raceways, ducts and cable trays should not be used in lieu of equipment grounding conductors.

Fault Protection Conductors (Continued)

Equipment Grounding Conductor Materials

Equipment grounding conductors may be made up of one or more, or a combination, of the following types of materials:

- Copper or other corrosion-resistant material (solid, stranded, insulated, covered, or bare, and in the form of a wire or bus bar of any shape)
- Rigid metal conduit
- Intermediate metal conduit
- Electrical metallic tubing
- Flexible metal conduit
- Armor of AC-type cable
- Copper sheath of mineral-insulated, metal-sheath cable
- Metallic sheath or the combined metallic sheath and grounding conductors of type MC cable
- Cable trays as permitted by the National Electrical Code (NEC)
- Cable bus framework as permitted by the National Electrical Code
- Other electrically continuous metal raceways

Equipment Grounding Conductor Sizes

Refer to the table below to determine the size of the grounding conductor.

MINIMUM Size Equipment Grounding Conductors for Grounding Raceway and Equipment		
Ampere Rating of Overcurrent Protection Device	**Copper Wire No.**	**Aluminum or Copper-clad Aluminum Wire No.**
15	14	12
20	12	10
30, 40, 60	10	8
100	8	6
200	6	4
300	4	2
400	3	1
500	2	1/0
600	1	2/0
800	1/0	3/0
1000	2/0	4/0
1200	3/0	250 kcmil
1600	4/0	350 kcmil
2000	250 kcmil	400 kcmil
2500	350 kcmil	600 kcmil
3000	400 kcmil	600 kcmil
4000	500 kcmil	800 kcmil
5000	700 kcmil	1200 kcmil
6000	800 kcmil	1200 kcmil

Fault Protection Devices

Introduction

Fault protection devices include:

- Fuses
- Circuit breakers
- Ground fault sensors
- Ground fault circuit interrupters (GFCIs)

Note: To ensure that fault protection is maintained, the above devices should be installed as required to best suit the needs of a given facility

Fuses

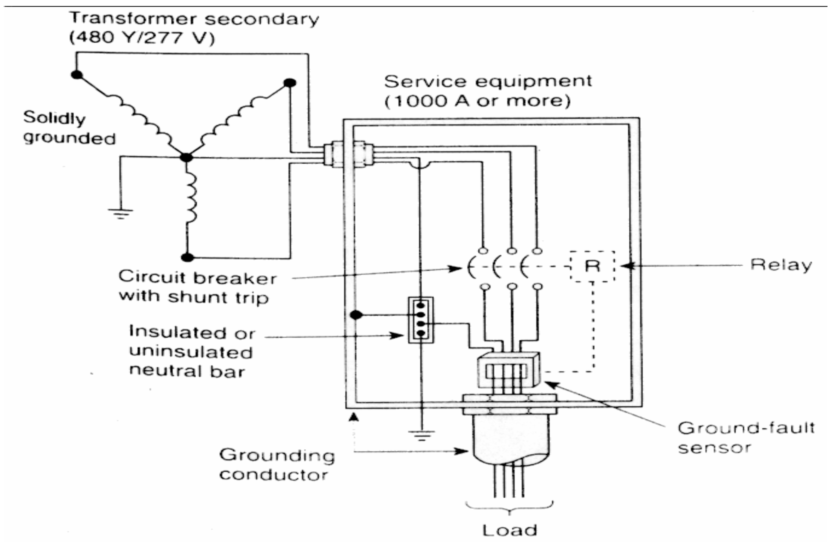
Each ungrounded service conductor (phase lead) should have overload protection provided by an overcurrent device such as a fuse. The fuse should be in series with each ungrounded service conductor and have a rating or setting no higher than the current carrying capability of the conductor.

Circuit Breakers

Circuit breakers allow for manually making, carrying and breaking currents under normal circuit conditions, making and carrying currents for a specified time, and automatically breaking currents under specified abnormal circuit conditions

Ground Fault Sensors

Ground fault sensors operate in a manner similar to GFCI but primarily serve to protect equipment from fault conditions. The sensors monitor the current that runs through them and cause circuit breakers to trip whenever a fault condition exists.

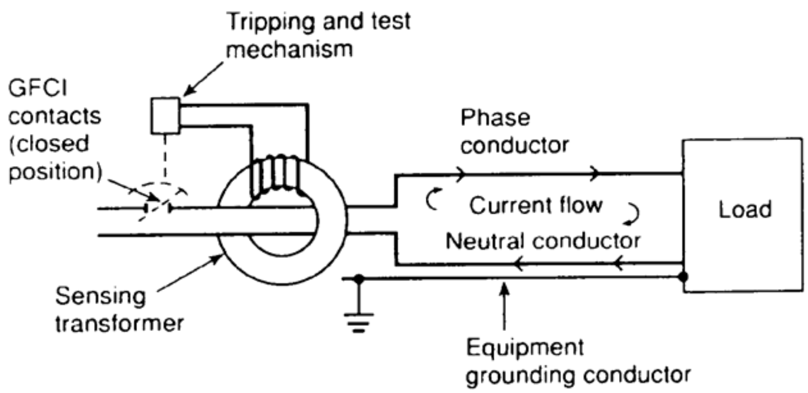


Fault Protection Devices (Continued)

Ground Fault Circuit Interrupters (GFCIs)

GFCIs have a very fast response time, and their sensitivity to detection of fault currents makes these devices extremely valuable for personnel safety. GFCIs monitor the current supplied from the source and the current returning from the load.

Whenever a change in current is detected, the GFCI's trip mechanism will activate and disconnect the equipment from its source of supply. Refer to the diagram below:



MIL-STD-188-124B recommends that GFCIs be installed on 120-volt, single-phase, 15- and 20-ampere receptacles of C-E facilities.

Non-Current-Carrying Metal Structures

Introduction

Non-current-carrying metal structures include:

- Metal frames or enclosures of apparatus
- Metal sheaths and the armor of armored cables
- Metal conduits and joints in metal conduits

Inspecting Non Current-Carrying Metal Structures

Inspecting non-current-carrying metal structures includes inspecting:

- Metal frames or enclosures of apparatus to ensure that they are fixed to, and in metallic contact with the ship's structure, provided that the surfaces in contact are clean and free from rust, scale or paint when installed and are firmly bolted together

  Note: Metal frames or enclosures of apparatus shall be connected to the hull, either directly or via the grounding terminal of a receptacle outlet. Do not rely solely on metallic cable sheaths for this purpose.

- Metal sheaths and the armor of cables shall be designed and grounded by means of connectors intended to ensure an effective ground connection and be firmly attached in order to make an effective electrical contact with a grounded metal structure

Metal conduits and joints in metal conduits shall be grounded by either being screwed into a metal enclosure, or by nuts on both sides of the wall of a metal enclosure or by means of clamps or clips of corrosion-resistant metal, making effective contact with the sheath or armor and grounded metal; provided the surfaces are clean and free from rust, scale or paint and that the enclosure is grounded.

Metal conduits, ducts and metal sheaths of cables which are used for ground continuity, shall be soundly made and protected where necessary against corrosion.

Inspection Procedures

Introduction

Inspecting the fault protection subsystem involves two types of inspections:

1. A visual inspection of the system conductors and devices.
2. An electrical inspection of system conductors.

Inspection Schedule

Inspections of the fault protection subsystem are to be performed:

- During the initial site survey,
- Annually, after the initial site survey, and
- Following any major changes to equipment or systems.

Note. Before beginning the inspections, review the past 12 months for any occurrences of power disturbances, (blackouts, sag, surges, impulses, distortion or noise) and document any findings and subsequent changes made to the fault protection subsystem resulting from the inspection.

Visual Inspections

Visually inspecting system conductors for low-impedance connections and lead reversals between ground and neutral conductors takes up most of the work involved in maintaining the fault protection subsystem.

Electrical Inspections

Performing an electrical inspection requires tools and strict adherence to safety procedures.

Inspection Tools

Tools normally used for performing inspections include:

- Safety glasses
- Insulated tools (pliers, screwdrivers, etc.)
- Multimeter
- Clamp-on ammeters
- Ohmmeters capable of measuring resistance as low as 1 milliohms (.001-ohms)

Fault Protection Inspection Job Aids

Introduction

An inspection of the fault protection subsystem is divided into two parts:

- A visual inspection, and
- An electrical inspection.

Refer to the appropriate job aids below to perform each of these inspections.

Visual Inspection Procedure

To complete a visual inspection of the facility's fault protection subsystem, complete the checklist below.

Step	Action	YES	NO	N/A
1	Obtain copies of MIL-STD-188-124B, NEC documentation and MIL-HDBK-419.			
2	Is there a separate grounding conductor (green wire) for the power system and is it installed with phase and neutral conductors? *Ref: MIL-STD 188-124B Para. 5.1.1.2.1.*			
3	Are there any white-wire/green-wire reversals?			
4	Are green wires of the required size? *Ref: NEC handbook, Chap. 2, Table 250-66*			
5	Are the neutral and green conductors properly interconnected and grounded at the first service? *Ref: MIL-STD 188-124B Para. 5.1.1.2.5.*			
6	Are all major non-current carrying metal objects grounded, to include metal support structures, cable trays and wireways? *Ref: MIL-STD 188-124B, Para. 5.1.1.2.1.*			
7	Are all main metallic structural members electrically continuous and grounded? *Ref: MIL-STD 188-124B, Para. 5.1.1.2.2.*			
8	Are all metallic piping, tubing and supports electrically continuous and grounded? *Ref: MIL-STD 188-124B, Para 5.1.1.2.3.*			

Continued next page

Fault Protection Inspection Job Aids (Continued)

Visual Inspection Procedure (continued)

Step	Action	YES	NO	N/A
9	Are all electrical supporting structures electrically continuous and grounded? *Ref: MIL-STD-188-124A, Section 5.1.1.2.4*			
10	After disconnecting power and opening electrical boxes, distribution panels and switch boxes, are any white (neutral) wires grounded?			
11	Are the ground terminals of all AC outlets connected to the facility ground system through the grounding (GREEN) conductor? *Ref: MIL-STD 188-124B, Para 5.1.1.2.5.3.*			
12	Do bonds show any sign of corrosion? *Ref: MIL-STD-188-124B, Para. 5.2.3.1*			
13	Do all bonds appear to be tight? *Ref: MIL-STD-188-124B, Para. 5.2.3.3 & 5.2.6.5*			
14	Do bonding clamps conform to AN 735 and AN742? C-clamps or spring type clamps are not permitted. *Ref: MIL-STD-188-124B, Para. 5.2.6.6*			
15	Are bonded areas visually clean? *Ref: MIL-STD-188-124B, Para. 5.2.8*			
16	Are bonds exposed to moisture or bonds located in areas not reasonably accessible for maintenance painted with a moisture proof paint or sealed with a silicone or petroleum-based sealant? *Ref: MIL-STD-188-124B, Para. 5.2.3.1*			
17	Is each subassembly and chassis bonded to the rack, frame, or cabinet IAW the reference? *Ref: MIL-STD-188-124B, Para. 5.2.10*			

Continued next page

Fault Protection Inspection Job Aids (Continued)

Visual Inspection Procedure (continued)

Step	Action	YES	NO	N/A
18	Are all cabinets individually grounded by a single, unbroken ground conductor attached to the ground rail of each cabinet and terminated at the facility ground? *Ref: MIL-STD-188-124B, Para. 5.2.10.2* *MIL-HDBK-419A, Volume II, Section 3.2.3*			
19	Are adjacent cabinets and racks bonded to each other? *Ref: MIL-STD-188-124B, Para. 5.2.10.2* *MIL-HDBK-419A, Volume II, Section 3.2.3*			
20	Are cable connectors adequately mounted to their panel so that bonding between the mating jack and plug is accomplished completely around the periphery of the flange of the connectors? *Ref: MIL-STD-188-124B, Para. 5.2.11*			
21	Are shields of coaxial cables fastened according to the reference? *Ref: MIL-STD-188-124B, Para. 5.2.12.*			
22	Are shield pigtails less than 2.5 cm (1 inch) long? *Ref: MIL-STD-188-124B, Para. 5.2.12.*			
End				

Fault Protection Inspection Job Aids (Continued)

Electrical Inspection Procedure Job Aid

To complete an electrical inspection of the facility's fault protection subsystem, complete the checklist below.

Step	Action	YES	NO	N/A
1	Obtain copies of MIL-STD-188-124B, NEC Handbook and MIL-HDBK-419.			
2	Is the facility fault protection subsystem and signal reference network free of AC neutral return current? Note: Generally less than 1.0 Amp is acceptable, depending on the situation. *Ref: MIL-STD 188-124B, Para 5.1.1.2.5.*			
3	Do any bonds have a resistance across the bond in excess of 1 milliohm? Note: Measure the bond resistances according to MIL-HDBK 419, Volume II, Section 2.2.2.3.1 of five to 10 bonds that visually appear tight, well-made, and corrosion- free. Note: Measure the bond resistances of at least 10 bonds that exhibit visual defects such as corrosion or loose connections. *Ref: MIL-STD-188-124B, Para. 5.2.4*			
4	Are all neutral conductors grounded only at one point? (At the facility first service disconnect point or to the earth electrode system point nearest to the facility common distribution transformer.) Note: Generally less than 1.0 Amp is acceptable, depending on the situation. *Ref: MIL-STD 188-124B, Para 5.1.1.2.5.*			
End				

Documenting and Reporting Discrepancies

Refer to MIL-HDBK-419A, Sections 2.2.2.2.4 and 2.3.2.4 for more information on inspecting, maintenance, and reporting major discrepancies found during inspections.

Practice Exercise

Practice Exercise Instructions

This exercise is meant to check your comprehension of the material covered in this lesson. Read each question and write the answers in the spaces provided. Check your answers in the Feedback section following the exercise. If you are having difficulty understanding a section, go through it again or ask someone for help.

1. If the service-entrance conductor is copper wire size 1, what size copper wire should be used for the grounding electrode conductor for the AC system?

   ____

2. Metal raceways, ducts and cable trays should not be used in lieu of equipment grounding conductors. (Circle correct answer):

   True   False

3. If the current rating of the overcurrent protection device is 500, what is the minimum copper wire size for the equipment-grounding conductor? ______

Practice Exercise Feedback

Exercise Answers and References

Question	Answer	Reference Page
1	Wire size no. 6	3-4
2	True	3-5
3	Wire size no. 2	3-6

Lesson 4

INSPECTING LIGHTNING PROTECTION SUBSYSTEMS

Overview

Introduction

This lesson provides training on the maintenance and inspection of lightning protection subsystems. The lightning protection subsystem provides a nondestructive path to ground for lightning energy contacting or induced in facility structures. To effectively protect a building, mast, tower, or similar self-supporting objects from lightning damage, an air terminal (lightning rod) of adequate mechanical strength and electrical conductivity to withstand the stroke impingement must be provided. An air terminal will intercept the discharge to keep it from penetrating the nonconductive outer coverings of the structure, and prevent it from passing through devices likely to be damaged or destroyed. A low-impedance path from the air terminal to earth must also be provided. These requirements are met by either:

- An integral system of air terminals, roof conductors, and down conductors securely interconnected to provide the shortest practicable path to earth; or
- A separately mounted shielding system, such as a metal mast or wires (which act as air terminals) and down conductors to the earth electrode subsystem.

Objectives

Upon completing this lesson, you will:

- **LIST** the types of devices used for lightning protection subsystem.
- **INSPECT** the lightning protection subsystem.

References

The following references were used for this lesson:

- *Electronics Manual*, COMDTINST M10550.25(series)
- Military Handbook MIL-HDBK-419A (*Grounding, Bonding, and Shielding for Electronic Equipment and Facilities Vol. 1 and 2*)
- *Standards for the Installation of Lightning Protection Systems*, NFPA 780, 1997 Edition
- *Code of Federal Regulations* – Title 46: Shipping, Subchapter J – Part 111: Electric Systems – General Requirements

Lightning Fundamentals

Introduction

To understand lightning, it is best to review the basic theory of lightning—what are its causes, its characteristics, the likelihood of being struck by lightning and its effects.

Causes of Lightning

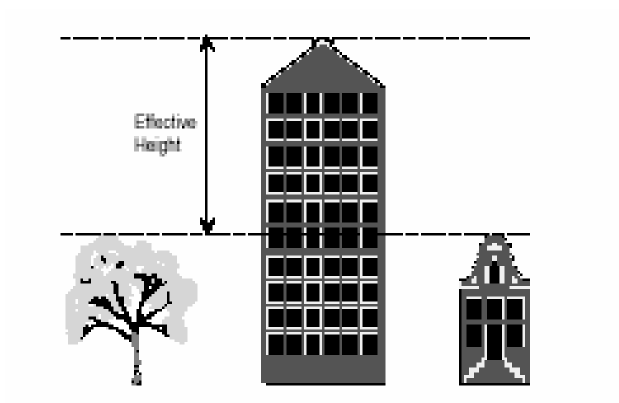
Lightning is caused by the static buildup of positive and negative charges within clouds, and between the clouds and ground. This static buildup can charge the cloud to a point (millions of volts) where it will exceed the breakdown dielectric of air. Once this occurs, a lightning strike will occur.

Characteristics of Lightning

Most lightning flashes (strikes) observed from the ground are actually a series of strokes occurring so fast that they appear to be just one single strike. An average lightning strike consists of about three strikes, with the first strike discharging an average of 18 kA. Subsequent lightning strikes will discharge about half the current of each preceding lightning strike.

Determining Strike Likelihood

Determining strike likelihood involves analyzing the effective height of a facility or structure. If a tall building stands by itself in a relatively large area, its effective height equals its actual height from top to bottom. However, the same building surrounded by other structures (buildings, trees etc.) has an effective height equal to the difference between its height and the height of the surrounding structures as shown below:



Effects of Lightning on Personnel and Property

Research has shown that on an average there are 1.5 million lightning strikes each year across the United States. These strikes kill more than 90 people a year and cause more than $5 billion dollars in property damage.

Effects of Lightning

Introduction

Any object struck by lightning is subject to damage. The severity of the damage depends upon the effects of the lightning strike. Below are listed each of the five types of effects along with a brief description.

- Thermal
- Mechanical
- Electrical
- Conductor Impedance
- Induced Voltage

Thermal Effects

How much damage an object sustains depends in part on the conductive power of the object. Large metal structures will probably withstand all but the strongest of lightning discharges. Even a telephone wire will be left intact, except at the point of entrance or exit where severe damage is most likely to occur. The damage caused by thermal effects may include the following:

- Small deformation at the tip of a lightning rod or small melted area on the intercepting cable.
- Very strong discharges that can melt or burn holes in solid metal plates.

Mechanical Effects

A short duration, high-peak current pulse will produce a mechanical effect that may tear or bend metal parts because of the electromagnetic force created by the current surge. This effect makes it necessary to ensure that lightning rods, down conductors, and other elements of the protection system are securely fastened.

Electrical Effects

The voltages developed by fast-rising, high-current lightning strikes are usually high enough to:

- Cause insulation breakdown.
- Pose a safety hazard for personnel.
- Cause component and device failure.

Continued next page

Effects of Lightning (Continued)

Conductor Impedance Effects

Impedance effects of conductors cause extremely high voltages to develop across conductors due to inductance. Inductance refers to the property of a conductor that opposes a change in current. The high voltage that develops may be high enough to cause a flashover to conducting objects located as close as 14 inches away. For this reason, metal objects within six feet of lightning down conductors should be electrically bonded to the down conductors.

Induced Voltage Effects

The high voltage developed in a down conductor will be induced to nearby electronic circuits when such circuits run parallel to the down conductor.

For this reason, cables that terminate in electronic devices should not run parallel to down conductors. This includes power, signal, and control lines. If this situation cannot be avoided, the separation between the down conductors and other cables should be as large as possible.

Lightning Protection Requirements

Introduction

In order to protect facilities and personnel from lightning strikes, certain requirements must be implemented into the facility's design to minimize the damage caused by even a direct lightning hit.

Applicable Codes

The lightning protection code, NFPA No. 780, issued by the National Fire Prevention Association, contains the basic requirements for personnel protection from a lightning strike to a structure.

Code of Federal Regulations (CFR), Title 46 – Shipping, Subchapter J – Part 111: Electric Systems and General Requirements for shipboard applications.

Basic Requirements

To protect any structure, such as a building, vessel, mast, etc., from lightning damage, the following basic requirements must be met:

- An air terminal must be installed to attract the lightning to the terminal and away from the facility and equipment.
- Roof and down conductors must be a separate 0000 AWG cable, continuous, unspliced and installed in as straight a line as possible in order to provide a low-impedance path from the highest conductive surface (air terminal) to the main ground connection point.
- Where a metal mast is used, it should be connected to the ground plates using a size 0000 AWG cable. Equipment on the mast requiring grounding should be grounded to the mast.
- Nonmetallic masts and topmasts must have a lightning ground conductor using a size 0000 AWG cable.
- Dedicated ground rods (for ashore units) and ground plates (for afloat units) must be used to connect the roof/down conductors and lightning ground conductors respectively.

Protection Devices

Introduction

Lightning protection devices include:

- Air terminals.
- Down conductors.
- Ground rods.

Air Terminal

An air terminal attracts the lightning and protects other structures from direct lightning hits. The tip of the air terminal should be at least 10 inches above the structure you are protecting. The air terminal should be a conductor of adequate strength, and must posses the conductivity to withstand the high lightning current that will pass through it.

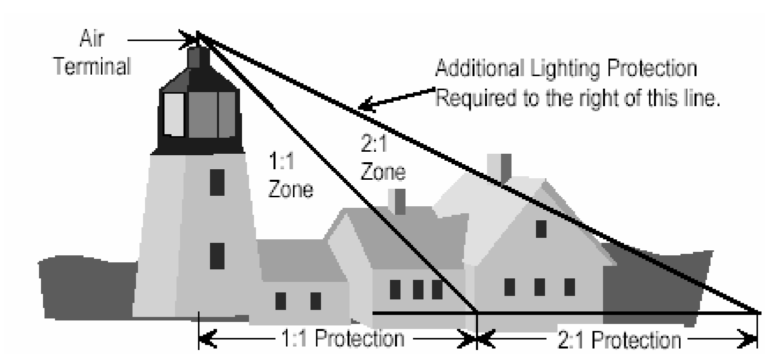
Air Terminal Placement

The air terminal should be placed in an area where lightning will most likely strike. (For example, the highest point of a structure, such as a chimney that extends past the roof in a building.) Refer to the chart below.

If building has a..	**Then air terminal placement should be…**
Flat roof	On the corners or edges
Pitched roof	Within two feet of ridged ends
Sloping roof	On the corners and edges where terminals that are: • Less than 24 inches in height are spaced a maximum of 20 ft. apart • Equal to or greater than 24 inches in height are spaced a maximum of 25 ft. apart

Air Terminal Example

A tall structure with lightning protection offers a cone of protection to smaller structures nearby. Any critical structures within a 1:1 cone of protection do not require lightning protection. Any non-critical structures within a 2:1 cone of protection also do not require protection.



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Protection Devices (Continued)

Air Terminal Example, contd.

In the example on the opposite page, the structure closest to the air terminal is critical and is inside of the 1:1 cone of protection. The next nearest structure is non-critical and is within the 2:1 zone, so it requires no additional protection. A portion of structure farthest away from the air terminal is outside of the 2:1 zone and does require additional protection.

Air Terminal Placement on Various Types of Roofs

The following diagrams illustrate the proper location of air terminals on various types of roofs.

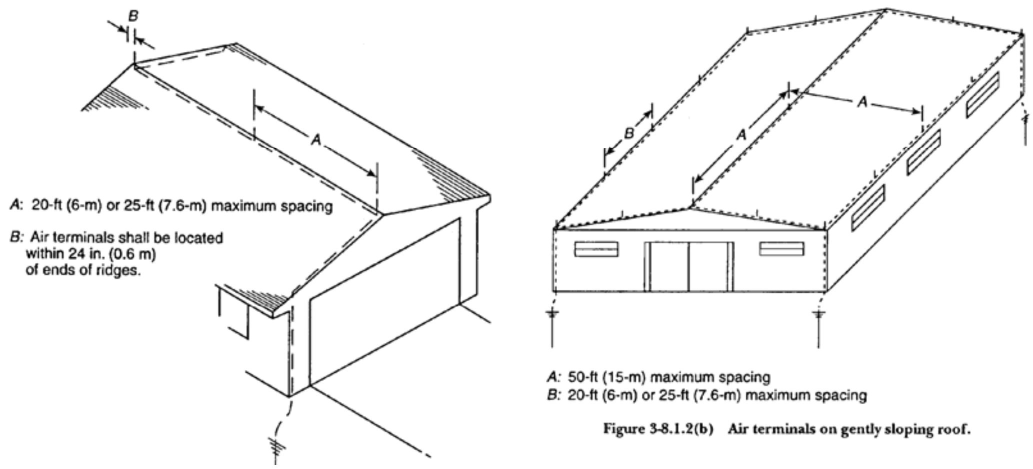
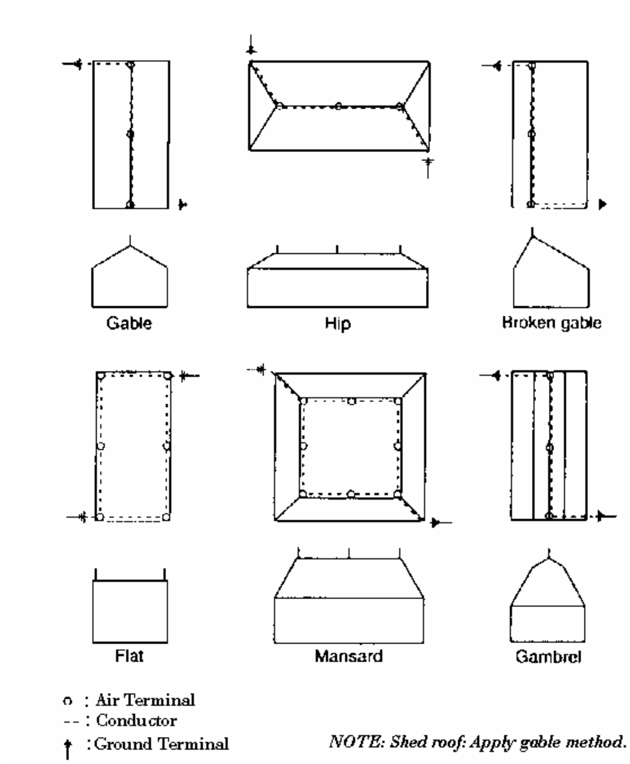


Figure 3-8.1.2(b) Air terminals on gently sloping roof.



Protection Devices (Continued)

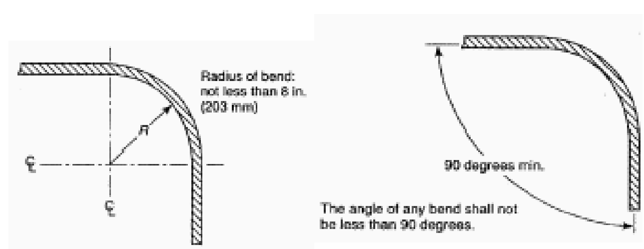
Down Conductor

As the conductor connecting the air terminal or overhead ground wire to the earth electrode subsystem, the down conductor must be:

- Continuous and bonded to the earth electrode subsystem.
- Bonded to tower legs at the base in situations where the structural elements of the metal tower are not used as down conductors.
- Protected against mechanical damage.
- Installed in plastic or non-metallic conduit as it passes through foundations or footings.

Down Conductor Requirements

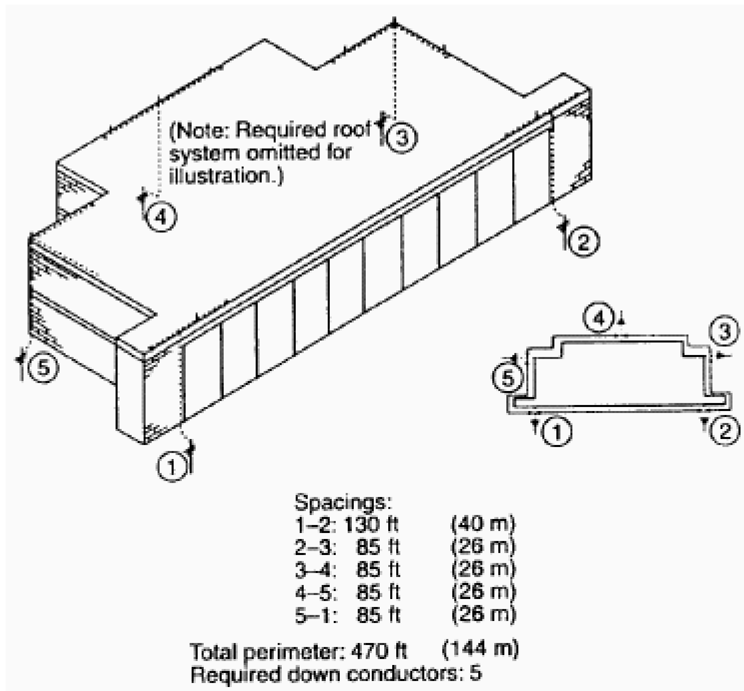
When copper-clad steel is used as a down conductor, the DC resistance shall meet the following specifications:

Conductors up to 75 ft.	The maximum DC resistance shall not be greater than 0.176 ohms per 1000 ft.
Conductors more than 75 ft.	The maximum dc resistance shall not be greater than 0.088 ohms per 1000 ft.
Size	The size of the wire shall not be less than No. 14 AWG. (No. 6 AWG copper wire is recommended.)
Conductivity	The conductivity of copper-clad steel shall not be less than 30% of a solid copper conductor with an equivalent cross-sectional area.
Bends	Bending of the down conductor should be gradual; the bend radius should not be less than eight inches. The angle of any bend shall not be less than 90 degrees. 

Protection Devices (Continued)

Down Conductor Placement

An air terminal must have at least two paths for discharging the lightning to ground. This is accomplished through the use of roof and down conductors. Roof conductors interconnect all air terminals to the down conductors. At least two down conductors shall be placed on any structure. On structures exceeding 250 ft. in perimeter, an additional down conductor is required for each additional 100 ft. of perimeter. The average distance between down conductors shall not exceed 100 ft.



Ground Rods

Ground rods make up the final element of the lightning protection subsystem.

- Ground rods are constructed of copper-clad steel, solid copper, hot-dipped galvanized steel, or stainless steel.
- The ground rod shall be at least eight feet long and ½ inch in diameter.
- A ground rod dedicated exclusively for lightning protection shall terminate each down conductor.
- All lightning ground rods shall be connected together and to the facility's earth electrode subsystem.

Note: To prevent galvanic corrosion, all ground rods should be constructed of the same materials. This includes the earth electrode subsystem ground rods.

Lightning Protection Inspections

Introduction

A site survey of the lightning protection subsystem is divided into two parts:

- A visual and mechanical inspection, and
- An electrical inspection.

Refer to the appropriate job aid on the following pages to perform each of these inspections.

Inspection Frequency

The lightning protection subsystem should be inspected visually every two months and mechanically every 12 months per NETA guidelines.

Visual and Mechanical Inspections

Visual and mechanical inspections include:

- Verifying that all facility components and antennas are within the cone of protection.
- Checking for evidence of burning and/or pitting, as well as melting of air terminals.
- Checking for burned fasteners.
- Checking for broken or melted down conductors or severely damaged as well as distorted roof conductors, down conductors, and bonding jumpers.
- Looking for signs of arcing or flashover indicating a need for bonding jumpers or spark gaps.
- Checking for corroded or loose connectors and fasteners.
- Verifying that copper-to-aluminum contact does not occur except through Underwriters Laboratories (UL) approved bimetallic connectors.
- Verifying that all guards for down conductors are in place and without severe mechanical damage.
- Verifying that all guards are bonded to down conductors (at both ends of guard).

Electrical Inspection

Electrical inspection of the lightning subsystem tests a sample of the bonds included in the lightning protection subsystem from the air terminal to the earth electrode subsystem or shipboard ground plane.

Lightning Protection Inspection Job Aids

Procedure

Follow the procedure below to complete an inspection of the facility's lightning protection components. Refer to MIL-HDBK-419A, Sections 2.2.2.2.3 and 2.3.2.2 for additional information on inspection, maintenance, and reporting major discrepancies found during inspections.

Step	Action	YES	NO	N/A
1	Obtain copies of MIL-STD-188-124B, NEC documentation and MIL-HDBK-419.			
2	Is the facility protected against lightning? *Ref: MIL-STD 188-124B, Para 5.1.1.3.2*			
3	Do large structures with flat or gently slopping roofs have lightning protection as described in MIL-HDBK-419A, Volume II, Section 1.3? *Ref: MIL-STD-188-124A, Para. 5.1.3.8.3*			
4	Are all antennas inside a 1:1 cone of protection? *Ref: MIL-HDBK-419B, Volume I, Section 3.5.2*			
5	Are all down conductors, fasteners, and mounting hardware secure and corrosion free? *Ref: MIL-HDBK-419A, Vol. II, Para 1.3.2.3.b.*			
6	All down conductors of the lightning protection subsystem have bends with a radius less than 20 cm (8 inches) or bends not less than 90°? *Ref: MIL-STD-188-124A, Para. 5.1.1.3.3*			
7	Are all metal objects within 1.8 meters (6 ft) of the lightning down conductor bonded or grounded to the facility ground? *Ref: MIL-STD 188-124B, Para 5.1.1.3.3.*			
8	Are all bonds between elements of the lightning protection subsystem welded, brazed, or secured by UL-approved clamps? *Ref: MIL-STD 188-124B, Para 5.1.1.3.4.*			

Continued next page

Lightning Protection Inspection Job Aid (Continued)

Procedure, contd.

Step	Action	YES	NO	N/A
9	Are two tower legs independently grounded to the earth electrode subsystem? *Ref: MIL-STD 188-124B, Para 5.1.1.3.8.1.*			
10	Are the down conductors from the tower bonded to the tower at the base? *Ref: MIL-STD 188-124B, Para 5.1.1.3.8.1.*			
11	Are two bare 1/0 AWG copper cables, using different routes, used to bond the tower earth electrode subsystem to the earth electrode subsystem of the building and structure that have signal, control and power line interface with the tower and are separated by less than 60 meters (200 ft). *Ref: MIL-STD 188-124B, Para 5.1.1.3.8.1.*			
12	Are all lightning down conductors continuous and welded or brazed to the electrode subsystem. *Ref: MIL-STD 188-124B, Para 5.1.1.1.5*			
13	Are all waveguides and the outer shields of rigid and semi-rigid coaxial cables grounded near the antenna, at the vertical to horizontal transition, and at the transmission line entry port? *Ref: MIL-STD 188-124B, Para 5.1.1.3.8.5.a*			
14	Are the shields of all coaxial cables entering the building bonded to the facility's entrance plate and in turn to the earth electrode subsystem IAW the guidelines presented in MIL-HDBK-419A, Volume II, Paragraph 1.3.3.4. *Ref: MIL-STD-124B, Para. 5.1.1.3.8.6*			
15	Are handrails, ladders, stairways, antenna pedestals and objects subject to human contact grounded? *Ref: MIL-STD-188-124A, Para. 5.1.1.3.9*			

Continued next page

Lightning Protection Inspection Job Aid (Continued)

Procedure, contd.

Step	Action	YES	NO	N/A
16	Are exposed and underground power lines, not otherwise protected, provided with UL approved lightning arrestors, also known as transient voltage surge suppressors (TVSS), at the point of entrance into the facility? *Ref: MIL-STD-188-124B, Para. 5.1.1.3.12*			
17	Are arrestors properly installed? *Ref: National Electrical Code, Article 280 and MIL-HDBK-419A, Vol II, Para 1.3.3.5.12*			
18	Are all unused wires/pairs of communications cables grounded at each end? *Ref: MIL-HDBK-419A, Vol. II, Para 1.3.3.5.27*			
19	Are all security or perimeter fence grounded IAW MIL-HDBK-419A, Volume II, Section 1.12. *Ref: MIL-STD-188-124B, Para. 5.1.1.3.13*			
20	Are there signs of arcing or flashover?			
21	Are there signs of burning, pitting, or melting air terminals?			
22	Are there signs of burned or melted conductors or fasteners?			
23	Are guards bonded to the down conductor at both ends?			
24	Are there signs of broken or damaged roof conductors, down conductors, or bonding jumpers?			
End				

Practice Exercise

Exercise Instructions

This exercise is meant to check your comprehension of the material covered in this lesson. Read each question and write the answers in the spaces provided. Check your answers in the Feedback section following the exercise. If you are having difficulty understanding a section, go through it again or ask someone for help.

1. The five effects of lightning are:

   ____

   ____

   ____

   ____

   ____

2. Due to ______________________ effects, all elements of the lightning protection subsystem must be securely fastened.

3. Insulation breakdown may be due to the ____________________ effect of lightning.

4. Metal objects within six feet of lightning down conductors should be bonded to the down conductors in order to avoid __________________.

5. To reduce the possibility of ______________________________ effects, cables that terminate electronic devices (such as power, signal and control lines) should not be run in parallel to down conductors.

6. The tip of the air terminal must be a minimum of ____________ inches above the structure.

7. The bend of any down conductor shall not be less than _____ degrees.

Practice Exercise Feedback

Exercise Answers and References

Answers to the Review Exercise are listed below. If you require additional clarification, ask for help.

Question	Answer	Reference Page
1	Thermal effects Mechanical effects Electrical effects Conductor impedance effects Induced voltage effects	4-3
2	Mechanical	4-3
3	Electrical	4-3
4	Flashovers	4-4
5	Induced voltage	4-4
6	10 inches	4-6
7	90 degrees	4-8

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Lesson 5

INSPECTING SIGNAL REFERENCE GROUND SUBSYSTEMS

Overview

Introduction

This lesson provides training on the maintenance and inspection of signal reference ground subsystems. The signal reference ground subsystem establishes a common point to reference all signals for Communications Electronics (C-E) equipment by minimizing voltage differences between equipment units. This common reference point also reduces the current flow between equipments and minimizes or eliminates noise voltages on signal paths or circuits. Within a single unit of equipment, the signal reference ground subsystem may be a bus bar or conductor that serves as a reference for some or all of the signal circuits within the equipment. Between equipments, the signal reference subsystem will be a network consisting of a number of interconnected conductors. Whether serving a collection of circuits within a single equipment unit or serving several equipment units within a facility, the signal reference ground network may use multiple point or equipotential planes but may also utilize a single reference point ground system depending upon equipment's design, facility, and frequencies used.

Objectives

Upon completing this lesson, you will:

- **STATE** the purpose of a signal reference ground subsystem.
- **STATE** how the signal reference ground subsystem is connected to the facility's ground system.
- **INSPECT** the signal reference ground subsystem.

References

The following references were used for this lesson:

- *Electronics Manual*, COMDTINST M10550.25 (series)
- *Grounding, Bonding, and Shielding for Electronic Equipment and Facilities*, MIL-HDBK-419A

Grounding Configurations

Introduction

The signal reference ground subsystem establishes a common reference for C-E equipment by minimizing voltage differences between equipments and reducing the current flow between equipments resulting in minimizing or eliminating noise voltages on signal paths or circuits.

Configurations

Signal reference subsystem grounding configurations for all of the equipment in a facility falls into one of three grounding configurations:

- Floating ground configuration
- Single-point ground configuration
- Multi-point (or equipotential) ground configuration

Note: Of the three configurations listed above, the multi-point or equipotential ground configuration is preferred for Communications Electronics (C-E) facilities.

Floating Ground Configuration

Introduction

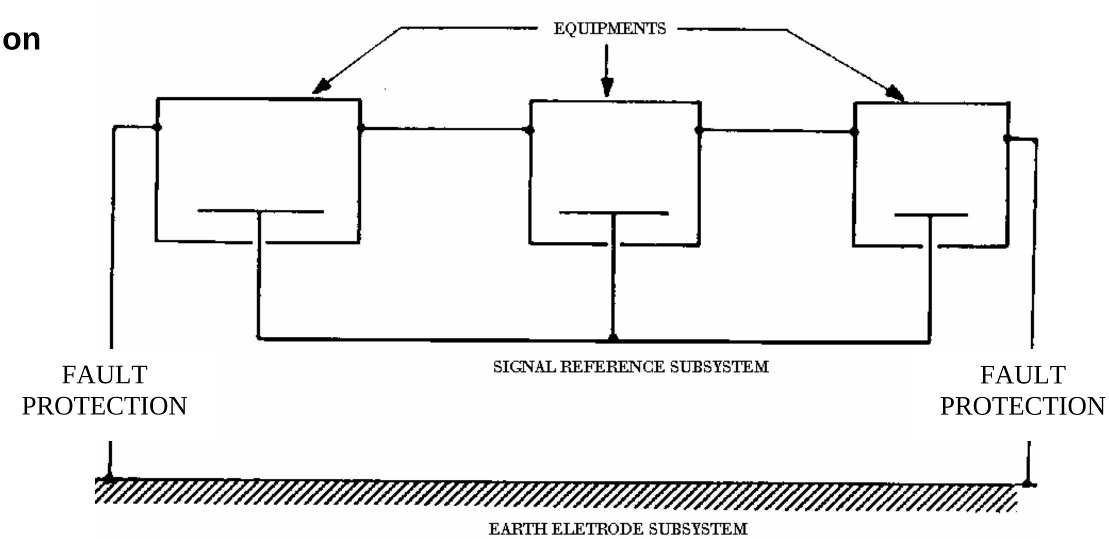
In the floating ground configuration, the signal ground is electrically isolated from the building ground and other conductive objects.

Advantages and disadvantages of the floating ground configuration are listed below:

Advantages	Disadvantages
• Prevents noise that may be in the facility's ground from being conductively coupled to the signal circuits • Prevents noise currents in equipment cabinets from being coupled to the signal circuits	• Static charge buildup on the isolated signal circuits may present a shock and/or spark hazard. • Power faults to the signal system can cause the system to rise to hazardous voltage levels relative to other conductive objects in the facility. • There is a danger of flashover between cabinet and signal system in the event of a lighting strike to the facility, which causes insulation breakdown and arcing. • Electrical isolation is difficult to maintain in a shore facility, thus it is not generally recommended for C-E facilities.

Floating Ground Configuration Diagram

A floating ground subsystem is depicted below.



Single Point Ground Configuration

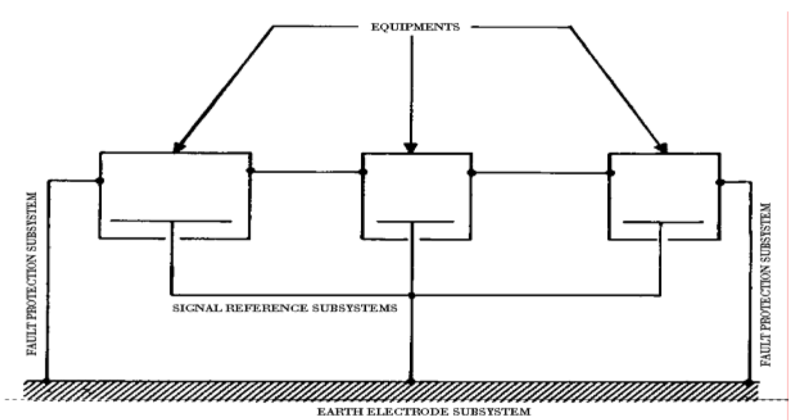
Introduction

The single point ground configuration is recommended for use in low-frequency electronic systems (up to approximately 300 kHz). In this configuration, signal circuits are referenced to a single point which is then connected to the facility ground. The advantages and disadvantages of using this type of configuration are listed below:

Advantages	Disadvantages
• Control of conductively coupled interference by minimizing the effects of lower frequency noise currents that may be flowing in the facility ground	• Single-point grounds are extremely poor grounds at RF frequencies because the ground impedance varies with frequency. • Grounds used become transmission lines at higher frequencies. • Every piece of equipment bonded to a single-point ground system becomes a tuned stub. • Long conductors in large installations are required. • Single-point grounds are not recommended for use in C-E facilities.

Single Point Ground Diagram

A single point ground system is depicted below. All signal circuits are connected to a single point, and that point is then connected to the facility's ground.



Multi-Point Ground Configuration

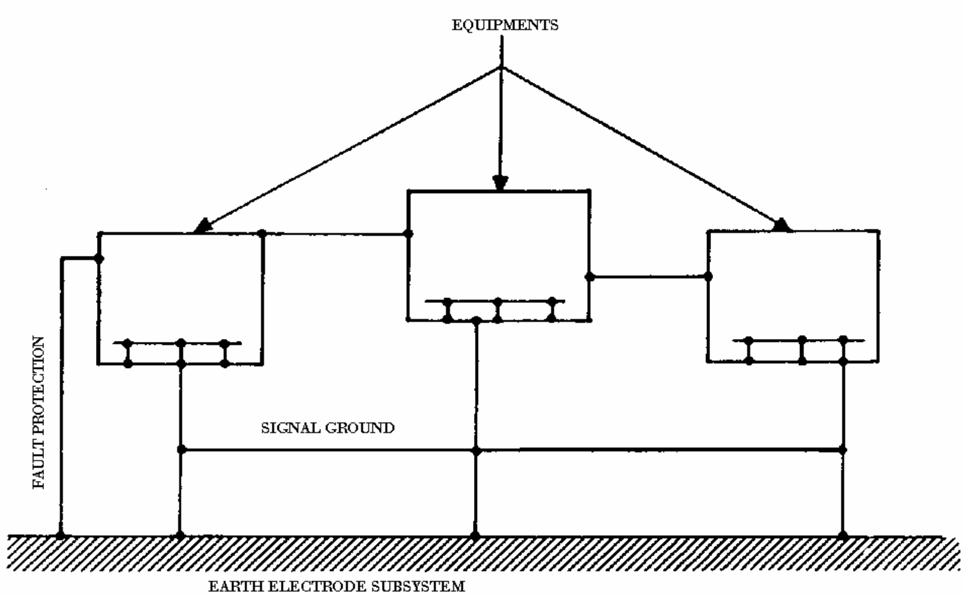
Introduction

The multi-point ground type of configuration is recommended for higher frequencies—30 kHz and above. Multi-point grounds provide many conductive paths from any electronic system or piece of equipment to the earth electrode subsystem. To be effective, this type of configuration requires the use of an **equipotential ground plane** whenever the conductors exceed 1/8 wavelength at the highest frequency of concern. The advantages and disadvantages of using this type of configuration are listed below:

Advantages	Disadvantages
• Simplification of circuit construction inside complex equipment • Easier interface of equipment employing coaxial cables because the outer conductor of the coaxial cable does not have to float relative to the equipment cabinet or enclosure	• Exhibits transmission line characteristics at RF frequencies. • Requires the use of equipotential ground plane. • Care must be taken to ensure low-frequency currents are not coupled into the signal circuits, creating interference facilities.

Multi-point Ground Diagram

A multi-point ground subsystem is depicted below.



Equipotential Ground Plane

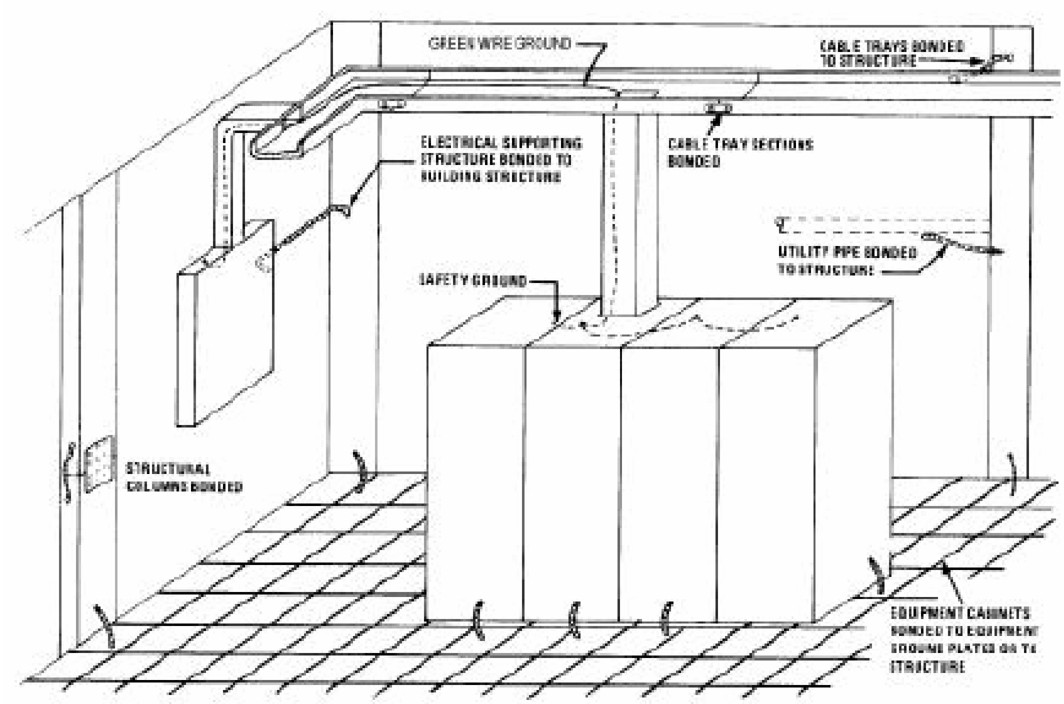
Introduction

The equipotential ground plane consists of a network of multiple conductors connected in the form of a grid or mesh that offers very low impedance to ground at high frequencies. New facilities can be designed with an equipotential plane built into the floor of the equipment to be protected. In the case of an existing facility, the plane can be installed above the equipment to be grounded. The advantages and disadvantages of using this type of configuration are listed below:

Advantages	Disadvantages
• Proper equipment operation • Suppression of noise and static • Reduction of electromagnetic interference (EMI) • Reduction or elimination of noise in cables or conductors by the use of filters or bond straps by "shorting out" the noise field.	• Possible exposure to high potentials when metallic conductors (which are part of the ground plane) are not properly bonded. This high potential is in respect to earth. • May increase interference by providing conductive coupling paths or inductive loops.

Equipotential Ground Diagram

An equipotential ground plane is depicted below.



Equipotential Ground Plane Types

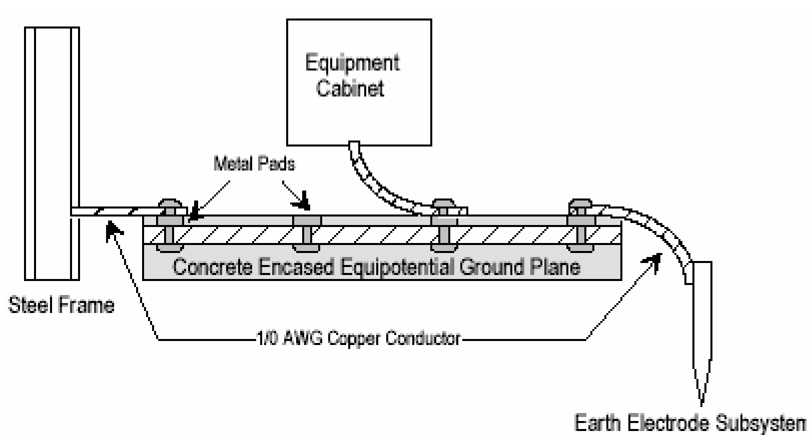
Introduction

Equipotential ground planes may exist in the floors or ceilings of buildings. The equipotential ground plane may be installed either during the construction of a new building or after construction is completed. Building characteristics present several different configurations of installation, with the most common configuration being in the floor or sub-floor. Below is a list of the most common types:

- Concrete floor with embedded copper grids
- Raised floors, with metal panels, stringers or pedestals installed (e.g., computer floors)
- Sub-floor of tile or carpet with a metal sheet of aluminum, copper, or phosphor bronze screen laid underneath
- Overhead in the ceiling above the equipment using a grid

Concrete Floor

This type of equipotential ground plane is installed during the construction of a new facility. A typical installation will consist of TWO-inch square metal pads located throughout the building, flush with the surface of the concrete floor. Equipment cabinets are bonded to these pads or to a bus that is bonded to the pad. Refer to the diagram below:



Equipotential Ground Plane Types (Continued)

Raised Floor

Raised computer floors provide support for equipment cabinets and provide space between the original floor and the computer deck to run air-conditioning ducts, cables, etc. The bolted-grid stringer system is the only acceptable type for use as an equipotential plane. This type of computer floor provides:

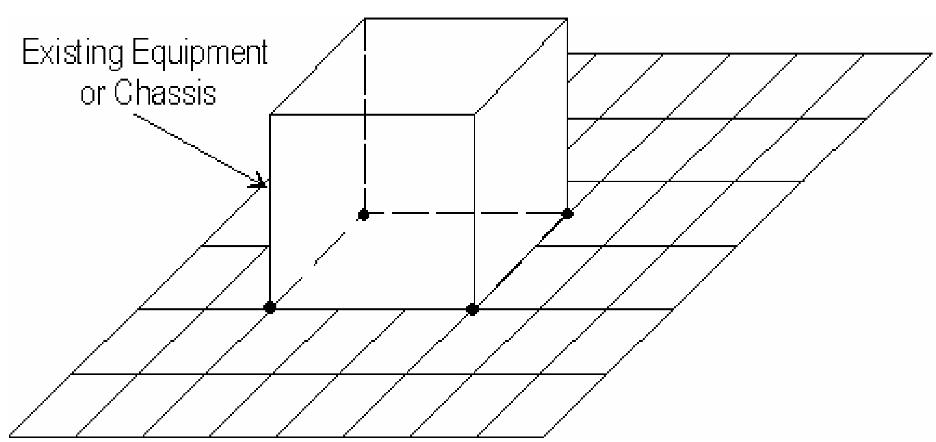
- An electrically continuous sheet at RF frequencies.
- A low-impedance path to earth at lower frequencies by connecting the equipment cabinets with bonding straps.

Construction of a computer floor equipotential plane consists of:

- Drop-in panels constructed of metal or metal-plated wood (should not be larger than 24" x 24").
- Stringers that are used for connecting the equipment cabinets.
- Pedestals that provide support for metal plates and equipment cabinets.

Sub-floor

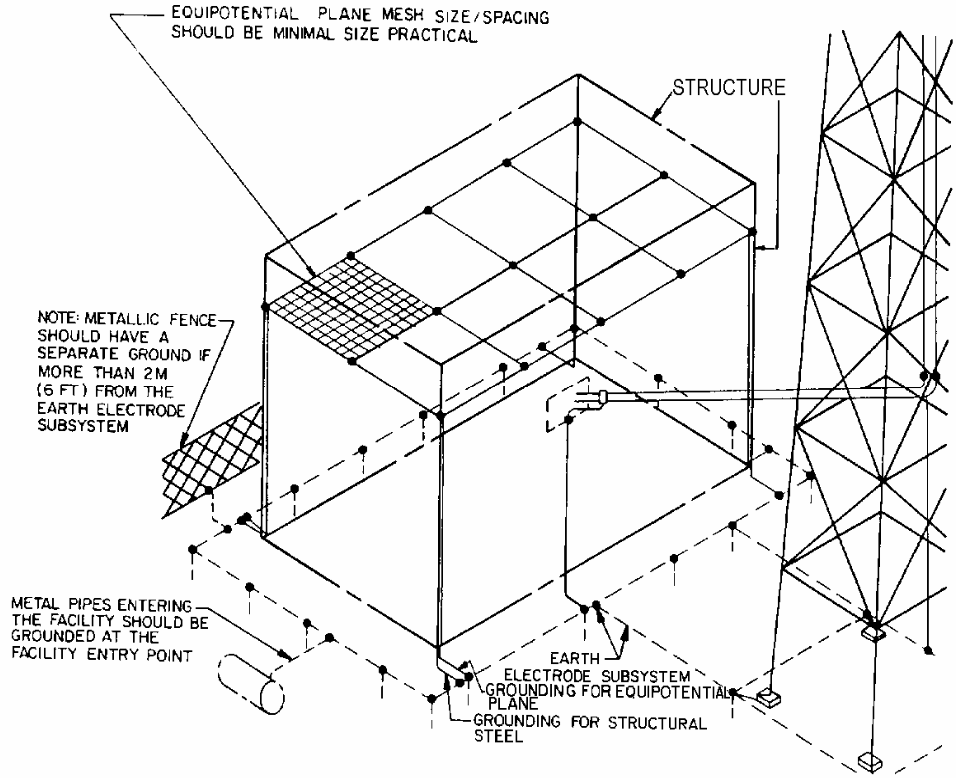
Sheets of metal or rolls of aluminum, copper, or phosphor bronze under the floor tile or carpet can be installed to provide an equipotential ground plane. The plane should be bonded to the main structural steel members of the building at multiple locations. The steel member should, in turn, be bonded to the earth electrode subsystem. In the case of an existing facility, the conducting plane does not have to be installed underneath the equipment cabinets but should be bonded to the equipment at all four corners.



Equipotential Ground Plane Types (Continued)

Overhead

An alternative to installing the equipotential ground plane on the floor is to install an overhead plane, which can be constructed of thin metal sheets or screen above the ceiling. Phosphor bronze screen is light, durable, and easy to work with; therefore, it is the preferred material for this type of installation. When bonding equipment to the plane, use bond straps which are as short as possible; this will provide a low-impedance path at lower frequencies. Ground the plane to the building structure as before.



Inspecting Signal Reference Grounding

Introduction

Inspecting the signal reference ground subsystem for equipment consists of:

- Visually inspecting signal reference ground connections for proper bonding and grounding.
- Performing signal reference ground connection resistance checks.

Note: Inspections vary by equipment category.

Equipment Categories

Connection methods used to connect the signal reference ground subsystem to electronic equipment varies by the category of equipment being connected. The three categories of equipment are:

- Low frequency equipment (with frequencies from DC to 30 kHz).
- High frequency equipment (with frequencies above 30 kHz).
- Hybrid equipment (with both lower and higher frequencies).

Inspecting Low Frequency Equipment

Performing a Visual Inspection

When performing a visual inspection of low frequency equipment and the signal reference ground subsystem, ensure that:

- Equipment is connected using a single-point ground system via a ground terminal (See Single point ground diagram on page 5-4).
- The signal reference ground is isolated from the chassis of the equipment (See signal reference ground isolation diagram on page 5-12).
- Balanced lines are used to interconnect low-frequency signals between units of low frequency equipment (See balanced line diagrams on page 5-13).

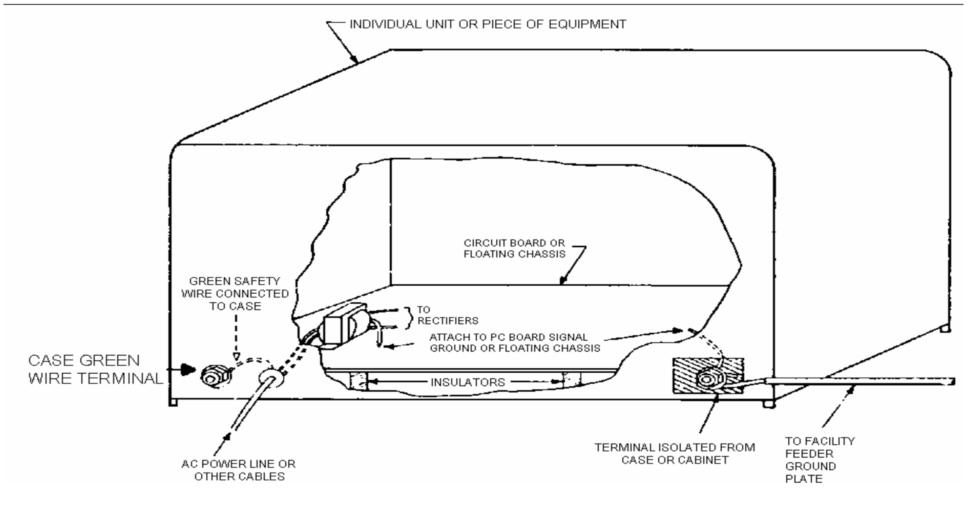
Visually Inspecting the Ground Terminal

When inspecting the ground terminal connection, verify that one of the following methods are used to connect the low frequency equipment to the signal reference ground subsystem:

- Connector pin
- Screw or pin on a terminal strip
- Insulated wire or insulated stud
- Jack
- Feed-through type connection

Note: If using insulated wires, they must be at least 16 AWG. If 16 AWG is used, it must be less than five feet in length. The signal ground terminal should be marked with a permanent yellow label or color-coded.

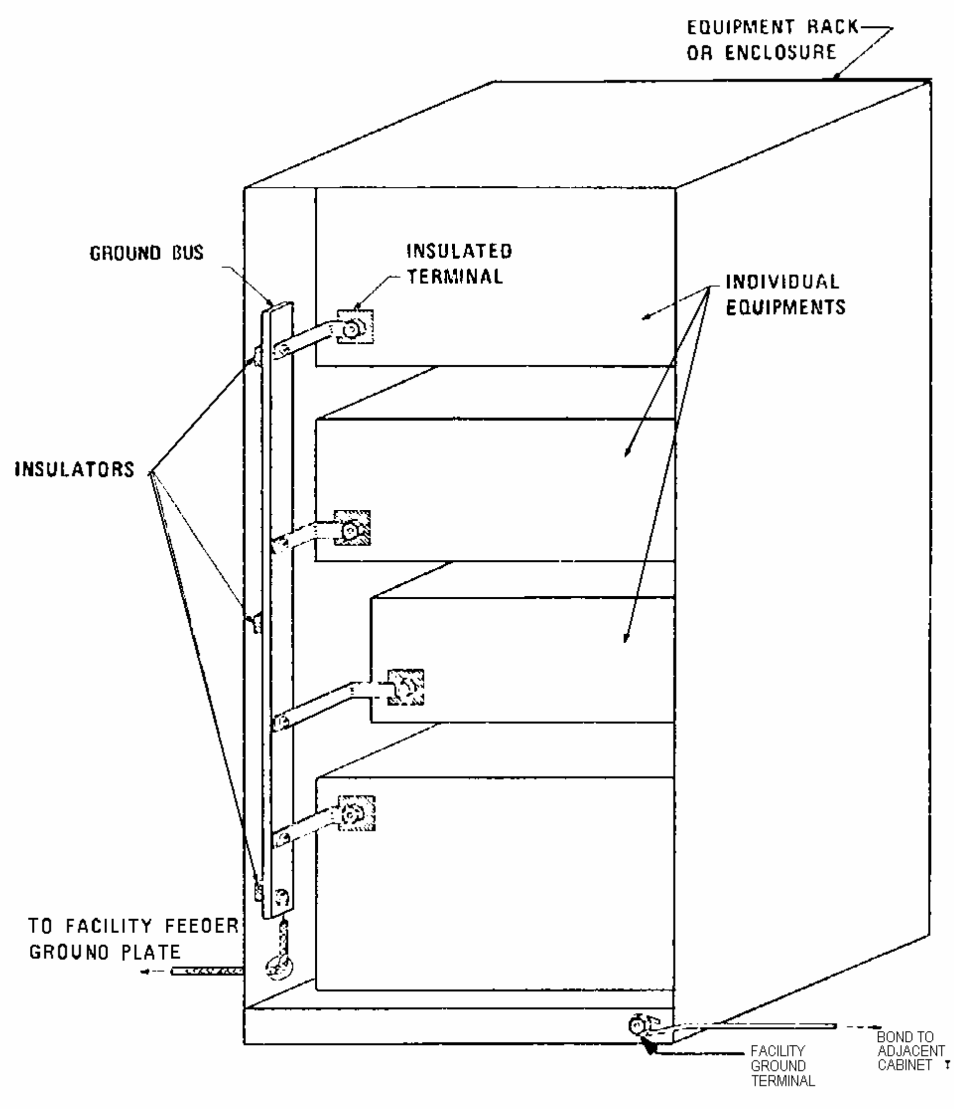
Ground Terminal Diagram



Visually Inspecting for Signal Reference Ground Isolation

When verifying that the signal reference ground is isolated from the chassis of the low frequency equipment, ensure that ground bus bars and any signal reference ground wires are not in contact with the chassis.

Unless proper installation procedures are followed, the isolated insulation resistance of the equipment will be defeated when the equipment chassis makes contact with the cabinet enclosure. See diagram below.



Note: The bus bar in the diagram above is isolated from the cabinet.

Inspecting Low Frequency Equipment (Continued)

Visually Inspecting for Balanced Lines

Visually inspecting for balanced lines between equipment cabinets ensures that grounding the cable shield connecting two or more pieces of equipment is grounded at only one end. This provides for a single-point ground in which there is only one path for the signal reference to ground. See diagram A below.

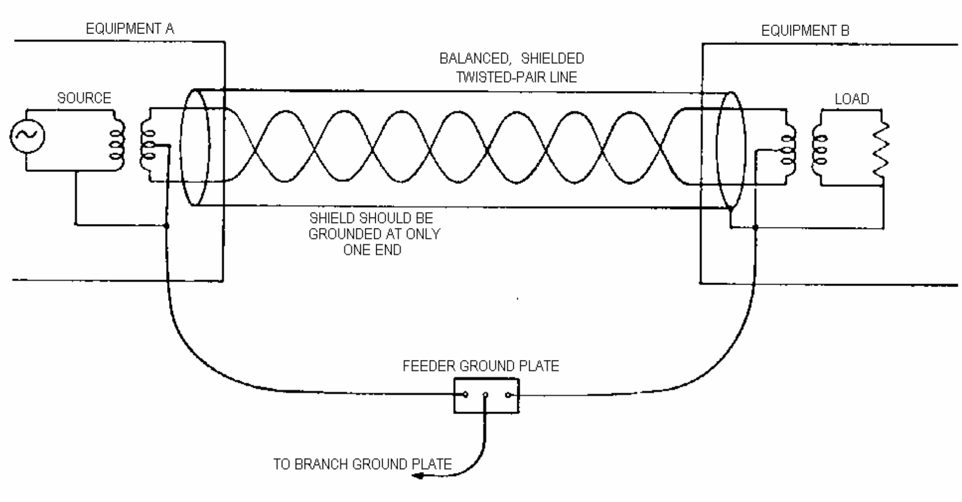


Diagram A

If the shield is grounded at both ends, it establishes two return paths for the signal ground and thus can create ground loops. See diagram B below.

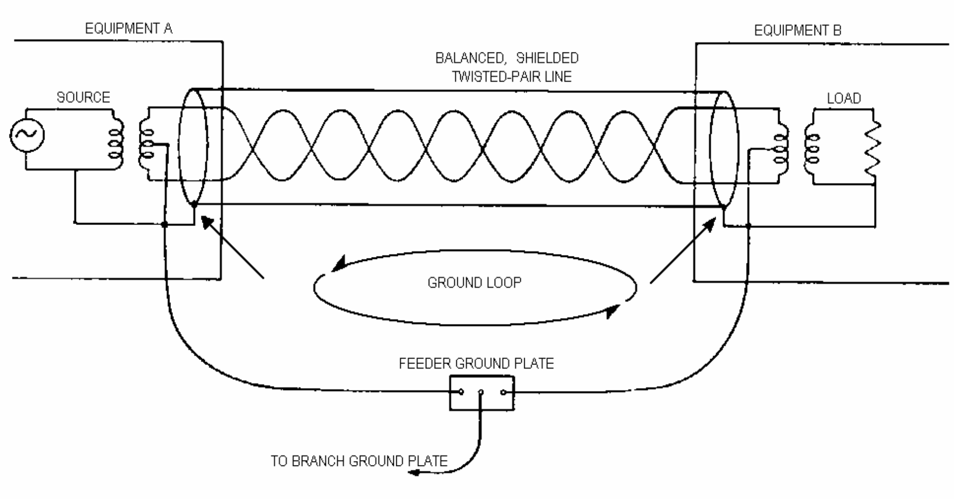


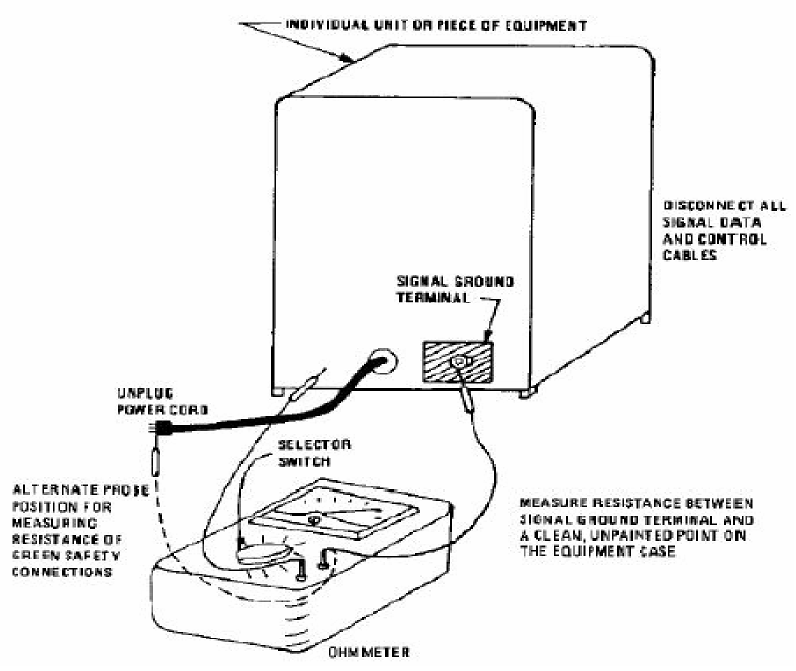
Diagram B

Inspecting Low Frequency Equipment (Continued)

Measuring Insulation Resistance

All low-frequency equipment must be isolated from the ground network and checked to ensure that the insulation resistance of the equipment is at least 1 megohm. Refer to the diagram below for measuring insulation resistance.

Measuring Insulation Resistance Diagram



Signal Ground Terminal to Signal Reference Ground Subsystem Cable Size

Use the table below to determine the required cable size for connecting the signal ground terminal to the signal reference ground subsystem.

AWG No.	Cross-Sectional Area in cmil
4/0	211,600
3/0	167,800
2/0	133,100
1/0	105,500
1	83,690
2	66,370
4	41,740
6	26,250
8	16,510
10	10,380
12	6,530
14	4,107
16	2,583
18	1,624
20	1,022

Inspecting High Frequency and Hybrid Equipment

Inspecting High Frequency Equipment

When connecting high frequency equipment to the signal reference ground subsystem, the chassis is normally used as the signal reference ground plane. The chassis is then grounded through the case or cabinet to the equipotential ground plane.

Yellow covered wire or cable of adequate size should be employed for all interconnections of the higher frequency signal reference network.

To interface signals between high-frequency equipment, use unbalanced, constant-impedance, transmission lines such as coaxial cables. The shield of coaxial cables should be grounded at both ends of the cable and at intermediate points along the cable run.

Inspecting Hybrid Equipment

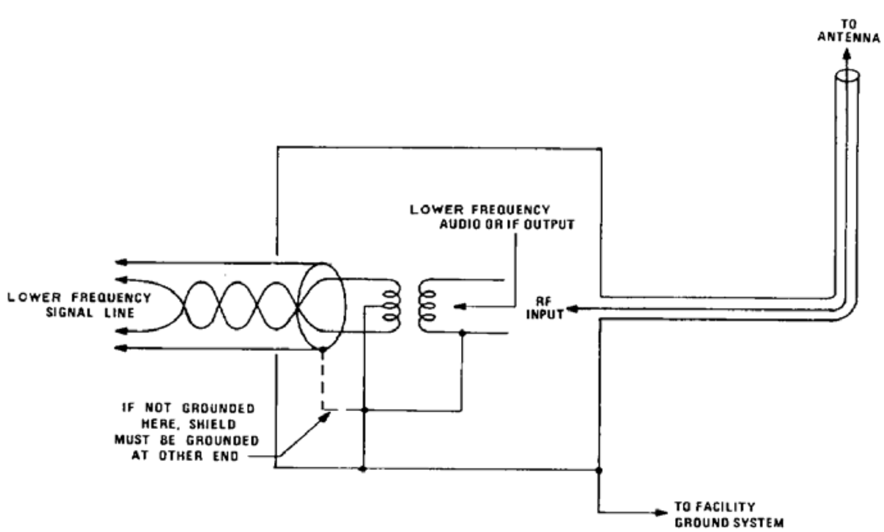
In equipment where both lower and higher frequency circuits must share a common signal ground, the equipment must be grounded using the same criteria as used for inspecting higher frequency equipment.

The important thing to remember is to interface the low- and high-frequency signals accordingly. For example, to interface:

Low frequency equipment	Use balanced, twisted-pair lines with the shield grounded at one end only.
High-frequency equipment	Use coaxial cables with the shield grounded at both ends.

Grounding Hybrid Equipment to the Signal Reference Ground

Refer to the illustration below for grounding hybrid equipment to the signal reference ground.



Inspection Job Aids

Introduction

To complete a visual inspection of the facility's signal reference ground subsystem, the first place to start would be to differentiate between the low frequency, high frequency and hybrid equipment. Once you have identified the various types of equipment, you will complete the checklists included for each type of equipment.

Low Frequency Equipment Visual Inspection Procedure

Step	Action	YES	NO	N/A
1	Obtain copies of MIL-STD-188-124B, NEC documentation and MIL-HDBK-419.			
2	Is the ground terminal correctly color-coded or identified with a yellow label?			
3	Are balanced signal lines used between equipment cabinets?			
4	Are the shields of cables utilized for low frequency such as telephone, audio and digital traffic with data rates less 38.4 KBPS connected to the earth electrode subsystem at only one point? *Ref: MIL-STD-188-124B, Para 5.1.1.4.3*			
5	Is the routing and layout of wire, are power lines and signal lines kept separate? *Ref: MIL-STD 188-124B, Para 5.3.2.5.2*			
6	Are signal lines shielded by using shielded cable, conductive conduit or conductive duct? *Ref: MIL-STD-188-124B, Para. 5.3.1* *MIL-HDBK-411B, Volume I, Para. 4.19.1.1*			
7	Are all signal lines separated from power circuits by a minimum of 15 cm (6 inch)? *Ref: MIL-HDBK-411B, Vol I, Para 4.19.1.2.*			
8	Are all metallic power, control and signal lines fed into a shielded enclosure through filters, feed-thru capacitors, or optic isolators? *Ref: MIL-STD-188-124B, Para 5.3.2.3*			

Continued next page

Inspection Job Aids (Continued)

Low Frequency Equipment Visual Inspection Procedure, (continued)

<table>
<tr><th>Step</th><th>Action</th><th>YES</th><th>NO</th><th>N/A</th></tr>
<tr><td>9</td><td>Are conductive gaskets and finger stock used on doors and covers used on shielded enclosures clean and in good repair?

Ref: MIL-STD-188-124B, Para 5.3.1</td><td></td><td></td><td></td></tr>
<tr><td>10</td><td>Is it possible to receive FM radio or television inside the shielded enclosure without the use of an antenna that is external to the enclosure? (Shielded Facilities Only)

Ref: MIL-STD-188-124B, Para 5.3.1.</td><td></td><td></td><td></td></tr>
<tr><td>11</td><td colspan="2">Is the proper size wire used for the signal ground cable?
<table>
<tr><th>Step</th><th>Action</th><th>Result</th></tr>
<tr><td>a.</td><td>Multiply the length of the signal ground reference cable by 500.</td><td>Total cmil:
__________</td></tr>
<tr><td>b.</td><td>Determine the next largest cross-sectional area using the AWG table on page 16.</td><td>Cross-sect.
__________</td></tr>
<tr><td>c.</td><td>Select the cable size according to the results in Step b using the table on page 16.</td><td>Cable size:
__________</td></tr>
</table></td><td></td><td></td></tr>
<tr><td colspan="5">End</td></tr>
</table>

Low Frequency Equipment Resistance Measurement Procedure

The following steps inspect the resistance measurement of low frequency equipment to the signal reference ground subsystem.

<table>
<tr><th>Step</th><th>Action</th><th>YES</th><th>NO</th><th>N/A</th></tr>
<tr><td>1</td><td>Disconnect all interface cables from the equipment.</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Is the resistance between the signal ground terminal and the equipment case within limits?<table><tr><th>If the resistance is...</th><th>Then...</th></tr><tr><td>Less than 1 megohm,</td><td>Continue to Step 3.</td></tr><tr><td>Greater than 1 megohm,</td><td>Skip to Step 7.</td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Are all cables disconnected from the equipment?<table><tr><th>If cables are...</th><th>Then...</th></tr><tr><td>Disconnected,</td><td>Continue to Step 4.</td></tr><tr><td>Not disconnected,</td><td>Disconnect remaining cables.</td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Is the signal ground terminal isolated from the equipment chassis?<table><tr><th>If signal ground terminal is...</th><th>Then...</th></tr><tr><td>Isolated from chassis,</td><td>Skip to Step 7.</td></tr><tr><td>Not isolated from chassis,</td><td>Continue to Step 5.</td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Isolate signal ground terminal from chassis.</td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Repeat Step 2.</td><td></td><td></td><td></td></tr>
</table>

Continued next page

Inspection Job Aids (Continued)

Low Frequency Equipment Resistance Measurement Procedure, contd.

<table>
<tr><th>Step</th><th>Action</th><th>YES</th><th>NO</th><th>N/A</th></tr>
<tr><td>7</td><td>Is the resistance measurement between the green safety wire and the equipment case correct?
<table><tr><th>If the resistance between the green safety wire and chassis is..</th><th>Then..</th></tr><tr><td>Less than .1 ohm, (within accepted limits)</td><td>Skip to Step 9.</td></tr><tr><td>Greater than .1 ohm, (outside of accepted limits)</td><td>Continue to Step 8.</td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>Is the green wire connected to the equipment case?</td><td></td><td></td><td></td></tr>
<tr><td>9</td><td>Is the green wire connected to bare metal?</td><td></td><td></td><td></td></tr>
<tr><td>10</td><td>Is the green wire securely fastened to the equipment case?</td><td></td><td></td><td></td></tr>
<tr><td>11</td><td>Is the proper size wire used for the signal ground cable according to Step 11 on page 20?
<table><tr><th>If the signal ground wire size is..</th><th>Then..</th></tr><tr><td>Correct,</td><td>Continue to Step 12.</td></tr><tr><td>Not correct,</td><td>Replace the incorrect wire size with the correct size.</td></tr></table></td><td></td><td></td><td></td></tr>
<tr><td>12</td><td>Connect the signal ground terminal to the nearest ground plate of the low frequency signal network.</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">End of Procedure</td></tr>
</table>

Inspection Job Aids (Continued)

High Frequency Equipment Visual Inspection Procedure

<table>
<tr><th>Step</th><th>Action</th><th>YES</th><th>NO</th><th>N/A</th></tr>
<tr><td>1</td><td>Obtain copies of MIL-STD-188-124B, NEC documentation and MIL-HDBK-419.</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td>Is the ground terminal correctly color-coded?</td><td></td><td></td><td></td></tr>
<tr><td>3</td><td>Is the high frequency reference point directly grounded to the chassis and the equipment case?</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Is the high frequency plane directly grounded to the chassis and the equipment case?</td><td></td><td></td><td></td></tr>
<tr><td>5</td><td>Are the shields of cables utilized for high frequency terminated to a ground at both ends?</td><td></td><td></td><td></td></tr>
<tr><td>6</td><td>Are the interfacing cables properly matched constant-impedance cables?</td><td></td><td></td><td></td></tr>
<tr><td>7</td><td>Do the line shield terminations outside of the equipment case have any pigtails?</td><td></td><td></td><td></td></tr>
<tr><td>8</td><td>Are the interfacing cable connectors properly mounted?</td><td></td><td></td><td></td></tr>
<tr><td>9</td><td>Are the interfacing cable connectors secure?</td><td></td><td></td><td></td></tr>
<tr><td>10</td><td>Are the interfacing cable connectors clean?</td><td></td><td></td><td></td></tr>
<tr><td>11</td><td colspan="4">Is the signal ground cable size correct?
<table>
<tr><th>Step</th><th>Action</th><th>Result</th></tr>
<tr><td>a.</td><td>Multiply the length of the signal ground reference cable by 500.</td><td>Total cmil: __________</td></tr>
<tr><td>b.</td><td>Determine the next largest cross-sectional area using the AWG table on page 16.</td><td>Cross-sect. __________</td></tr>
<tr><td>c.</td><td>Select the cable size according to the results in Step b using the table on page 16.</td><td>Cable size: __________</td></tr>
</table>
Note: Cable must be at least 2000 cmil/foot</td></tr>
<tr><td colspan="5">End</td></tr>
</table>

Inspection Job Aids (Continued)

High Frequency Equipment Resistance Measurement Procedure

The following steps inspect the resistance measurement of low frequency equipment to the signal reference ground subsystem.

<table>
<tr><th>Step</th><th>Action</th><th>YES</th><th>NO</th><th>N/A</th></tr>
<tr><td>1</td><td>Disconnect all interface cables from the equipment.</td><td></td><td></td><td></td></tr>
<tr><td>2</td><td colspan="4">Is the resistance between the interfacing cable connectors within limits?
<table><tr><th>If the resistance is..</th><th>Then..</th></tr><tr><td>Greater than 20 milliohms,</td><td>Continue to Step 3.</td></tr><tr><td>Less than 20 milliohms,</td><td>Skip to Step 4.</td></tr></table></td></tr>
<tr><td>3</td><td>Replace interfacing cable connectors and repeat Step 2.</td><td></td><td></td><td></td></tr>
<tr><td>4</td><td>Restore and secure all disconnected interface cables that were disconnected in Step 1 above.</td><td></td><td></td><td></td></tr>
<tr><td colspan="5">End</td></tr>
</table>

Practice Exercise

Exercise Instructions

This exercise is meant to check your comprehension of the material covered in this lesson. Read each question and write the answers in the spaces provided. Check your answers in the Feedback section following the exercise. If you are having difficulty understanding a section, go through it again or ask someone for help.

a. The three types of signal reference ground network configurations are:

____

____

____

b. Which type of equipotential ground plane must be installed during new construction of a facility? ______________________________

c. In a single-point ground system, how many paths are there for the signal reference to ground? ______________________________

d. What should the resistance be when measuring between the signal ground terminal and the equipment case? ______________________________

e. What should the resistance be when measuring between the green safety wire and the equipment case? ______________________________

Practice Exercise Feedback

Exercise Answers and References

Compare your answers to the following:

Question	Answer	Reference Page
1	Floating, single-point, multi-point	5-2
2	Concrete floor with embedded copper grids	5-7
3	One	5-13
4	Greater than 1 megohm	5-18
5	.1 ohm or less	5-19

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Appendix A

PAMPHLET REVIEW QUIZ

1. Data gathered during the site survey consists of data collected IAW: __________________.

2. For a complete list of site survey requirements, refer to: _____________________________.

3. Electronic and telecommunications equipment are effectively grounded through ______ accidental contact or intentional contact.

4. Facility ground system inspections and site surveys are conducted: at least _____________.

5. _____ from buried electrodes entering buildings often serve as the principal ground point for connections to equipment ground systems.

6. For metallic and non-metallic hull ships, all Class _____ extensions to the ship's ground potential shall be designated as the ship's ground plane.

7. The most common type of ground rods are those made of ____________________________.

8. If at all possible, fault protection conductors should be physically __________ from signal reference ground conductors except at where they connect to the earth electrode subsystem.

9. List the four elements that make up the facility ground system.

    ____

    ____

    ____

    ____

10. Lighting protection devices include:
    ____.

Appendix B

PAMPHLET REVIEW QUIZ – ANSWER KEY

Question	Answer	Reference Page
1.	MIL-STD-188-124B, National Electrical Code (NEC)	1-3
2.	MIL-HDBK- 419A, Vol. II Section 1.4.9.	1-3
3.	capacitive coupling	1-2
4.	annually	1-3
5.	Extensions	2-3
6.	"A"	2-5
7.	copper-clad steel	2-3
8.	separate	3-3
9.	The four elements that make up the facility ground system are: • Earth electrode subsystem or shipboard ground plane. • Fault protection subsystem. • Lightning protection subsystem. • Signal reference ground subsystem.	1-2
10.	Ground rods, down conductors, and air terminals	4-6

Appendix C
GLOSSARY

Air Terminal
The lightning rod or conductor placed on or above a building, structure, tower, or external conductors for the purpose of intercepting lightning.

American National Standards Institute (ANSI)
A private, non-profit organization that administers and coordinates the U.S. voluntary standardization and conformity assessment system in order to enhance both the global competitiveness of U.S. business and the U.S. quality of life by promoting and facilitating voluntary consensus standards and conformity assessment systems, and safeguarding their integrity.

Attractive Area
Areas that stems from tall structures such as antenna towers and flagpoles (which extend past their surroundings), that tend to attract more lightning than their cross-sectional area might otherwise indicate. See Cone of Protection/Zone of Protection.

Bond
A conductive (electrical current) path between two metallic surfaces by welding, bolting/clamping or addition of a bond strap.

Bond Classes (Classification)
Methods used in creating a bond, such as a:

- Class A bond: Welding of metallic surfaces.
- Class B bond: Bolting or clamping of metallic surfaces.
- Class C bond: Bridging using a metallic strap.

Bonding
The act of creating a bond.

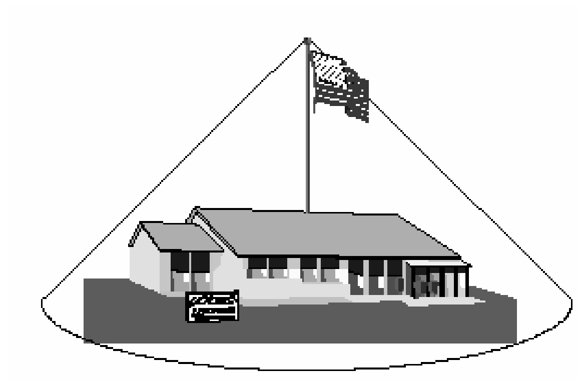
Bonding
An electrical union between two metallic surfaces used to provide a low-impedance path between them.

Circuit Breaker
A device designed to open and close a circuit by non-automatic means and to open a circuit automatically on a predetermined overcurrent without damage to itself.

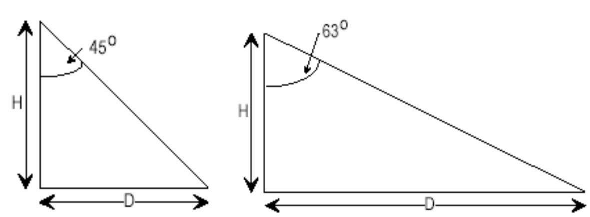
Conductor
A substance, body or medium that allows sound, electricity, light or heat to pass along or through it.

Cone of Protection or Zone of Protection

Areas below and adjacent to taller structures that attract lightning to themselves and thus create a space that is substantially immune to direct lightning discharges.



The cone of protection is expressed as a ratio of the horizontal protected distance (D) to height (H) of the mast or wire. A 1:1 ratio is recommended for critical structures, while a 2:1 ratio is acceptable for ordinary structures. A communications facility (C-E) is an example of a critical structure.



Disconnecting Means

A device, or group of devices, or other means by which the conductors of a circuit can be disconnected from their source of supply. (For example, fuses, circuit breakers, and relays.)

Down Conductor

The conductor connecting the air terminal or overhead ground wire to the earth electrode subsystem.

Electrode Conductors

Conductors used to connect equipment grounding conductors or grounded conductors to the earth electrode subsystem.

Electro-Magnetic Interference (EMI)

Electromagnetic energy that interferes with the detection and analysis of a desired signal.

Appendix C
GLOSSARY (CONTINUED)

Equipment Conductors	Conductors used to interconnect all non-current-carrying metal parts of equipment, raceways, and other enclosures to the system grounded conductor, the grounding electrode conductor, or both, at the service equipment or at the source of a separately derived system.
Equipotential Ground Plane	A ground plane that has the same or uniform potential throughout.
Equipotential Plane	A grid, sheet, mass or masses of conducting material which, when bonded, offers a negligible impedance to current flow.
Exothermic Welding	A commercially established technique for joining copper bus bars and earth and lightning conductors requiring no external power or heat source.
Fall of Potential Technique	A method commonly used to measure ground resistance by employing three terminals: the ground electrode under test, a current electrode and a voltage probe. Current is applied to the ground electrode under test and measured at different distances from the ground electrode using the voltage probe.
Flashover	Conduction of high voltage to objects as close as 14 inches away developed by a lightning strike.
Ground	Point, plane or surface designated as the zero potential common reference point for electrical or electronic equipment.
Ground	A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth, or to some conducting body that serves in place of the earth.
Ground Fault Circuit Interrupter (GFCI)	A device intended for the protection of personnel that functions to de-energize a circuit or portion thereof within an established period of time when a current to ground exceeds some predetermined value that is less than that required to operate the overcurrent protective device of the supply circuit.
Grounded	Connected to the earth or some conducting body that serves in place of the earth.
Grounded Conductor	A conductor in a system or circuit that is intentionally grounded. In electrical/electronic equipment, this is usually the neutral lead supplied by the power source.

GLOSSARY (CONTINUED)

Grounding Conductor

A conductor used to connect equipment or the grounded circuit of a wiring system to the earth electrode subsystem. In electrical/electronics equipment, this is usually the green safety conductor supplied by the power source. Grounding of the fault protection subsystem is accomplished via “grounding” conductors and must meet certain specifications, depending on their use. Grounding conductors types include:

- Equipment
- Electrode

Grounding Electrode Conductor

The conductor used to connect the grounding electrode to the equipment grounding conductor, to the grounded conductor, or to both, of the circuit at the service equipment or at the source of a separately derived system.

Grounding Equipment Conductor

The conductor used to connect the noncurrent-carrying metal parts of equipment, raceways and other enclosures to the system grounded conductor, the grounding electrode conductor, or both at the service equipment or at the source of a separately derived system.

Lightning

A transient, high-current, electrical discharge associated with thunderstorm activity. Lightning can occur within a cloud, from cloud-to-cloud, or from cloud-to-earth. The greatest threat comes from cloud-to-earth discharges because of the potential for danger to personnel and destruction of property and equipment.

National Electrical Code (NEC)

A set of regulations pertaining to electrical installation and design in the interest of the protection of life and property. The NEC is adopted by NFPA and approved by ANSI. It is the preferred standard of guidelines used by most electrical regulatory boards in the USA.

National Fire Protection Association (NFPA)

The world’s leading advocate of fire prevention and an authoritative source on public safety. NFPA’s 300 codes and standards influence every building, process, service, design, and installation in the United States, as well as many of those used in other countries. NFPA is accredited by the American National Standards Institute (ANSI).

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Suggestions and Corrections

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