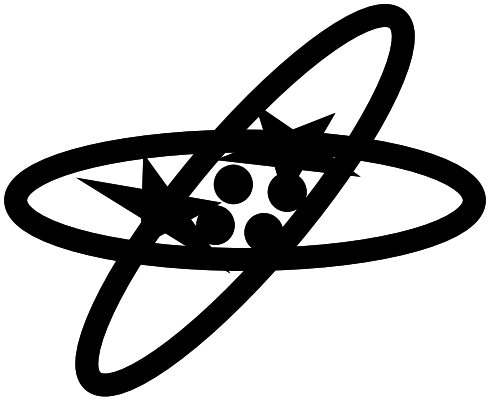
U.S. Department of
Homeland Security

United States
Coast Guard

ET1 UNIT 2: ELECTRONIC INSTALLATION STANDARDS



Coast GUARD
Training Center Petaluma

U. S. Coast Guard
Pamphlet No. P12203
(11/09)

ET1 UNIT 2: ELECTRONIC INSTALLATION STANDARDS

Creation Date: 11/09
Revision Date: 11/12

U. S. Coast Guard
Training Center
Petaluma, CA. 94952
(707) 765-7129

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

Record of Changes			
Change Number	Date of Change	Date Entered	By Whom Entered

TABLE OF CONTENTS

TITLE	PAGE
Acknowledgements and References	ii
Notice to Students	iii
Lessons	
#1 How to Verify SOVT	1-1
#2 How to Verify Proper Grounding for Electronic Systems	2-1

Appendixes

A Pamphlet Quiz	A-1
B Pamphlet Answers	B -1

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. Copies or reproductions of the material are NOT 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:

ETC Chris Meyer

ETC Kevin Odom

ETC David Baker

ET1 Rodney Spalding

Mr. Kevin Glenn

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)
- SOVT documentation
- 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
- Grounding, Bonding, and Shielding for Electronic Equipment & Facilities, MIL-HDBK-419A

Notice to Students

Purpose

This pamphlet serves as a training aid to provide you with a general knowledge of Electronic Installation Standards tasks required of an ET1.

Important Note

This text has been complied 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 revision 03-2009.

Course Content

This course content is based on the requirements stated in the Enlisted Performance Qualifications revision 03-2009.

Record of Changes

From time to time courses, after they are printed, have minor editorial changes made to them by the Subject Matter Specialist that do not require a new course. The student is responsible for any changes made to the course after printing and receipt from the Coast Guard Institute. The Coast Guard Institute will post on their web site a listing of current changes based on the course code and edition that should be downloaded in a **.pdf** format and entered in the current course material. The Coast Guard Institute will send an errata sheet out with each ordered course that list the required changes.

Pamphlet Content

This pamphlet contains two lessons:

Lesson 1: How to Verify SOVT

Lesson 2: How to Verify Proper Grounding for Electronic Systems

Notice to Students

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 each pamphlet has a pamphlet review quiz. You will find the answers to each quiz on the pages following the quiz. Included are the reference pages for the answers.

These self-quizzes are meant to check your comprehension of the material you covered. If you are having 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 (EOCT).

SWE Study Suggestion

Servicewide exam questions for your rate and pay grade are based on the Professional and Military Requirements sections of the Current information is available from the Enlisted Performance Qualifications revision 03-2009.

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

Lesson 1

HOW TO VERIFY SOVT

Overview

Introduction

This lesson introduces the tasks and documentation involved in performing a System Operation and Verification Test (SOVT). The following topics will be presented in this lesson:

- SOVT Purpose
- SOVT Definition
- Key Personnel
- Role of the ET
- SOVT Document
- Signed SOVT Document
- Links to SOVT Examples

Objectives

Given the proper equipment and job aids, **VERIFY** equipment operation via the System Operation and Verification Test (SOVT).

References

The following references were used for this lesson:

- Electronics Manual, COMDTINST M10550.25 (series)
- SOVT Documentation
- Equipment Technical Manual

SOVT Purpose

Purpose

The purpose of the SOVT process and documentation is to verify, validate, and demonstrate that the newly installed equipment, system, or systems and all other affected systems are operating as intended.

Definition

The definition of SOVT is as follows:

A test or battery of tests that verifies that the installed or modified equipment, systems, interfaces with existing systems, and systems impacted by the installation are properly installed and operates as intended at the platform specific location and environment.

Key Personnel

Key personnel involved in the planning and execution of a SOVT are listed below:

- System Engineer or Technical Lead
- In-Service Engineering Activity (ISEA) Representative
- Installation Project Engineer
- SOVT Manager
- Platform Witness
- Additional personnel as necessary (e.g., CO, XO, Navigator, LPO, EMO)

Role of the ET

The role of an ET in the SOVT process will be to serve as a **"Platform Witness".** At a minimum, the Platform Witness should be a basic system qualified operator and/or maintainer . The purpose of the platform witness is **observe** and **verify** the following:

- Required tests as approved by the competent technical authority are properly completed
- Results are properly recorded in tables provided within each section of the SOVT Document
- Discrepancies found during testing and their current status are recorded in Appendix B of the SOVT Document
- Verify test completion and results by signing SOVT Document

SOVT Documentation

SOVT Documentation

The SOVT document provides procedures with pass/fail criteria as applicable to verify and validate the following:

- Safety
- Security
- Environmental conditions
- Signal connectivity
- Configuration (i.e., strapping, ECs, etc.),
- Internal and external system interfaces
- System integration
- Offline/Online system functionality
- Required operational modes
- Impacted equipment/systems functionality
- Designed operating requirements

When required to verify external system interfaces or functions that can only be tested with another platform, the SOVT document contains procedures to test the operational interface and functionality with other platforms.

SOVT Document (Continued)

Document Information

The following table describes each section and the type of information that must be included in the SOVT:

Section	Type of Information
Cover Sheet	Each SOVT document shall include a cover sheet that provides key identification data about the document. At a minimum, the cover sheet shall include a document title, document number, project identification number (platform SOVTs only), distribution statement, and the date the document was approved.
Approval Statement	Immediately following the cover sheet, each approved SOVT shall include the developer's signature, certifying compliance with the SOVT Preparation and execution Guide (SPEG), as well as a signed statement indicating by whose authority the SOVT document was approved for.
Front Matter	The document shall also include a record of changes, table of contents, and listings of any tables, figures, and appendices.
Section 1 *Introduction and Administration*	This section shall introduce and summarize the SOVT document. At a minimum, this section shall include the following information: • Purpose of SOVT document • Scope of the SOVT document • References • Points of Contact • Applicable safety and security information • Summary description of systems under test • Functional block diagrams • Required test and support equipment and software

Continued on next page

SOVT Document (Continued)

Document Information (Continued)

Section	Type of Information
Section 2 *Inspection and Validation Tests*	This section describes those aspects of the system or specific installation that should be inspected and validated. The results of the audit are recorded in Appendix A of the SOVT document. As a minimum the inspection should include the following: • Audit of hardware and software configuration • Validation that all safety and security measures associated with this system or specific installation exist and no hazards are left unresolved, e.g. safety interlocks, raised floor hazards • Observation of correct installation standards (e.g., TEMPEST, power, etc.) • Measurement of adequate clearance for personnel and equipment • Inspection of cable management to include stress relief and red/black separation
Section 3 *Cold Checks*	This section provides procedures to ensure that the installation has been accomplished in accordance with approved installation plans and specifications. Cold Check tests shall verify: • Cabinet power and ground connections • Equipment power and ground connections • Signal cable connections
Section 4 *Equipment Tests*	This section provides “off-line” testing procedures that determine if individual equipment performs within the expected performance parameters. These tests are conducted in isolation from the integrated system.
Section 5 *Intra-System Tests*	This section provides procedures for testing within a single system. It shall likely include tests between equipment or groups of equipment within the same system to verify that the system is functioning correctly.

Continued on next page

SOVT Document (Continued)

Document Information (Continued)

Step	Explanation
Section 6 *Inter-System Tests*	This section provides procedures that test functionality and interfaces between the installed or changed system and the other systems with which it interfaces.
Section 7 *Operational Tests*	This section provides procedures that cutover the newly installed or upgraded system to an "on-line" status and tests functions that couldn't be tested "off-line".
Section 8 *At-Sea and Other Special Tests*	This section provides procedures that are specifically aimed at conducting a test or a series of tests in a real time "At-Sea" scenario.
Appendices	The standardized SOVT document, as a minimum, shall include the following appendices: • Configuration Audit Results • Record of Resolved and Unresolved SOVT Discrepancies • SOVT Signature Page ***Note:*** This document is not readily available for printing. The SOVT personnel shall make their own word document using formatting that is easily readable. This document is always submitted to the SMEF for the system.

Signed SOVT Document

The signed SOVT document is defined as:

- A completed or executed SOVT plan that has been witnessed and signed, with all test results and any discrepancies recorded.

The signing of the SOVT by the Platform Witness is commonly seen as the point in time when the system is deemed operational, quite possibly with a work around if there are any open discrepancies. The only valid reason for not signing the SOVT is if the testing is incomplete and the system is not operational.

SOVT Examples

Links to Examples

Although SOVT documentation is standardized in format, the content will vary widely based on the equipment and installations to be tested, the type of test performed and the operating platform upon which the test is conducted. These variables preclude this lesson from containing all of the possible test procedures and checklists that a Platform Witness may be required to verify. To assist you in the performance of this task, the table below provides links to on-line examples of SOVT documentation and along with check-off sheets which provide instruction and diagrams:

Note: *The links below will only be available on the CGWEB using a SWIII. For review at home you will need to print the documents out using the SWIII.*

Example	Link
110’ Automated Information System (AIS) SOVT	http://cgweb.lant.uscg.mil/c2cen/Files/110_WPB_AIS_SOVT.pdf
MX-420 DGPS	http://cgweb.lant.uscg.mil/c2cen/Files/MX-420-SMEF-ADVIS-SOVTwithNATON.pdf
47’ Scalable Integrated Navigation System (SINS)	http://cgweb.lant.uscg.mil/c2cen/Files/47SOVT.pdf

Review Quiz

Questions

1. What does acronym SOVT stand for?

   A. System Order and Verification Test
   B. System Operation and Verification Test
   C. Simulated Ordnance and Variation Test
   D. Simulated Operation and Variation Test

2. What is the purpose of a SOVT?

   _____

   _____

3. What is the difference between an Intrasystem test and an Intersystem test?

   _____

   _____

This page intentionally left blank

Review Quiz Answers

Block Label

Question	Answer	Reference
1.	B	1-1
2.	To verify, validate, and demonstrate that the newly installed equipment, system, or systems and all other affected systems are operating as intended.	1-2
3.	An Intrasystem test checks functionality within a single system and Intersystem tests checks functionality within multiple systems.	1-5 and 1-6

`

Lesson 2

HOW TO VERIFY PROPER GROUNDING OF ELECTRONIC EQUIPMENT

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.

Objectives

Upon completing this lesson, you will be able to:

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

References

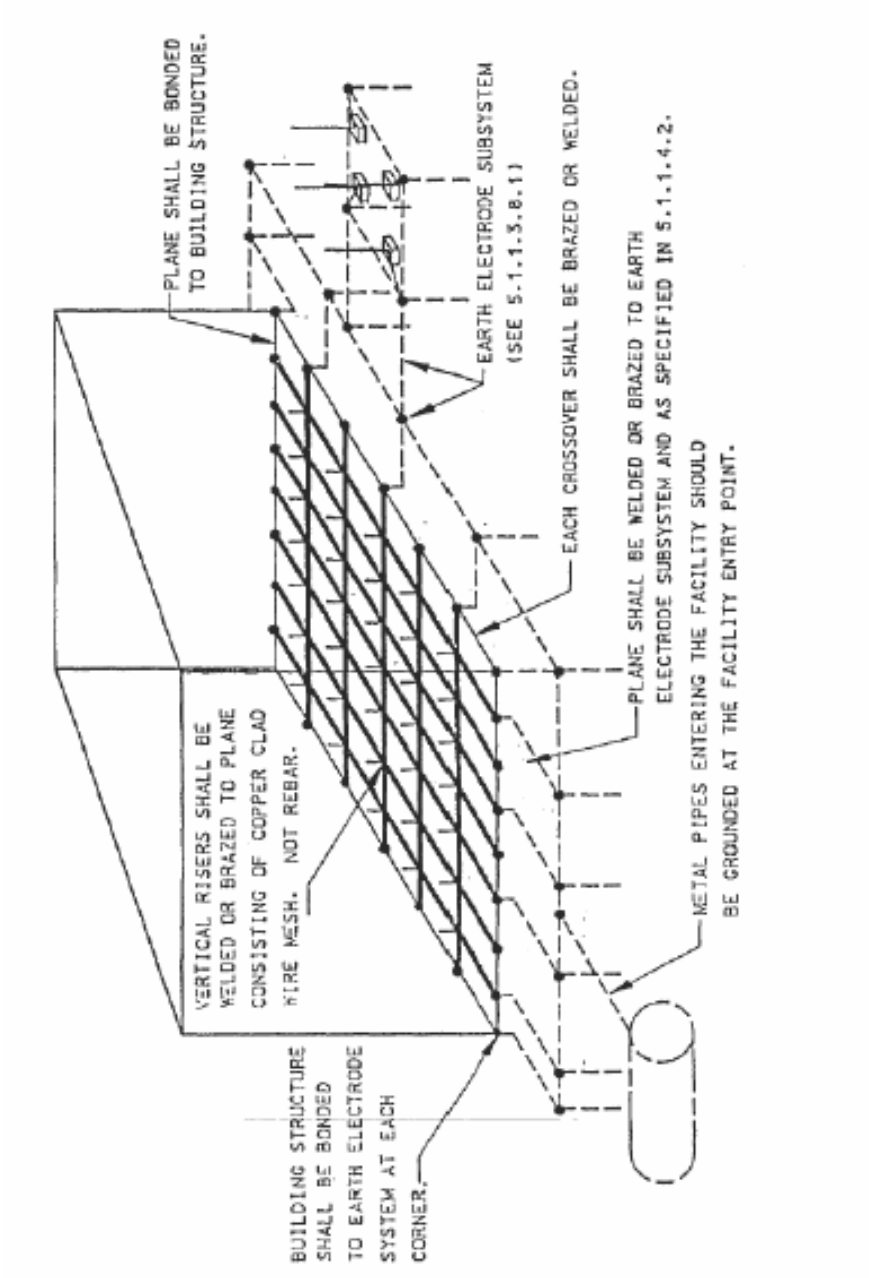
The following lesson was written using the following references:

- 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
- Grounding, Bonding, and Shielding for Electronic Equipment & Facilities, MIL-HDBK-419A

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

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
- 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)
- 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).

Earth Electrode Subsystem (Continued)

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

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.

Metal 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

Metal 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.

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 Requirements

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.

Earth Electrode Subsystem Visual Inspect

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. 1/0AWG, 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

Continued on next page

Inspection Procedures (Continued)

Fall of Potential Method

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

Inspection of 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

Fault Protection

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

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

Conductors

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

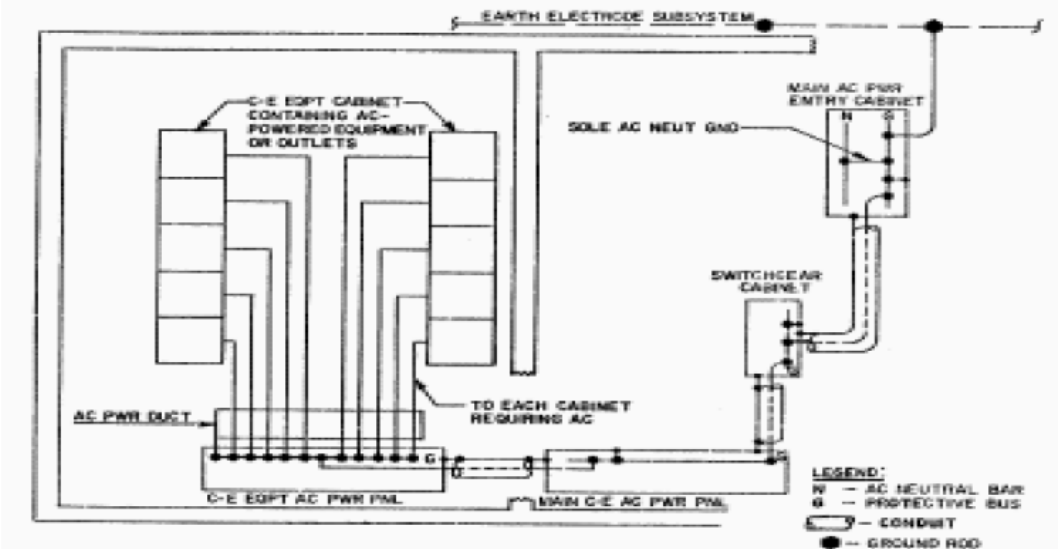
Note: *If at all possible, fault protection conductors should be physically separate from signal reference ground conductors except at where they connect to the earth electrode subsystem.*

Continued on next page

Fault Protection (Continued)

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 equipment and from the equipment to ground. See example below:



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.*

Continued on next page

Fault Protection (Continued)

Grounding Electrode 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 steel

Grounding Electrode Types

Grounding electrode conductors may be:

- Solid
- Stranded
- Insulated
- Covered
- Bare wires

Fault Protection (Continued)

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

Fault Protection Devices

Introduction

Fault protection devices include:

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

Fuses

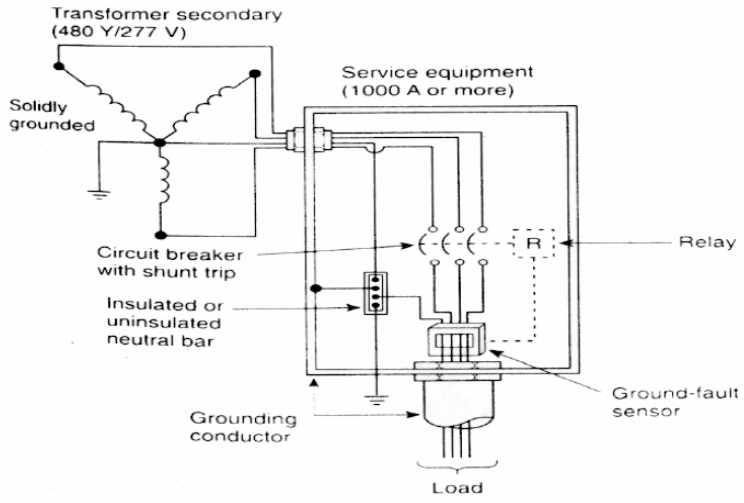
Each ungrounded service conductor (phase lead) should have overload protection provided by an over-current device such as a fuse. The fuse should be in series with each ungrounded service conductor and have a rating or setting no higher than the current carrying capability of the conductor.

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. Below is an example:



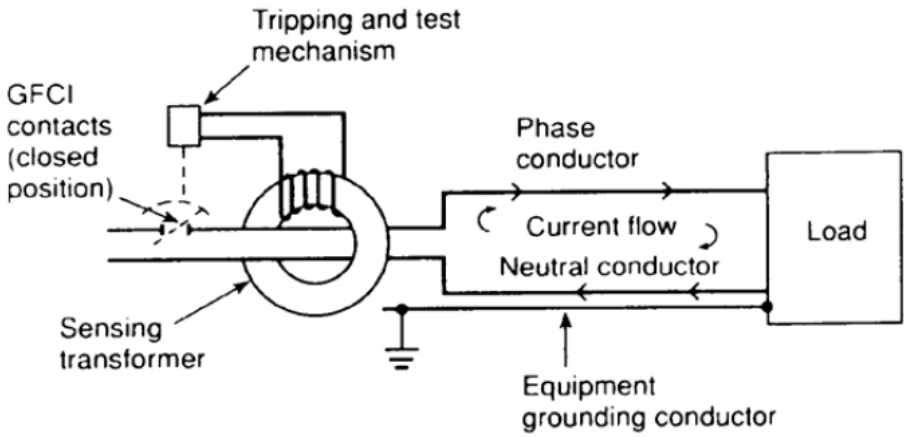
Continued on next page

Fault Protection Devices (Continued)

GFCIs

GFCIs (Ground Fault Circuit Interrupters) 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

Inspection

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.

Fault Protection 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.

Inspection Tools

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

Fault Protection Inspection Job Aids (Continued)

Inspection Procedure (Cont'd)

Step	Action	Yes	No	N/A
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*			
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*			

Continued on next page

Fault Protection Inspection Job Aids (Continued)

Inspection Procedure (Cont'd)

Step	Action	Yes	No	N/A
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*			

Electrical Inspection Procedure

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*			

Inspecting Lightning Protection Subsystems

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
- 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

Fundamentals

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

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

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.

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

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, un-spliced 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 possess the conductivity to withstand the high lightning current that will pass through it.

Air Terminal Placement

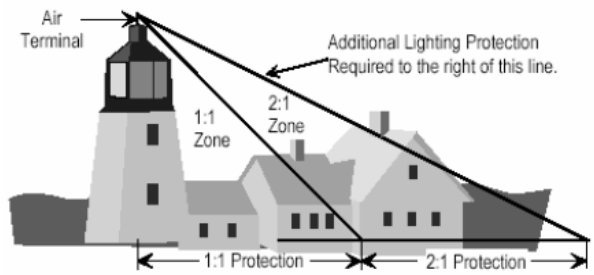
The air terminal should be placed in an area where lightning will most likely strike. (For example, the highest point of a structure, such as a chimney that extends past the roof in a building.) Refer to the chart below:

If a 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

Protection Devices (Continued)

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.



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.

Continued on next page

Protection Devices (Continued)

Air Terminal Placement on Roofs

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

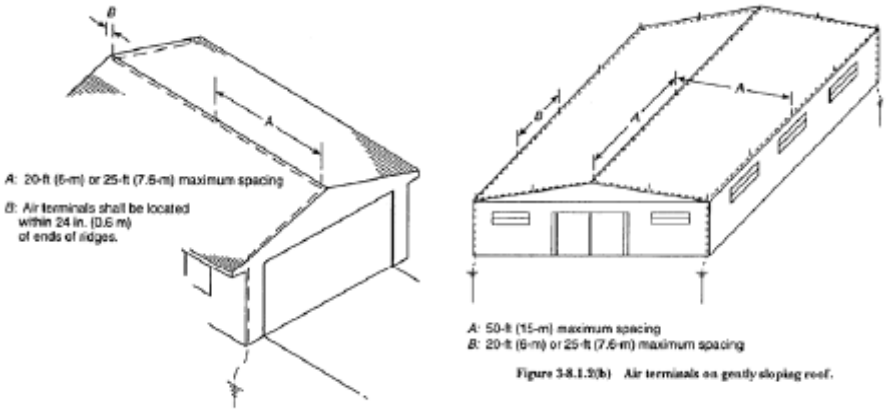
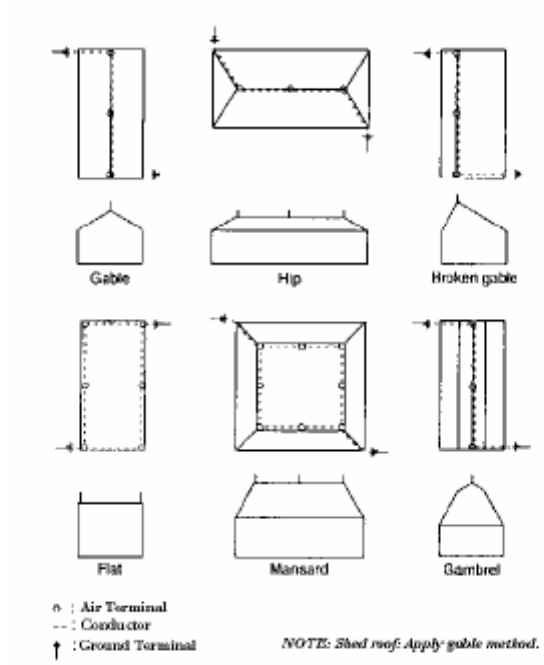


Figure 3-8.1.2(b) Air terminals on gently sloping roof.



Continued on next page

Protection Devices (Continued)

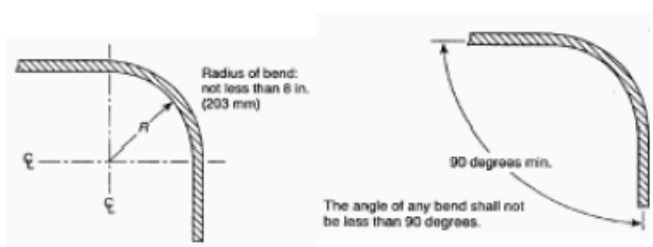
Down Conductors

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:

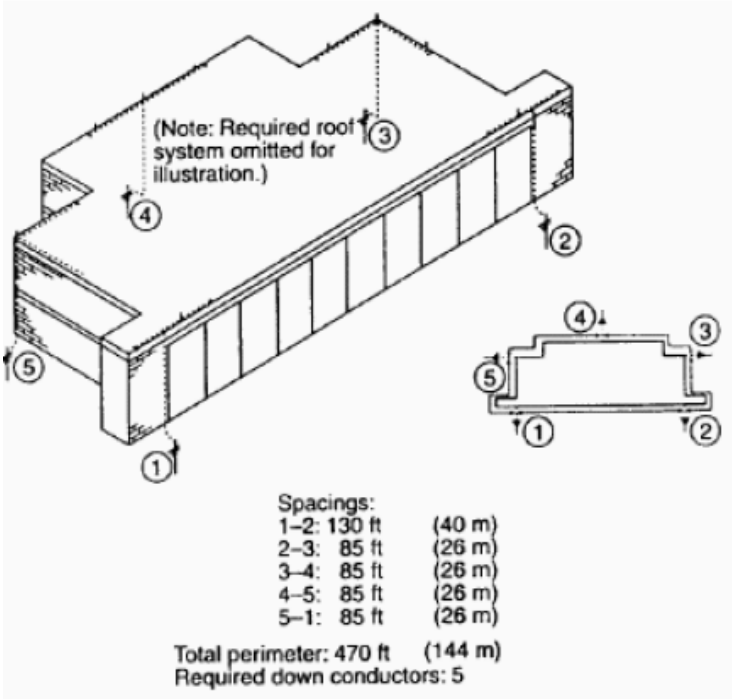
Conductors up to 75 ft.	The maximum DC resistance shall not be greater than 0.176 ohms per 1000 ft.
Conductors more than 75 ft.	The maximum dc resistance shall not be greater than 0.088 ohms per 1000 ft.
Size	The size of the wire shall not be less than No. 14 AWG. (No. 6 AWG copper wire is recommended).
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. 

Continued on next page

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.



Continued on next page

Protection Devices (Continued)

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
- 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).

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 Handbook 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*			
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*			

Continued on next page

Lightning Protection Inspection Job Aid (Continued)

Procedure (Cont'd)

Step	Action	Yes	No	N/A
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? *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*			
16.	Are exposed and underground power lines, not otherwise protected, provided with UL approved lightning arrestors, also known as transient voltage surge suppressors (TVSS)? *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*			

Lightning Protection Inspection Job Aid (Continued)

Procedure (Cont'd)

Step	Action	Yes	No	N/A
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?			

Inspecting Signal Reference Ground Subsystems

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.

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.

Grounding 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

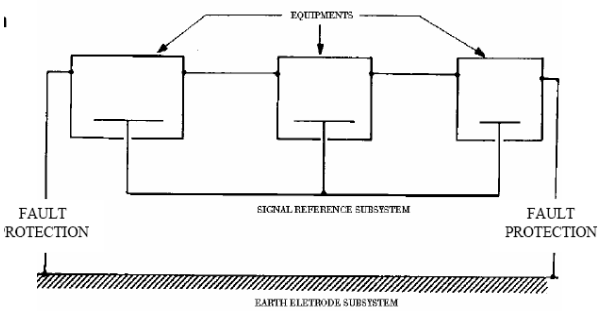
Introduction

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 lightning 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 Diagram

A floating ground subsystem is depicted below:



Single Point Ground Configuration

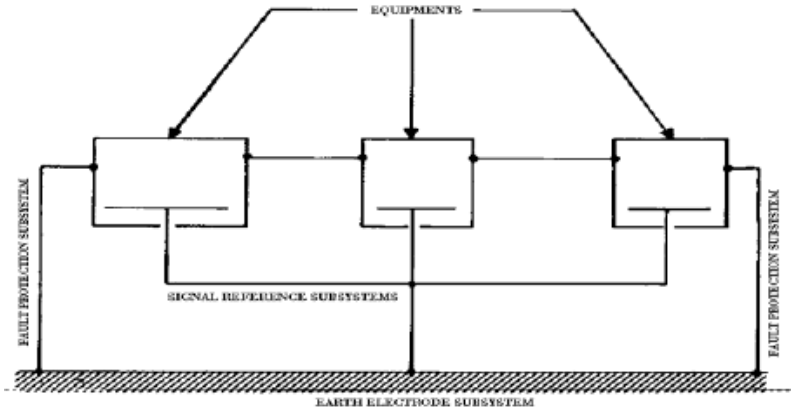
Introduction

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

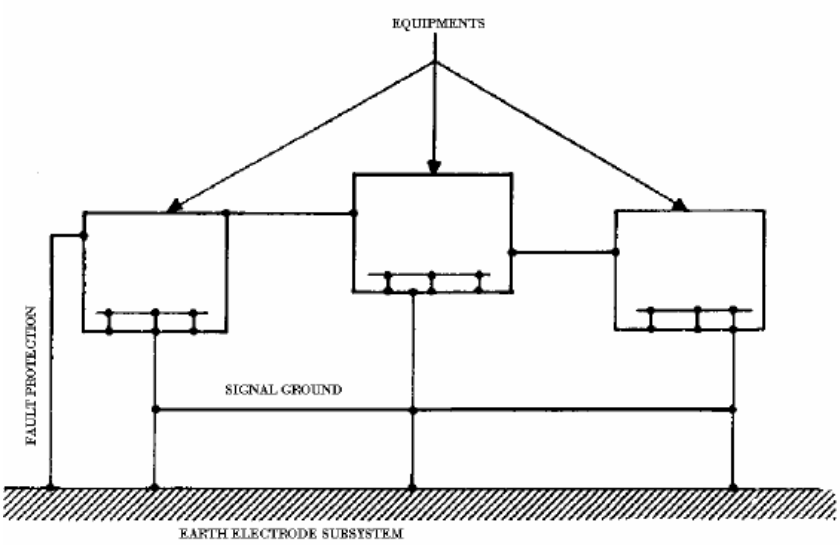
Introduction

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

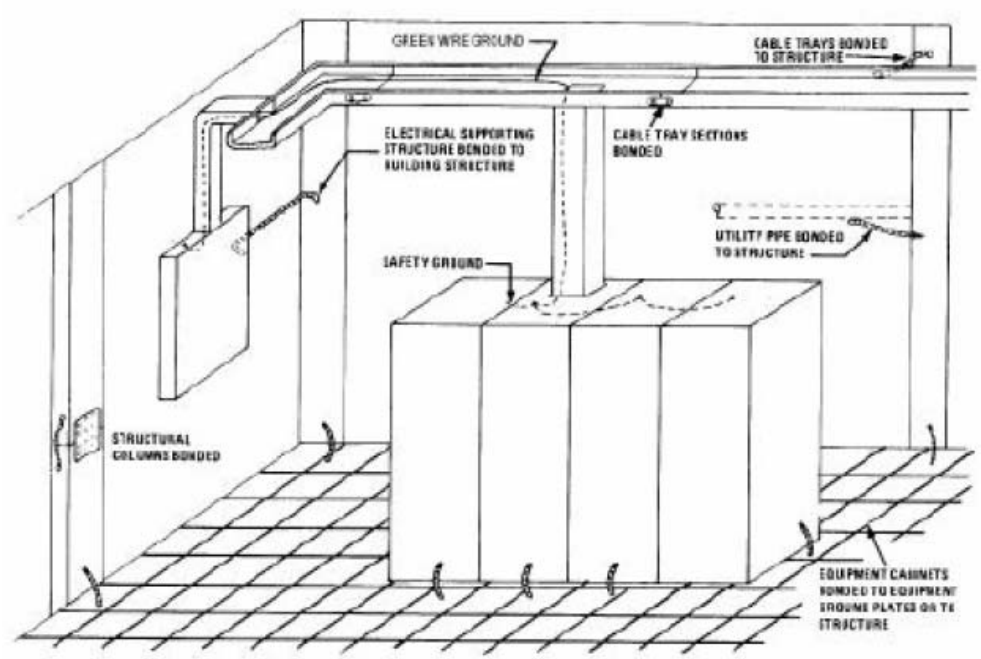
Introduction

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

An equipotential ground plane is depicted below:



Equipotential Ground Plane Types

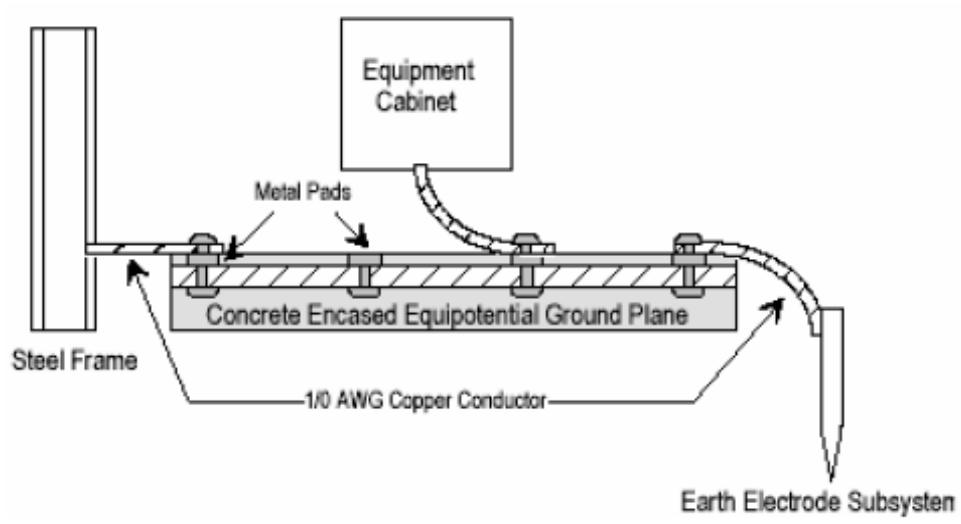
Introduction

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 subfloor. 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:



Continued on next page

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:

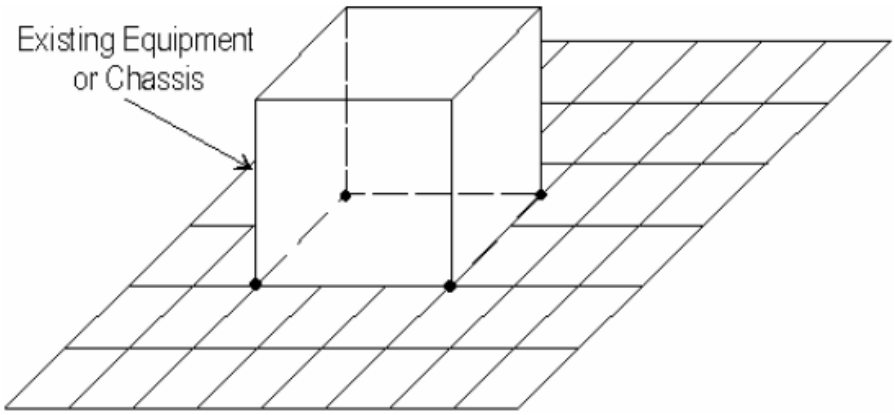
- An electrically continuous sheet at RF frequencies
- A low-impedance path to earth at lower frequencies by connecting the equipment cabinets with bonding straps

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.

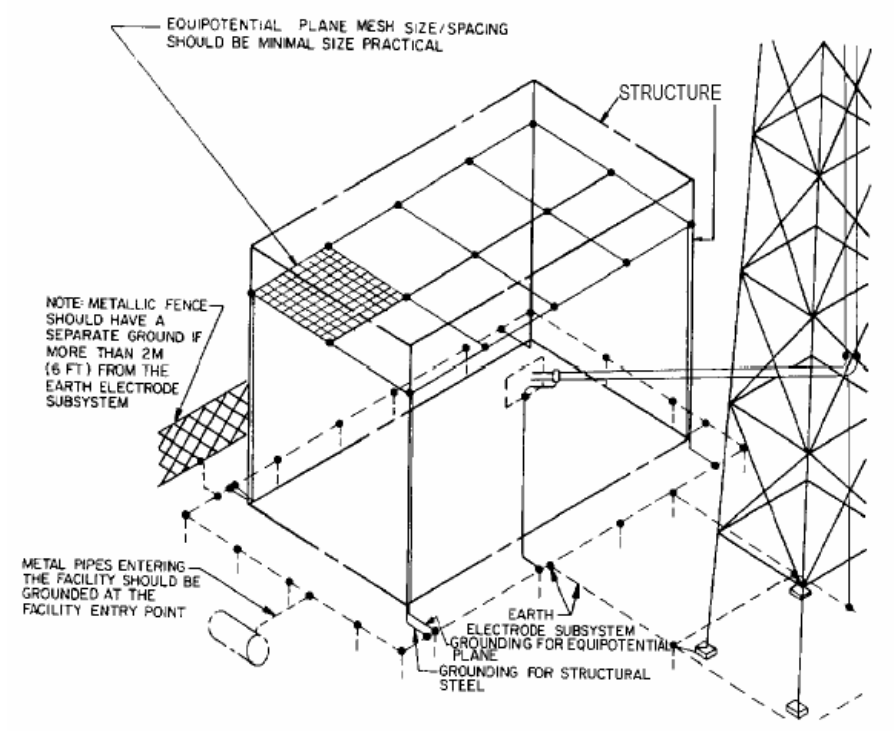


Continued on next page

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 pages 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)

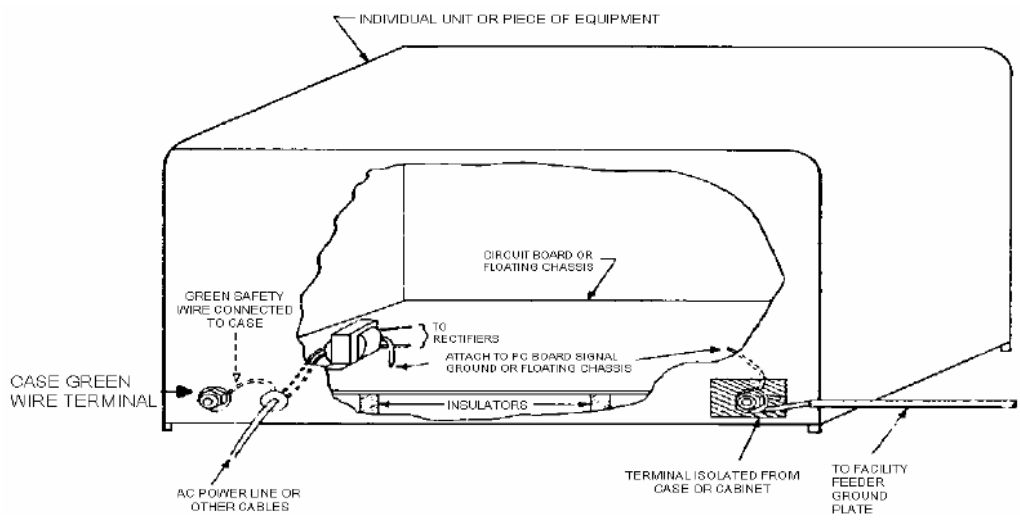
When inspecting the ground terminal connection, verify that one of the following methods are used to connect the low frequency equipment to the signal reference ground subsystem:

- 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.*

Inspecting Low Frequency Equipment (Continued)

Ground Terminal Diagram



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

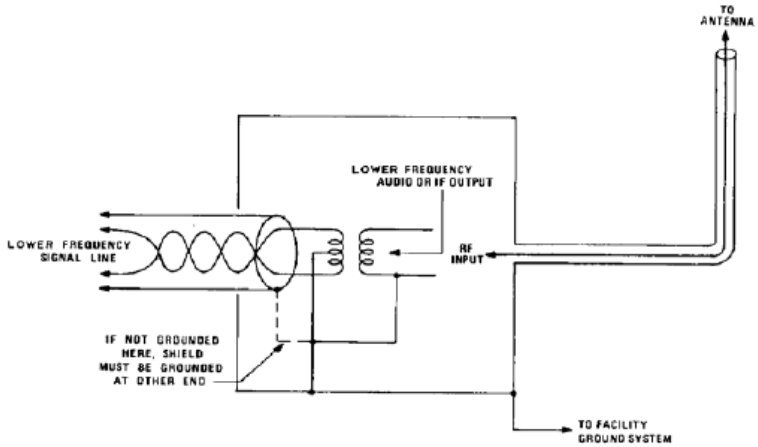
In equipment where both lower and higher frequency circuits must share a common signal ground, the equipment must be grounded using the same criteria as used for inspecting higher frequency equipment.

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

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 Procedures

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*			
9.	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*			

Continued on next page

Inspection Job Aids (Continued)

Low Frequency Equipment Inspection

Step	Action	Yes	No	N/A
10.	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*			
11.	Is the proper size wire used for the signal ground cable?			

Inspection Job Aids (Continued)

High Frequency Equipment Procedures

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?			
3.	Is the high frequency reference point directly grounded to the chassis and the equipment case?			
4.	Is the high frequency plane directly grounded to the chassis and the equipment case?			
5.	Are the shields of cables utilized for high frequency terminated to a ground at both ends?			
6.	Are the interfacing cables properly matched constant-impedance cables?			
7.	Do the line shield terminations outside of the equipment case have any pigtails?			
8.	Are the interfacing cable connectors properly mounted?			
9.	Are the interfacing cable connectors secure?			
10.	Are the interfacing cable connectors clean?			
11.	Is the signal ground cable size correct?			

This page intentionally left blank

Review Quiz

Questions

1. What is the length and diameter of a typical grounding rod?

   A. 12 feet long by 3/4 in. diameter
   B. 10 feet long by 3/4 in. diameter
   C. 10 feet long by 1/2 in. diameter
   D. 12 feet long by 1/2 in. diameter

2. Which of the following metals should NOT be used in the construction of down conductors?

   A. Aluminum
   B. Copper
   C. Tin
   D. Copper clad steel

3. The metal framework of a building should have a resistance of less than _____ ohms.

   A. 10
   B. 25
   C. 20
   D. 15

4. Which class of bonding involves welding of two pieces of metal together?

   A. Class A
   B. Class B
   C. Class C
   D. Class D

5. DC resistance across bonding and grounding junctions shall NOT exceed _____ ohms.

   A. 5
   B. 1
   C. .5
   D. .1

6. When installing an earth electrode subsystem, which wire color denotes the grounding conductor?

   A. Red
   B. Black
   C. Gray
   D. Green

Continued on next page

Review Quiz (Continued)

Questions (Cont'd)

7. Which of the following references is NOT used when inspecting a fault protection subsystem?

   A. MIL-STD-188-124B
   B. Civil Engineering manual
   C. NEC documentation
   D. MIL-HDBK-419

8. To protect a structure, such as a building, vessel, mast, etc… from lightning damage, the grounding cable should be _____ AWG

   A. 12
   B. 0000
   C. 2
   D. 10

9. List the primary advantage of using a floating ground subsystem.

   _____

   _____

10. What is the recommended frequency range for a single-point ground configuration.

   _____

   _____

This page intentionally left blank

Review Quiz Answers

Answers

Question	Answer	Reference
1.	B	2-3
2.	C	2-3
3.	A	2-4
4.	A	2-5
5.	D	2-5
6.	D	2-9
7.	B	2-16
8.	B	2-22
9.	Prevents noise that may be in the facility's ground from being conductively coupled to the signal circuits and prevents noise currents in equipment cabinets from being coupled to the signal circuits.	2-34
10.	Up to 300 Khz	2-35

This page intentionally left blank

Appendix A

Questions

1. What type of information is found in Section 1 of the SOVT documentation?

   A. Front Matter
   B. Cover Sheet
   C. Introduction and Administration
   D. Approval Statement

2. Which of the following subsystems should **NOT** be considered an option when developing the earth electrode subsystem?

   A. A series of driven rods connected with bare wire buried underground
   B. A direct bond between two similar metals on top of the soil
   C. A ground plane of horizontal buried wires
   D. A metal piping system

3. RF impedance across bonding and grounding junctions shall not exceed _____ ohms.

   A. 05
   B. 10
   C. 20
   D. 25

4. Which of the following materials should be NOT when grounding an electrode?

   A. Zinc
   B. Copper
   C. Aluminum
   D. Copper-clad steel

5. If an initial lightning strike produces 220Kv, approximately how much voltage will subsequent strikes produce?

   A. 2.4Kv
   B. 10Kv
   C. 75Kv
   D. 110Kv

6. Which of the following systems does NOT use a signal reference grounding system?

   A. HF
   B. VHF
   C. LF
   D. Hybrid

This page intentionally left blank

Appendix B

Answers

Question	Answer	Reference
1.	C	1-3
2.	B	2-3
3.	D	2-5
4.	A	2-10
5.	D	2-19
6.	B	2-41

Request for Feedback ET1 Electronic Installation Standards

Suggestions and Corrections

Please note your suggestions, corrections, and comments below.

Page	Location on Page	What Correction is Needed

Your Comments

If you were writing this pamphlet, what improvements would you make? What was good about it? What did you not like about it? Please be specific in your comments/suggestions.

To Contact You

Please provide the following so that we can contact you if needed.

Name	Unit	Phone
		( )

Mail, Fax, or Call

Please mail, fax, or call your information to:

Commanding Officer (CED)
U.S. Coast Guard
Training Center Petaluma
599 Tomales Rd.

PHONE: (707) 765-7129
FAX: (707) 765-7033

ATTN: _ET _Subject Matter Specialist_

LIST OF MATERIALS FURNISHED

COURSE TITLE: **ET1** COURSE CODE: **0122** EDITION: **3**

1. The materials for the course you requested are listed below. If any item listed is not enclosed in this package, report that fact to your Educational Service Officer (ESO).

2. If you enrolled in this course for credit, you have **36 months** to complete the course. If you requested course materials only, you will not receive an End-of-Course Test (EOCT) and will not receive credit for the course.

COMPONENT	NUMBER	QTY
PQG Certification Pamphlet	P12201	01
Administration	P12202	01
Electronic Installation Standards	P12203	01
Electronic Systems Planned Maintenance	P12204	01