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ELECTROMAGNETIC COMPATIBILITY AND GROUNDING REQUIREMENTS FOR SPACE SYSTEM FACILITIES

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DEPARTMENT OF THE AIR FORCE
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MIL-STD-1542A (USAF)

Electromagnetic Compatibility and Grounding Requirements for Space System Facilities

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USAF Space Division, SD/ALM
P. O. Box 92960
Worldway Postal Center
Los Angeles, CA 90009-2960

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SECTION 1

SCOPE

1.1 PURPOSE

The purpose of this standard is to specify the design, performance, and verification requirements for electrical subsystems for space system facilities, including electromagnetic compatibility (EMC), electrical power grounding, bonding, shielding, lightning protection, and TEMPEST security. These requirements are interrelated and interdependent, and therefore require an integrated approach in the design.

1.2 APPLICATION

This standard is intended primarily for use in design and construction contracts for selected space system facilities. The requirements are applicable to all related facilities including, but not limited to, launch complexes, tracking stations, data processing rooms, satellite control centers, checkout stations, spacecraft or booster assembly buildings, and any associated stationary or mobile structures that house electrical and electronic equipment. The requirements are not intended to be applicable to earth-based communication system facilities (see MIL-STD-188-124A).

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SECTION 2

REFERENCED DOCUMENTS

2.1 GOVERNMENT DOCUMENTS

Unless otherwise specified, the following specifications, standards, and handbooks of the issue listed in that issue of the Department of Defense Index of Specifications and Standards (DoDISS) specified in the solicitation form a part of this standard to the extent specified herein:

MILITARY SPECIFICATIONS:

MIL-E-4158	Electronic Equipment Ground: General Specification For
MIL-F-15733	Filter, Radio Interference, General Specification for

MILITARY STANDARDS:

MIL-STD-188-124	Grounding, Bonding, and Shielding for Common Long Haul/Tactical Communications Systems
MIL-STD-220A	Method of Insertion-Loss Measurements
MIL-STD-285	Attenuation Measurement for Enclosures, Electromagnetic Test Purposes, Method of
MIL-STD-461	Electromagnetic Emission and Susceptibility Requirements for the Control of Electromagnetic Interference
MIL-STD-462	Electromagnetic Interference Characteristics, Measurement of
MIL-STD-463	Definitions and Systems of Units, Electromagnetic Compatibility Technology
MIL-STD-889	Dissimilar Metals
MIL-STD-1541	Electromagnetic Compatibility Requirements for Space Systems

MILITARY HANDBOOKS:

MIL-HDBK-419	Grounding, Bonding and Shielding for Electronic Equipments and Facilities

OTHER GOVERNMENT DOCUMENTS:

NACSIM 5203 (C)	Guidelines for Facility Design and Red/Black Installation (U)
NACSEM 5204 (C)	Shielded Enclosures (U)

(Copies of specifications, standards, handbooks, drawings, and publications required by contractors in connection with specified acquisition functions should be obtained from the contracting activity or as directed by the contracting officer.)

2.2 NONGOVERNMENT DOCUMENTS

The following documents form a part of this standard to the extent specified herein. Unless otherwise indicated, the issue in effect on the date of invitation for bids or request for proposal shall apply.

National Fire Protection Association:

NFPA No. 70	National Electrical Code
NFPA No. 78	Lightning Protection Code

Application for copies should be addressed to:

National Fire Protection Association,
Batterymarch Park,
Quincy, MA 02269

National Association of Corrosion Engineers:

NACE Std. RP-01-69	Recommended Practice - Control of External Corrosion on Underground or Submerged Metallic Piping Systems.

Application for copies should be addressed to:

National Association of Corrosion Engineers,
P.O. Box 218340,
Houston, TX 77218.

American National Standards Institute:

ANSI C 84.1-1982	Power Systems - Voltage Ratings for Electric Power Systems and Equipment (60 HZ)

Application for copies should be addressed to:

American National Standards Institute,
1430 Broadway,
New York, N.Y. 10018

(Nongovernment standards and other publications are normally available from the organizations which prepare or which distribute the documents. These documents also may be available in or through libraries or other informational services.)

2.3 ORDER OF PRECEDENCE

In the event of a conflict between the text of this standard and the references cited herein, the text of this standard shall take precedence. However, nothing in this standard shall supersede applicable laws and regulations unless a specific exemption has been obtained.

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SECTION 3

DEFINITIONS

Electromagnetic compatibility (EMC) terms are as defined in MIL-STD-463. Other terms are in accordance with the following definitions:

3.1 FACILITY.

A facility is a building or other structure, either fixed or transportable in nature, with its utilities, ground networks, and electrical supporting structures. All wiring and cabling that is provided under terms of the facility contract are considered to be part of the facility. Any electrical and electronic equipments required to be supplied and installed by the facility contractor are also part of the facility.

3.2 SPACE SYSTEM FACILITY.

A space system facility is an earth-based facility that houses technical equipment for the operational support of a military space system. The technical equipment may be electrical, electronic, mechanical, or any combination.

3.3 FACILITY GROUND NETWORK.

The facility ground network is a network of conductors that form direct low impedance paths between earth and various power, communications, and other equipments to effectively extend an approximation of ground reference throughout the facility. The facility ground network is comprised of five subsystems as follows:

a. Earth Electrode Subsystem. The earth electrode subsystem is a network of electrically interconnected rods, mats, or grids installed for the purpose of establishing a low resistance contact with the earth.

b. Lightning Protection Subsystem. The lightning protection subsystem is a low impedance path for lightning energy to the earth electrode subsystem. It conducts the high currents away from susceptible elements in the facility and limits voltage gradients developed by the high currents to safe levels.

c. Facility Ground Subsystem. The facility ground subsystem is an electrically interconnected set of ground return conductors, conductive elements, and bonded structural elements that provide multiple current paths to the earth electrode subsystem for facility equipment (such as air conditioning equipment and ducts, heating equipment and ducts, lighting, electric motors, and the metallic components of the structure). The facility ground subsystem also includes the metallic components of the structure, the junction boxes, conduit, cable raceways, cable duct work, equipment racks, cabinets, pipes, and other normally noncurrent-carrying elements in the facility.

d. Equipment Fault Protection Subsystem. The equipment fault protection subsystem is a set of ground return conductors (green wires) that provide a current path to the earth electrode subsystem of sufficient capacity so that protective devices (fuses and circuit breakers) can operate properly to protect personnel from shock hazard and equipment from damage..

e. Signal Reference Subsystem (Technical Ground). The signal reference subsystem, or technical ground, is a network of conductors that provide the ground reference for all technical equipment used for operational support. It provides the ground reference for both the signal and power circuits for the technical equipment that is related directly to the military space system. It may consist of a low frequency grounding network (single point grounding), or high frequency grounding network (multipoint grounding), or a combination of the two (a hybrid grounding network).

3.4 LOW FREQUENCY CIRCUITS.

For the purposes of this standard, low frequency electrical and electronic circuits are those that operate in the frequency range from dc to 30 kilohertz.

3.5 HIGH FREQUENCY CIRCUITS.

In this standard, high frequency electrical or electronic circuits are those that operate above 30 kilohertz.

3.6 SINGLE POINT GROUNDING.

Single point grounding is a method of circuit and shield grounding in which each circuit or shield of the system has only one physical connection to a ground reference subsystem, ideally at the same point for a given system. Single point grounding is used for low frequency circuits to prevent return currents from flowing in structural elements. Power distribution circuits utilize single point grounding.

3.7 MULTIPOINT GROUNDING.

Multipoint grounding is a method of circuit and shield grounding in which each circuit or shield of the system has more than one path to a ground reference subsystem. Multipoint grounding requires the existence of an equipotential ground plane (See 3.8 and Figures 1, 2, 3 and 10). Multiple connections are made to the equipotential plane for radio frequency circuits by the shortest, lowest impedance method. High frequency circuits utilize multipoint grounding.

3.8 EQUIPOTENTIAL PLANE.

An equipotential plane is a flat mass of earth or metal (solid or grid) that offers a negligible impedance to current flow so that differences in electrical voltage are minimized across the plane (see Figure 1 and 3). An equipotential plane is considered an earth ground for a signal reference subsystem (technical ground) regardless of its elevation from physical earth.

3.9 TECHNICAL POWER.

Technical power is the electrical power supplied to signal and power circuits of technical equipment used for the operational support of a military space system, such as: checkout equipment, test equipment, communications equipment, and data processing equipment.

3.10 FACILITY POWER.

Facility power is the electrical power supplied to a facility for lighting, heating, air conditioning, large surge loads, large electric motors, and other station-keeping functions.

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SECTION 4

GENERAL REQUIREMENTS

4.1 ELECTRICAL POWER CHARACTERISTICS.

When commercial electrical power quality or reliability is not sufficient to meet the program needs, alternate methods such as dedicated power generation, power conditioning, uninterruptible power systems (UPS), or motor generators shall be evaluated and utilized as required to meet the program needs. Unless otherwise specified, the electrical power shall be a DELTA-WYE configuration.

4.2 ELECTROMAGNETIC COMPATIBILITY.

Facility electrical and electronic subsystems and equipment shall be compatible with each other as well as with the technical equipment installed in the facility for support of space system operations. To achieve this goal with a high probability of success requires the imposition of conducted and radiated EMI limits on the facility equipment.

4.3 SHIELDING.

Shielding shall be provided as required for the protection of circuits, equipment, and groups of equipment; for electromagnetic compatibility within the system; and to comply with security (TEMPEST) requirements.

4.4 GROUNDING.

All space system facilities containing electrical and electronic technical equipment shall have an earth-referenced facility ground network. The facility ground network shall consists of the following electrically interconnected subsystems:

a. The earth electrode subsystem.

b. The lightning protection subsystem.

c. The facility ground subsystem

d. The equipment fault protection subsystem.

e. The signal reference (technical ground) subsystem.

These items together constitute the total grounding system for the facility (see Figure 2). The grounding of mobile facilities shall comply with the criteria of MIL-HDBK-419.

4.5 ELECTRICAL BONDING.

Electrical bonding is the procedure by which the conductive surface of a component or subassembly is electrically connected to another in a manner which provides a low impedance path between them. This reduces the development of electrical potentials between the interfacing surfaces for frequencies capable of causing interference. Low resistance bonding shall be provided as required for safety, for electromagnetic compatibility within the system, and to comply with security (TEMPEST) requirements..

4.6 FILTERING.

Filtering shall be provided as required for the purpose of establishing electromagnetic compatibility, TEMPEST, or shielded enclosure integrity. The design, performance, and testing of RFI filters shall be in accordance with the requirements specified.

SECTION 5

DETAILED REQUIREMENTS

5.1 ELECTRICAL POWER.

5.1.1 Electrical Power Characteristics. Power quality requirements cannot be imposed on commercial power sources when these are utilized for space system facilities. When commercial power quality is not sufficient to meet program needs, power conditioning equipment shall be provided. Unless otherwise specified, power conditioning equipment including motor generators, uninterruptible power subsystems (UPS), and dc power supplies shall comply with Part 9 of MIL-STD-461 and operate successfully to provide the following power source environment:

a.	Voltage Regulation	±5 percent no-load to full-load with power factor ranging from 1.0 to 0.8 lagging
b.	Frequency Regulation	±1 Hertz
c.	Harmonic Distortion	5 percent total
d.	Transients	MIL-STD-461 Part 4
e.	Distribution Voltage	Standard commercial voltages in accordance with ANSI C 84.1 shall be utilized, but not less than 480 volts.

5.1.2 Electrical Power Distribution

5.1.2.1 Technical Power. The technical power feeders from the main power distribution point shall be isolated by separate transformers from facility power feeders. Facilities that have multiple users of technical power shall provide separate step-down transformers at each users load (or by agreement the user may provide his own transformer). User transformers shall be the isolation type. Technical power characteristics shall comply with MIL-E-4158.

5.1.2.2 Facility Power. Facility power feeders from the facility main power distribution point shall be separate from technical power feeders.

5.1.3 Power Grounding.

5.1.3.1 Primary Utility Power. Primary power shall not be grounded except at the neutral of the secondary of the subsystem transformer, as required by the National Electric Code. Transformers shall be of the isolation type (i.e., primary windings mechanically and electrically isolated from the secondary winding), with electrostatic shielding incorporated. Transformers shall be DELTA-WYE. Ground side switching shall not be used.

5.1.3.2 Secondary Power. Secondary power that is converted from primary utility power shall have dc resistance isolation of 1 megohm between the secondary and primary power. The various secondary power subsystems shall have dc resistance isolation of 1 megohm between each other.

5.1.3.3 Ground Fault Circuit Interrupters. Receptacle outlets for 120-volt single phase (15- and 20-ampere) shall have ground fault circuit interrupters (GFCI) where required for personnel protection or by NEC Articles 210 and 215.

5.1.3.4 Power Sources. Rotary or other power sources shall have their frames and cases bonded to the facility ground subsystem. Unbalanced loads should be avoided as far as possible, especially in electronic power supplies. All load lines shall be twisted.

5.1.3.5 Thermostats and Heaters. The control of primary power by a thermostat is permitted only through a relay; the relay shall be suppressed and shielded. The relay and thermostat case shall be referenced to the facility ground subsystem. The metal case of the associated step-down transformers shall also be referenced to the facility ground. Connections between a thermostat and the control relay shall utilize a shielded twisted pair of wires, with the shield grounded at both ends. The shield shall not be used to carry current.

5.1.3.6 Small Power Tools. Small power tools shall have a case ground connection provided from the tool chassis to the wall receptacle.

5.1.3.7 Shop Equipment. All items such as motor case equipment frames shall be bonded to the power ground in accordance with requirements stipulated in MIL-H-DBK-419.

5.1.3.8 Voltage Regulators. Electronically-controlled voltage regulators and transformers used for voltage regulating shall have their frames and cases bonded to the facility ground subsystem. All regulated power load lines shall be of the standard twisted type.

5.1.3.9 Power Control and Switching Equipment. All power switch, gear motor, and control center distribution panels shall be bonded, shielded, and grounded to provide the maximum attenuation of radiated interference. All metal parts shall be bonded to the facility ground subsystem; in addition, all openings (access or ventilation) shall be covered with 60-mesh steel screening. Where two items are to be bonded that must remain capable of movement by either turning, twisting, or partial rotation, a solid laminated type strap shall be used. Properly shaped copper straps may be used for applications requiring moderate movements; beryllium copper or phosphorous bronze straps should be used for more excessive movement. All bonding shall meet the criteria established by MIL-HDBK-419.

5.2 ELECTROMAGNETIC COMPATIBILITY.

5.2.1 Facility Interference Limits. Unless otherwise specified, the conducted and radiated requirements of MIL-STD-461 shall apply as follows to facilities electrical equipment:

Fixed and Mobile Ground Facilities Equipment (Class A3)	Part 1 and 4
Noncritical Ground Areas (Class B - Shop Equipment)	Part 1 and 7
Electrical Power Equipment (Such as generators and UPS)	Part 1 and 9

5.2.2 EMC Testing. Compliance with Paragraph 5.2.1 requirements shall be determined by tests performed in accordance with MIL-STD-462 or approved test plans.

5.3 SHIELDING.

5.3.1 General. Shielding shall be utilized along with other basic interference control measures such as filtering, wire separation, wire twisting circuit layout, spectrum control, and frequency assignment to achieve compatibility of equipment. The degree of shielding shall be determined by the systems engineering process to meet the requirements of this standard and of the system.

5.3.1.1 Wire Shielding.

5.3.1.1.1 General. A double, triple, or solid conduit shield shall be used where a single braided shield is not adequate. Shields shall not be used as intentional current-carrying conductors, except for RF transmission lines.

5.3.1.1.2 Grounding. High frequency shields shall be grounded at both ends and at every point where a discontinuity exists in metal enclosures. Low frequency circuit shields shall be grounded at one end only; at the source end for interference-generating circuits and at the load end for interference-sensitive circuits. The shield shall maintain continuity through metallic enclosures. High frequency shields shall be grounded circumferentially to or inside connectors or equipment enclosures with no discontinuities in the external shield.

5.3.1.1.3 Isolation. Except for solid conduit shields, shields shall be isolated from each other and from any metallic component by at least 1 megohm (dc) when the shield ground is lifted. Except as may be specified in the contract, solid conduit shields shall not be isolated from each other or from structure.

5.3.1.2 Shielded Equipment Enclosures.

5.3.1.2.1 Materials. Equipment shields shall be constructed of materials that provide the required attenuation of electromagnetic interference. Materials shall be corrosion resistant and compatible as defined by MIL-STD-889.

5.3.1.2.2 Gaskets. Conductive gaskets, finger stock, or other sealing devices shall be installed on all doors, covers, joints, seams, or other closures that require frequent opening to the extent necessary to provide electromagnetic compatibility in their intended environment. Door sealing devices shall withstand 1000 open-close cycles without maintenance and retain the required attenuation. Beyond 1000 cycles, maintenance procedures and periodic testing to retain the required attenuation shall be developed and documented.

5.3.1.2.3 Filters. Filters shall be installed where required for interference control on power, control, and signal lines in a manner that maintains the integrity of the shield. Filters shall comply with the requirements of MIL-F-15733 and Paragraph 5.5 of this Standard.

5.3.1.3 Shielded Rooms.

5.3.1.3.1 General. Shielded rooms shall be provided when required for the control of TEMPEST signals or to provide a quiet electromagnetic environment for operation or testing of electrical and electronic devices. Shielded rooms shall meet the requirements of this standard as well as the requirements of Appendix B of NACSEM 5204 and Appendix O of NACSIM 5203. The attenuation requirements of the shield room walls, doors, and penetrations shall be appropriate to the application, or as specified in the contract.

5.3.1.3.2 Doors. Doors that utilize finger stock shall be of the recessed contact design. The recessed contact shall provide protection and wiping action shall be provided to maintain a low impedance contact. The cycling and maintenance requirements of Paragraph 5.3.1.2.2 shall apply.

5.3.1.3.3 Grounding. Internal and external grounding of the circuits and the shielded room shall be in accordance with Figure 4 and MIL-HDBK-419. High and low frequency grounding subsystems inside the shielded room shall be welded to the inside of the shield room wall. The exterior of the room shall be grounded to the earth electrode subsystem at multiple points. Cable size shall be in accordance with Paragraph 5.4.2.2.

5.3.1.3.4 Transformers and Filters. Transformers and filters may be located on either the outside or inside wall of the shielded room. The external enclosures of these units shall be bonded to the shield wall in either case.

5.3.1.3.5 Penetrations. Penetrations shall be made in a manner which meets the operational function while maintaining the integrity of the R.F. shield. All shielded room penetrations shall meet the requirements of Appendix B of NACSEM 5204 and Appendix O of NACSIM 5203.

5.3.1.3.6 Quality Assurance. All seams and penetrations shall be tested during construction to validate seam welding quality by means of approved "sniffer" type testing equipment.

5.3.1.3.7 Testing. The shield attenuation testing shall be performed in accordance with MIL-STD-285 and Appendix B of NASIM 5204. Test frequencies and test point locations shall be as specified in the contract, or as approved by the contracting officer. The receiving antennas shall be positioned and oriented for maximum signal pickup.

5.4 GROUNDING.

5.4.1 Earth Electrode Subsystem.

5.4.1.1 General. An earth electrode subsystem shall be installed at each space system facility to provide a low impedance path to earth for lightning and power fault currents, and to ensure that hazardous voltages do not occur within the facility. This subsystem shall be capable of dissipating to earth the energy of direct lightning strikes with no ensuing damage to itself. This subsystem shall also interconnect all driven electrodes and underground metal objects of the facility. The earth electrode subsystem for either fixed or mobile facilities shall be designed in accordance with MIL-HDBK-419.

5.4.1.2 Earth Resistivity Survey. The design of the earth electrode subsystem shall be based on an earth resistivity survey conducted at the site prior to the detailed design. The magnitude of earth resistivities shall be measured and recorded. Natural features such as rock formations and underground streams, as well as man-made features that have an effect on earth resistivity, shall be recorded. This data shall be documented as a part of the facility design data.

5.4.1.3 Resistance to Earth. The dc resistance to earth of the earth electrode subsystem shall not exceed 10 ohms. Where 10 ohms cannot be obtained with the basic electrode configuration due to high soil resistivity, rock formations, or other terrain features, alternate methods for reducing the resistance to earth shall be considered. These considerations include, but are not limited to, the following:

a. Increasing the number of ground rods.

b. Use of longer rods.

c. Use of horizontal wires or grids instead of vertical rods.

d. Lowering of the soil resistivity through chemical enhancement.

This Standard, MIL-HDBK-419 and MIL-STD-188-124A do not recommend the use of deep wells for the achievement of lower impedance to earth. Deep wells do achieve low dc resistance but have very small benefit in reducing ac impedance. The objective of the earth electrode subsystem is to reduce potentials between and within equipments.

If a separate power source (substation) earth electrode subsystem is utilized, the resistance to earth shall not exceed 10 ohms. MIL-HDBK-419 provides further information on earth electrode subsystems design.

5.4.1.4 Earth Electrode Subsystem Configuration. The basic earth electrode subsystem shall consist of driven ground rods uniformly spaced around the facility and placed 0.6 to 1.8 meters (2 to 6 feet) outside the drip line of structures. The rods shall be interconnected with number 4/0 AWG (American Wire Gage) bare copper cable buried at least 0.6 meters (2 feet) below grade (see Figure 5 and 6). The interconnecting cable shall be welded to each ground rod and close on itself to form a complete loop. MIL-HDBK-419 provides additional guidance for the design of earth electrode subsystems. All structural steel columns shall be connected to the earth electrode subsystem by number 4/0 AWG bare copper cable and all connections shall be welded.

5.4.1.5 Ground Rods. Ground rods shall be copper clad steel, a minimum of 3 meters (10 feet) in length, spaced apart not more than twice the rod length, and shall not be less than 19.0 millimeters (0.75 inches) in thickness. The thickness of the copper jacket shall not be less than 0.3 millimeters (0.012 inches). If deeper rods are required to meet the earth resistivity requirements of Paragraph 5.4.1.3, threaded rod extensions of the same specifications may be used. Extension joints shall be welded.

5.4.1.6 Connecting Risers. The lightning down conductors, the signal reference subsystem, and the fault protection subsystem shall be welded to the earth electrode subsystem. The risers (vertical conductors) shall be number 4/0 AWG bare copper cable (see Figure 6 and 7).

5.4.1.7 Power Transformer Grounding. Utility power shall be grounded only at the neutral of the secondary of the subsystem transformer as required by NFPA 70.

5.4.1.8 Ground Isolation. The signal reference subsystem,
or technical ground, and the facility ground subsystem shall be isolated from each other except at connection to the earth electrode subsystem. Isolation shall be maintained between the facility ground subsystem and the lightning grounds, except at the single point of connection of each lightning down conductor to the nearest facility structural element (See Figure 3 and 6).

5.4.1.9 Cathodic Protection. Cathodic protection of underground pipes or structures shall be designed and installed in accordance with the guidance provided in MIL-HDBK-419 and NACE Standard RP-01-69. Cathodic protection subsystems shall be isolated from the earth electrode subsystem.

5.4.1.10 Testing.

5.4.1.10.1 Resistance Measurements. The resistance to earth of the earth electrode subsystem shall be measured by the fall of potential method (see MIL-HDBK-419) during dry surface soil conditions prior to completion of construction of structures, in order to comply with the requirements of Paragraph 5.4.1.3. Dry surface soil is defined as no rainfall during the previous three-day period. It is recommended that resistance to earth measurements be made at least annually thereafter under dry surface soil conditions. For additional test information, see MIL-HDBK-419.

5.4.1.10.2 Cathodic Protection. Cathodic protection subsystems shall be tested for compliance with the criteria and methods established by NACE Standard RP-01-69.

5.4.2 Facility Ground Subsystem. A facility ground subsystem that provides multiple current paths to the earth electrode subsystem for facility elements shall be provided. Facility ground plates shall be provided as required.

5.4.2.1 Facility Structure Ground Returns. Facility structural elements shall be bonded together and grounded to the earth electrode subsystem by electrical ground return conductors, facility ground plates, and conductive elements that provide multiple current paths to the earth electrode subsystem. The ground return conductors for facility elements shall be of minimum length. They shall not be designed to carry operational current, except during certain cases resulting from fault conditions (See Figure 9).

5.4.2.2 Ground Feeders. The cross sectional area of the ground feeders shall be 2,000 circular mils per running foot (3.32 square millimeters per meter) and shall not be smaller than number 4/0 AWG.

5.4.2.3 Service Structures. Metallic structures, such as service towers, umbilical towers, and cherry pickers, shall be connected to the nearest facility ground plate by number 4/0 AWG bare copper cable or tubing. The grounding cable shall be as short as possible and not exceed 30 meters (100 feet).

5.4.2.4 Service Structure Tracks. The roll-back tracks shall be grounded by connecting a number 4/0 AWG bare copper cable or tubing to the nearest facility ground plate. The grounding cables shall be as short as possible and not exceed 30 meters (100 feet).

5.4.2.5 Launch Pad Structure. The launch pad structure shall be electrically bonded in accordance with Paragraph 5.6 and shall be grounded to the facility ground subsystem by a number 4/0 AWG (minimum) bare copper cable. The grounding cable shall be as short as possible and shall not exceed 30 meters (100 feet).

5.4.2.6 Passageways. The homogeneous bonding of the metal network of the interconnecting passageways shall be grounded by connecting the network of a passageway to the nearest facility ground plate or rail by number 4/0 AWG bare copper cable. The grounding cable shall be as short as possible and not exceed 30 meters (100 feet).

5.4.2.7 Security and Perimeter Fences. All security of perimeter fences shall be grounded according to procedures outlined in MIL-HDBK-419 (See Figure 3).

5.4.3 Lightning Protection Subsystem.

5.4.3.1 Buildings and Structures. Lightning protection shall be provided for all space system facilities and structures including, but not limited to, substations, technical equipment buildings, towers, antennas, and masts.

5.4.3.2 Air Terminals (Lightning Rods). Air terminals shall be designed and installed in accordance with NFPA 78, MIL-HDBK-419, and Figure 7 of this Standard. Refer to MIL-HDBK-419 and NFPA 78 for air terminal placement on nonflat-roof configurations and to Figure 7 for air terminal placement on flat-roofed structures.

5.4.3.3 Roof and Down Conductors. The roof and down conductors shall be number 4/0 AWG and shall be spaced not less than 15 meters (50 feet) apart (see Figure 7). Roof and down conductor spacings of Figure 7 also apply to nonflat-roof configurations. Down conductor bends shall have a radius greater than 200 millimeters (8.0 inches). Down conductors shall be located external to structures. Each down conductor shall be connected to the structural steel at the base of the building by welding, that in turn is connected to the earth electrode subsystem by welding. A minimum of two conductive paths shall exist between air terminals and the earth electrode subsystem.

5.4.3.4 Structural Steel. Substantial metal structural elements of buildings and towers shall be acceptable substitutes for lightning down conductors provided they are bonded in accordance with Paragraph 5.6.5 and do not contain sensitive electronic equipment. The air terminal cables shall be welded or brazed to the peripheral steel columns of the building. The bases of the steel columns shall be connected to the earth electrode system by number 4/0 AWG bare copper cables.

5.4.3.5 Waveguide Grounding. As a minimum, all waveguides located external to buildings shall be grounded as follows:

a. Waveguide to antennas shall be grounded to the earth electrode subsystem at three points: at the antenna, at the base of the tower, and at the waveguide entry port.

b. Metallic supporting structures for waveguide shall be electrically continuous and grounded to the earth electrode subsystem at all supporting columns using No. 6 AWG as a minimum.

5.4.3.6 Exterior Wires and Cables. Corrosion-protected steel conduit shall be used for all external power or signal lines to shield against lightning or lightning-induced currents and voltages. Junction boxes shall be electrically bonded to the conduit. The conduit shall be connected to the earth electrode subsystem at each end, and at intermediate points at 15 meter (50 foot) intervals. The use of fiber optic cables to guard against lightning induced voltage is recommended for external signal circuits. If fiber optic cables are not used, the circuit protective devices of Paragraph 5.4.3.8 are required. Buried conductors not in conduit shall be protected by guard wires of 1/0 bare copper placed 0.3 meters (1 foot) above each conductor or group of conductors. The ground wire shall be connected to the earth electrode subsystem at each end.

5.4.3.7 Bonds. All bonds between elements of the lightning protection subsystem shall be welded or brazed. All structural steel members shall be bonded to each other by welding.

5.4.3.8 Lightning Transient Protection. All power and signal circuits that may be damaged as a result of lightning-conducted or induced transients shall be protected against pulses that have the characteristics as specified in MIL-E-4158. Information on voltage limitations and surge protecting devices is contained in MIL-HDBK-419. Power Lightning Arrestors shall be installed in accordance with the national electrical code.

5.4.4 Equipment Fault Protection Subsystem.

5.4.4.1 General. The equipment fault protection subsystem grounding conductor (green wire) protects personnel from hazardous voltages, prevents static charge buildup, and provides a return conductive path for fault currents back to the power source so that the protective circuit breaker or fuse can clear faulted current. To protect personnel and equipment from hazardous voltages, all exposed metallic elements of electrical or electronic equipment shall be connected to the earth electrode subsystem by means of the green wire. A ground bus shall be provided in all electrical equipment cabinets, power panels, and switch gear cabinets, and a separate connecting grounding conductor (green wire) shall be carried within the same conduit or raceway as the ac power conductors. The installation shall comply with the requirements of Article 250 of the NFPA No. 70. Useful guidance information is provided in MIL-HDBK-419. A typical equipment fault protection subsystem conductor arrangement is shown in Figure 8.

5.4.4.2 Conduit, Pipes and Tubes. Metallic conduit, pipes, and tubes shall be electrically continuous and shall be grounded to the fault protection subsystem grounding network. All conduit, whether used for power, signal, or control wires, shall use lock nuts along with conductive lubricants to provide continuous conductivity. Conduit brackets and hangers shall be electrically continuous to the conduit and to the metal structures to which they are attached.

5.4.4.3 Cable Trays or Raceways. The individual sections of cable tray assemblies shall be electrically bonded to each other and to the structures that support them. All cable tray assemblies shall be connected to the fault protection system within 0.6 meters (2 feet) of each end of the run and at intervals not exceeding 15 meters (50 feet) along each run.

5.4.4.4 Wiring Enclosures. All electrical and electronic wiring, distribution equipment enclosures, and the frames of electrical equipment, such as motors and generators, shall be connected to the fault protection subsystem ground network.

5.4.5 Signal Reference Subsystem (Technical Ground).

5.4.5.1. General. A signal reference subsystem, or technical ground, shall be provided at each facility in which electronic equipment is installed to provide the ground reference connection from the earth electrode subsystem to all signal circuits in the technical equipment used for operational support. Signal circuits are grounded to control static charges, control electromagnetic interference, and establish a common reference for signals between sources and loads. Figure 2 is a grounding schematic showing a typical signal reference subsystem involving both high and low frequency circuits. Additional information on the design of signal reference subsystems is contained in Appendix B of MIL-STD-188-124.

5.4.5.2 Low Frequency Circuits. The signal reference subsystem, or technical ground, for low frequency signal circuits (from dc to 30 kilohertz) shall be connected to the earth electrode subsystem at one point only (single point) and shall be configured to minimize conductor path length. This network reduces stray currents (primarily 60 Hertz) which minimizes voltage potentials between points on the facility, thus minimizing common mode interference between power and signal circuits. For additional guidance, consult MIL-HDBK-419.

5.4.5.3 High Frequency Circuits. The signal reference subsystem, or technical ground, for higher frequency signal circuits (above 30 kilohertz) require an equipotential ground plane. Figures 1, 2, 3, 9, and 10 provide information on typical equipotential ground planes and how equipment is to be connected to it. The equipotential ground plane shall be connected to the facility structure at multiple points. Various configurations can be used based on the frequencies involved, such as copper grids, structural steel elements (Rebar), or flat copper sheets that can be installed under or over equipment. Connections from technical equipment to the equipotential ground plane shall be as direct as possible and shall utilize low impedance ground straps. High frequency equipotential ground planes shall be designed in accordance with MIL-HDBK-419. Modification of the high and the low frequency bands can be made with approval of the contracting officer. Examples of hybrid grounding subsystems, with low and high frequency circuits combined, are illustrated in the grounding diagram in Figure 2.

5.4.5.4 Technical Equipment. Technical ground plates shall be provided for technical equipment throughout the facility. The technical ground plates shall be copper at least 6.35 millimeters thick, 100 millimeters wide, and at least 150 millimeters long (1/4-inch thick, 4-inches wide, and at least 6-inches long) with holes for connecting equipment. Each signal ground shall be connected to the technical ground by an insulated copper cable meeting the requirements of Paragraph 5.4.2.2. Signal grounding cables between the technical equipment, technical ground plates, and the earth electrode subsystem shall be insulated from building steel and other grounds. Their connections to the earth electrode subsystem shall be at a single-point, readily accessible for inspection. Bonding techniques allowing quick disconnection shall be used. The ground system shall not be used to complete a signal circuit between that equipment and other equipment.

5.5 FILTERS.

5.5.1 General. This section of the standard establishes the requirements for RFI filters utilized for electromagnetic compatibility (EMC), TEMPEST, or shielded enclosure integrity and encompasses the design, performance, and testing of RFI filters. Optical isolators meeting the performance requirements of this standard are acceptable for monitoring control and communications circuits.

5.5.2 Requirements.

5.5.2.1 Filters. Filters shall be installed in all feeder breakers at distribution panels that provide power to EMI-sensitive equipment, or into rooms where such equipment is installed. The filters shall be part of the distribution panel and shall provide a minimum attenuation of 80 decibels (dB) between 100 kilohertz and 400 megahertz. Adequate filtering shall be provided between any source that generates interference that may be conducted into EMI-sensitive equipment areas. Filters used in this application shall conform to MIL-F-15733.

5.5.2.2 Design. Filters shall be designed in accordance with the requirements of MIL-F-15733. The design shall include prevention of underdamped resonant conditions with the source or load which would cause excessive voltages that can degrade the filter elements. Additional performance requirements may be specified in the contract.

5.5.2.3 Fungus Resistance. Materials used in the filter shall be fungus resistant or shall be treated to resist fungus.

5.5.2.4 Dissimilar Metals. Dissimilar metals, as defined by MIL-STD-889, shall not be used in contact with each other unless protected against galvanic corrosion. When it is necessary that dissimilar metals be assembled together, a material compatible with each shall be interposed between them.

5.5.3 Test Requirements.

5.5.3.1 Qualification Testing. Filters shall be tested in accordance with the requirements and test methods of MIL-F-15733. Except for the insertion loss test, it is acceptable for the contractor to submit certified copies of test reports of units of the same design.

5.5.3.2 Insertion Loss. The full load insertion loss shall be measured utilizing the approach outlined in MIL-STD-220, except that the insertion loss shall be measured for the full frequency range of the filter. The minimum number of measurements shall consist of three per decade. Simulated load impedances shall be used during the test. If load impedances are not known, estimates to be used shall be approved by the contracting officer.

5.6 BONDING

5.6.1 General. Bonding is the process by which a low impedance path for the flow of electric current is established between two metallic objects. Facilities containing electrical or electronic equipment shall be constructed so that interconnections between metallic objects prevent electric shock hazards, provide lightning protection, establish references for electronic signals, and reduce EMI. The joints shall not degrade with age by corrosion or other means.

5.6.2 Corrosion Protection. Bonds shall be galvanically compatible as defined by MIL-STD-889. Bonds shall be protected against weather, corrosive atmospheres, vibrations, and mechanical damage if the possibility of exposure to these environments exist where they are located at the facility.

5.6.3 Bond Straps. Bonding straps installed across shock mounts or other suspension or support devices shall not impede the performance of the mounting device and not suffer metal fatigue or other means of failure. RF bonds shall have a width-to-length ratio of at least 1 to 5 to provide low impedance.

5.6.4 Bond Resistance. Bonds for ground conductors whose primary function is to provide a reference for power circuits, electrical equipment, control circuits, signal circuits, or to provide lightning protection shall have a maximum resistance of 1 milliohm. The resistance across joints on seams or RFI seals in metallic members required to provide electromagnetic shielding shall also be 1 milliohm or less. Facility metallic structural members shall have a maximum bonding resistance of 10 milliohms between joining members. Such structures shall include, but not be limited to:

a. Building metallic support structures.

b. Mechanical fixtures such as air conditioning ducts, water lines, hydraulic lines, air lines, fuel lines, stairs, and railings.

c. Metallic pipes, conduits, and cable trays.

d. Movable platforms, hinged doors, and other movable devices.

5.6.5 Welding. Structural steel members shall be welded at least one place to joining members. If Rebar is used as an equipotential plane, each rod crossing shall be welded.

5.6.6 Brazing and Silver Soldering. Welding, brazing or silver soldering shall be acceptable for the permanent bonding of copper and copper alloy materials for applications inside structures. For external (outside) applications, including below-earth level, only welding shall be used.

5.6.7 Bonding of Copper to Steel. Either brazing or exothermic welding shall be used for the permanent bonding of copper conductors to steel or other ferrous structural members.

5.6.8 Structural Steel. The structural steel and reinforcing steel rods of a structure, such as launch pads, facility buildings, tracking stations, and safety shelters, shall be bonded to the facility structure ground subsystem located underneath or near the facility.

5.6.9 Metal Passageways. Metal passageways shall be designed to provide a maximum dc resistance of 50 milliohms between any two points on a passageway.

5.6.10 Facility Structural Steel. The structural framework and reinforcing steel shall be bonded to provide a single homogeneous construction with a maximum dc resistance of 50 milliohms between any two points of the interconnected structural members.

5.6.11 Metallic Items. Metal items such as cable trays, supporting fixtures, electrical conduits, and metallic fuel lines shall be bonded to each other to provide a maximum bonding dc resistance of 10 milliohms between any two metal interfaces.

5.6.12 Movable Metallic Items. Movable articles, such as hinged panels, metal doors, movable platforms, and sliding equipment, shall be provided with flexible bonding straps to ensure a maximum bonding dc resistance of 10 milliohms across any one bond.

5.6.13 Bond Protection. All bonds except those listed in 5.2.3.2 shall be suitably protected against weather, corrosive atmospheres, vibrations and mechanical damage. Under dry conditions, a corrosion preventive or sealant shall be applied with 24 hours of assembly of the bond materials. Under high humidity conditions, sealing of the bond shall be accomplished within one hour of joining.

5.6.14 Corrosion Protection. Each bonded joint shall be protected against corrosion by assuring that the metals to be bonded are galvanically compatible. Bonds shall be painted with a moisture proof paint or shall be sealed with a silicone or petroleum-based sealant to prevent moisture from reaching the bond area. Bonds which are located in areas not reasonably accessible for maintenance shall be sealed with permanent waterproof compounds. Iridited or other similarly protected bonds do not require painting to meet the requirements of this standard.

5.6.15 Compression Bonds in Protected Areas. Subject to the approval of the contracting officer, compression bonds between copper conductors or between compatible aluminum alloys which are located in readily accessible areas not subject to weather exposure, corrosive fumes, or excessive dust may not require sealing.

5.6.16 Bonding Tests.

5.6.16.1 Facility Bonding Test. A bonding resistance test shall be performed on all metal structures. Joints requiring bonding, whether by jumper or clamp-on metal-pressure fixture shall be tested, but it is not necessary to test all joints individually.

5.6.16.2 Bonding Joints. Bonding joints considered critical are those containing sensitive electrical and electronic equipment, cable trays to and from these areas, and all protection subsystems (for fault currents and lightning) and their connections to ground. All structural steel elements, though not classified as critical, shall be bonded and connected to the facility ground subsystem. The facility bonding test shall include measurements of these items. The number and location of the facility bonding tests shall be as approved by the contracting officer

5.6.16.3 Test Equipment. An acceptable piece of equipment for performing a test is the Shallcross Manufacturing Co. low-resistance test set, Type 673A or 673D. Equivalent equipment may be substituted with the approval of the contracting office.

5.6.16.4 Test Procedure. Testing shall be performed during all states of facility construction and subsystem installation. One lead of the test instrument should be connected to one bonded interface and the other lead connected to an adjacent level. A second set of measurements shall be made at the completion of construction to determine the over-all resistance of various joints on the bonded structure to the nearest counterpoise stub-up connection. A random "proof of bonding integrity" test shall be required at acceptance. The testing shall be performed in accordance with the test procedures in MIL-HDBK-419.

5.6.16.5 Success Criteria. No single critical joint measurement shall exhibit a dc resistance greater than 10 milliohms and the dc resistance from any point in the bonded structure of the various control rooms to the nearest facility ground plate or rail shall not exceed 100 milliohms. No single structural steel joint shall exceed a maximum resistance of 10 milliohms dc.

5.6.16.6 Data Requirements. A record shall be kept of the measurements of all points made in each area. These records shall be coded so that any desired measurement point can be relocated easily for later verification. These records shall be maintained until area acceptance.

5.7 TEMPEST SECURITY.

Unless otherwise specified, the facility grounding, bonding, and shielding requirements associated with TEMPEST security shall be in accordance with NACSIM 5203, NACSIM 5204, and MIL-HDBK-419. NACSIM 5203 refers to MIL-HDBK-419 for TEMPEST grounding.

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SECTION 6

NOTES

The contents of this Notes section are not compliant. The notes are intended for use by Government Acquisition personnel for guidance and information only.

6.1 INTENDED USE

This standard is intended for use in acquisition contracts for selected space system facilities. The requirements are applicable to all related facilities including, but not limited to, launch complexes, tracking stations, data processing rooms, satellite control centers, checkout stations, spacecraft or booster assembly buildings, and any associated stationary or mobile structures that house electrical and electronic equipment.

Note that this standard would not normally be used in the acquisition of other types of equipment, such as terrestrial communications subsystems (see MIL-STD-188-124A). However, there may be acquisition contracts for some other type of equipment requiring the special requirements as stated in this standard. For those facilities and equipment, a statement should be included in the contract or the statement of work that the words "space system facility" and "space equipment" in this standard are to be interpreted as the applicable system facility and equipment.

6.2 TAILORED APPLICATION

The requirements in each contract should be tailored to the needs of that particular program. Military specifications and standards need not be applied in their entirety. Only the minimum requirements needed to provide the basis for achieving the program requirements should be imposed. The cost of imposing each requirement of this standard should be evaluated by the program office against the benefits that should be realized. However, the risks and potential costs of not imposing requirements shall also be considered.

6.3 SUBJECT TERM (KEY WORD) LISTING

Air terminals
Bond straps
Buildings
Cable trays

Cathodic protection
Earth electrode
Earth resistivity
Electrical power
Electromagnetic compatibility
Electromagnetic pulse (EMP)
Facility power
Filters
Grounding
Ground rods
Isolation
Lightning protection
Lightning rods
Power distribution
Shielded enclosures
Shielding
Shielded rooms
Structures
Technical power
Transformers
TEMPEST

Custodians
Air Force - 19

Preparing Activity
Air Force - 19

(Project No. EMCS-F097)
Document 1500b/Arch 1223b

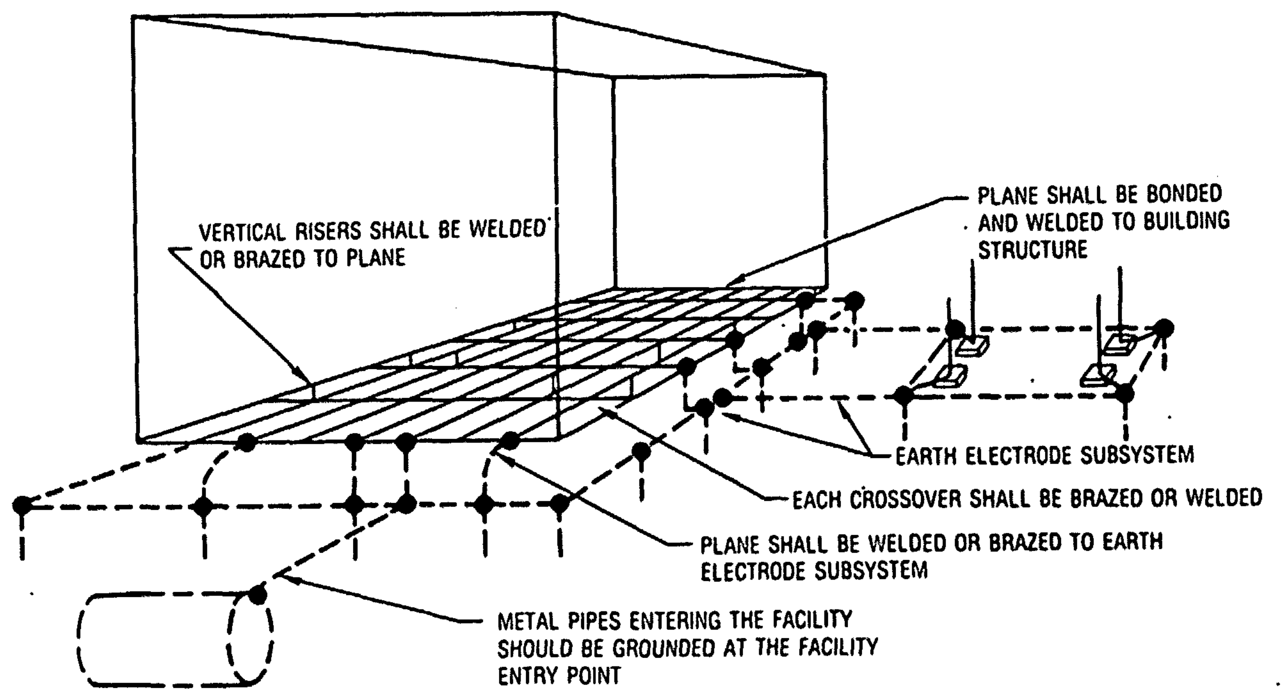


Figure 1. Example of Equipotential Plane for New Construction

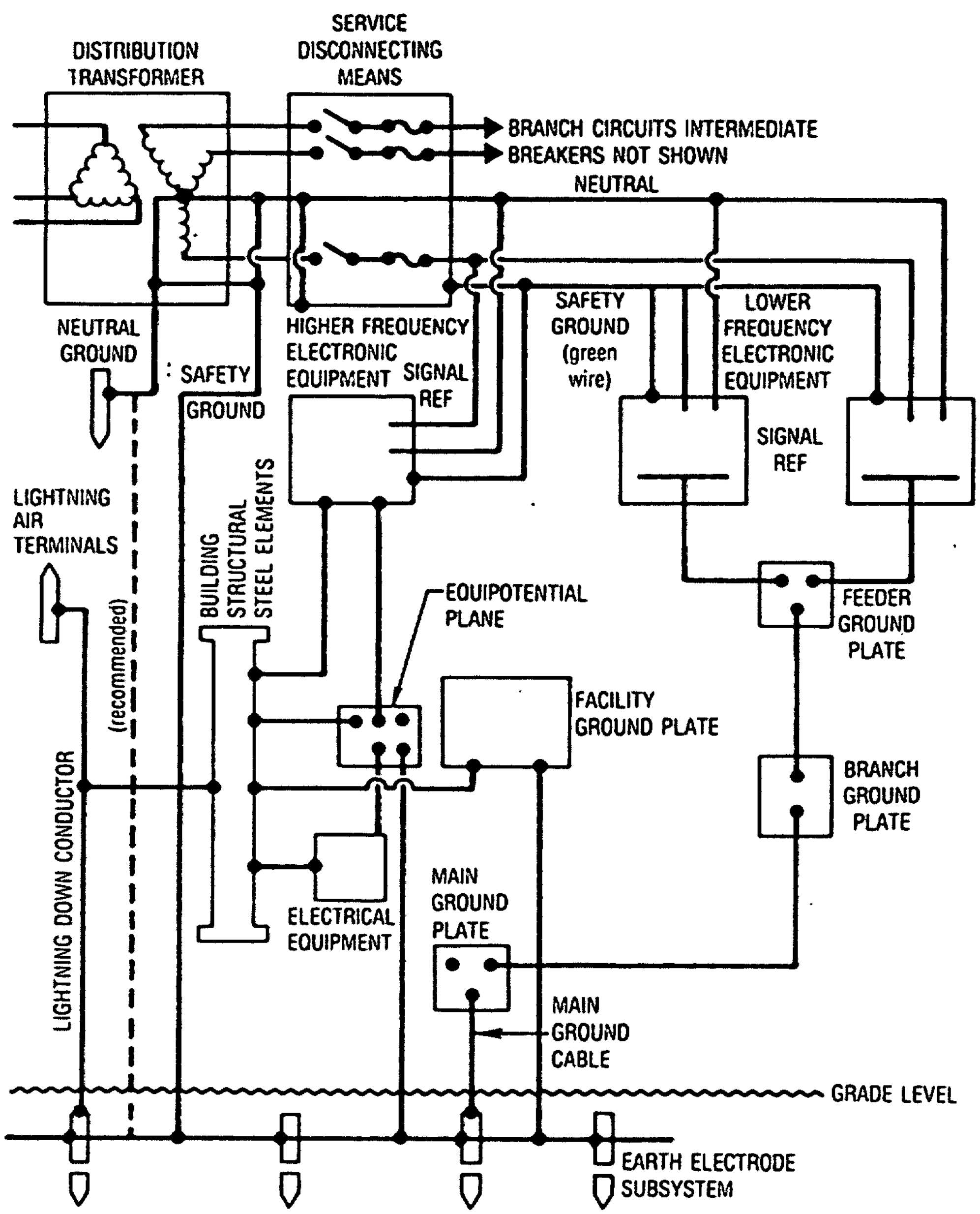


Figure 2. Earth Referenced Facility Ground Subsystem

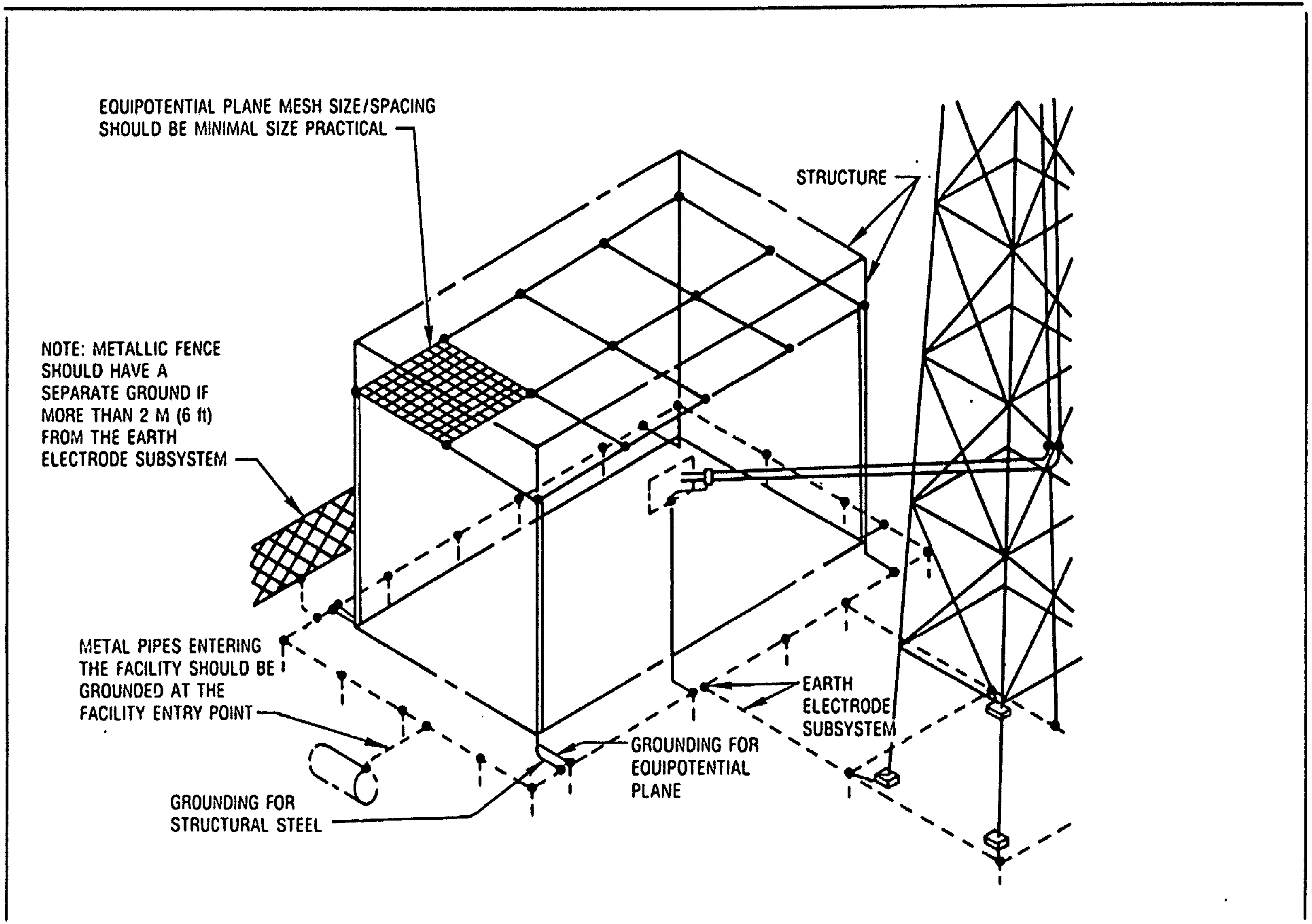


Figure 3. Example of Equipotential or Multipoint Grounding to Earth Electrode Subsystem for Overhead Equipotential Plane

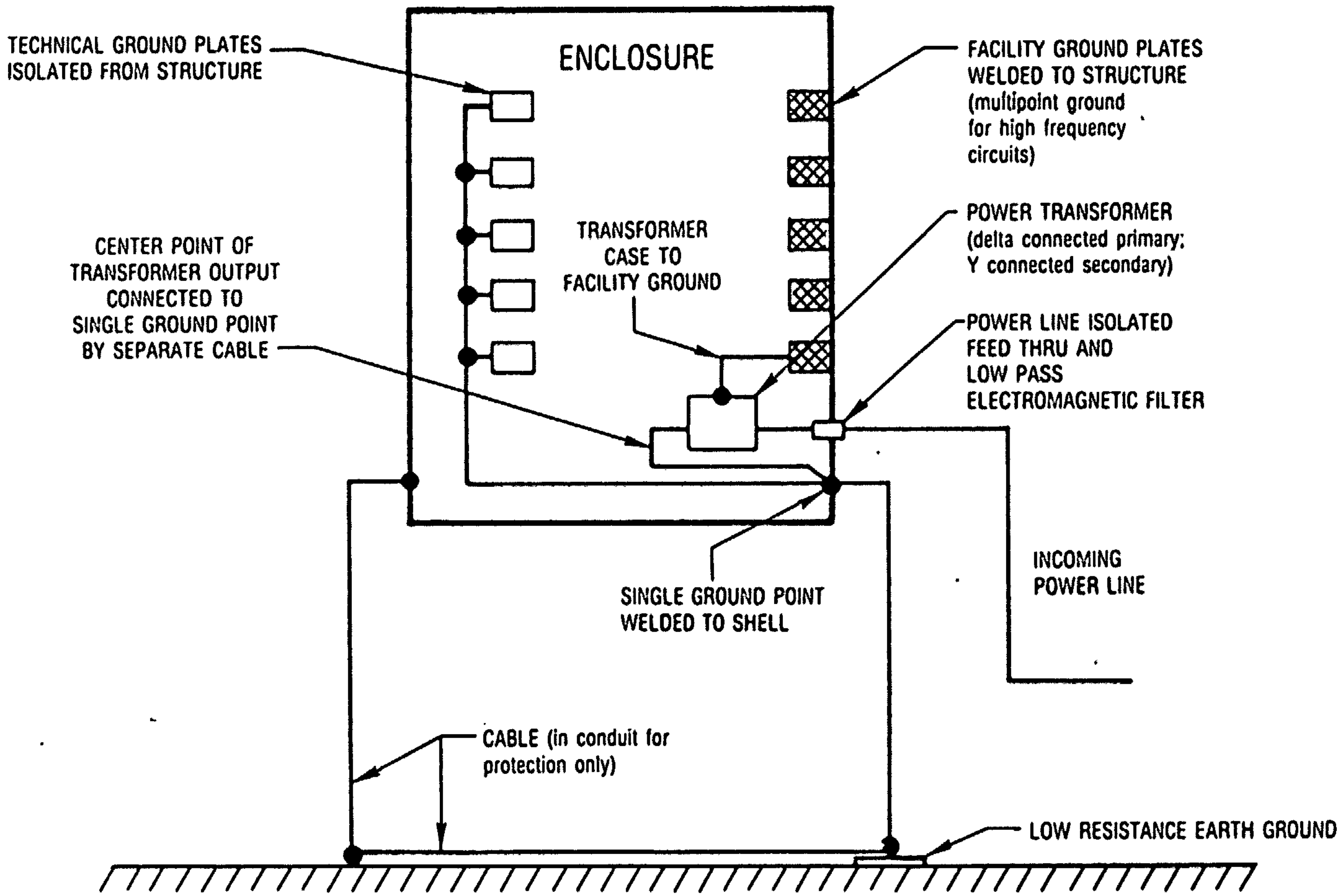


Figure 4. Shielded Room Grounding

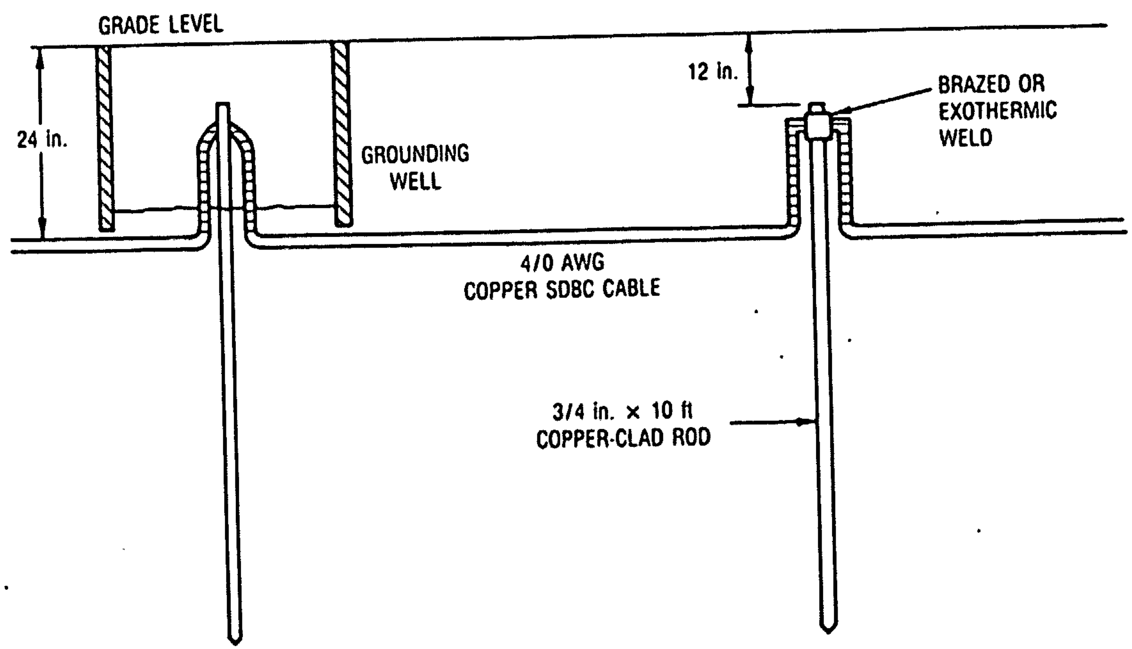


Figure 5. Details of Ground Rod or Earth Electrode Subsystem Installation

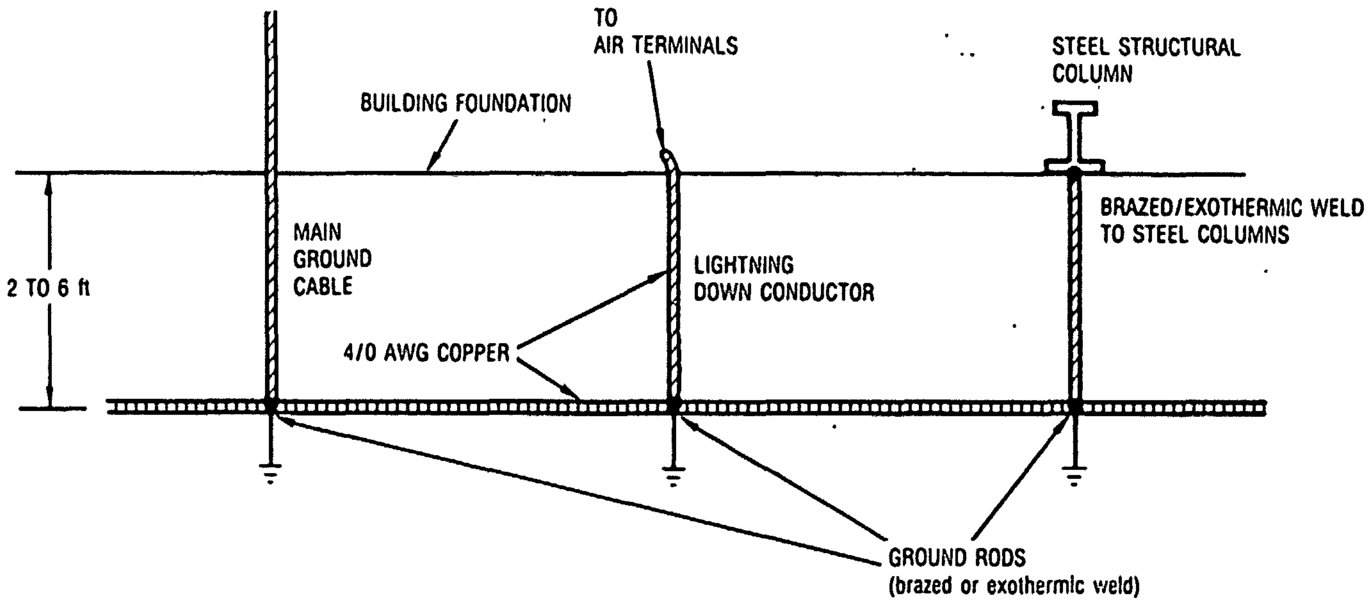


Figure 6. Connections to Earth Electrode Subsystem

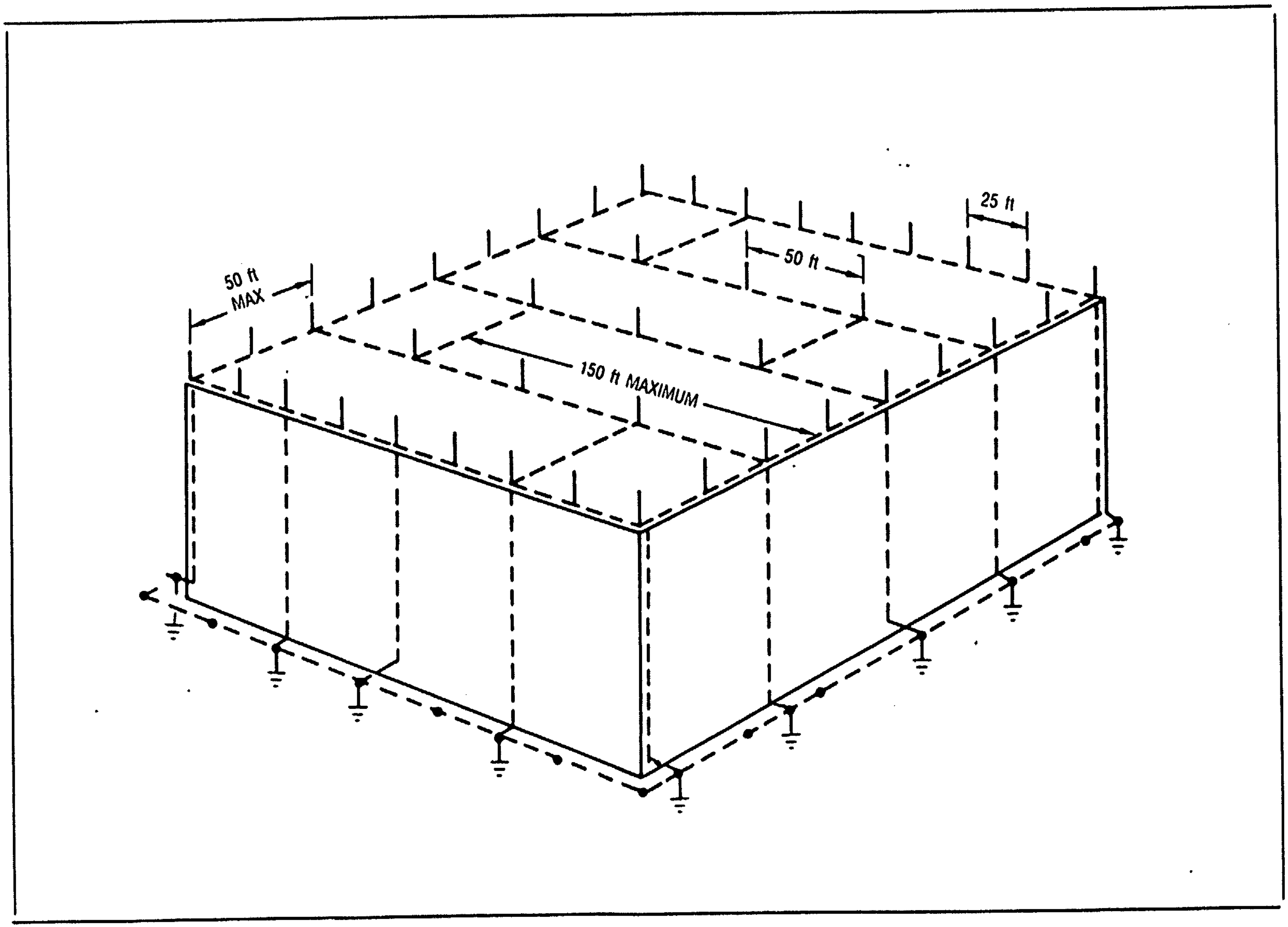
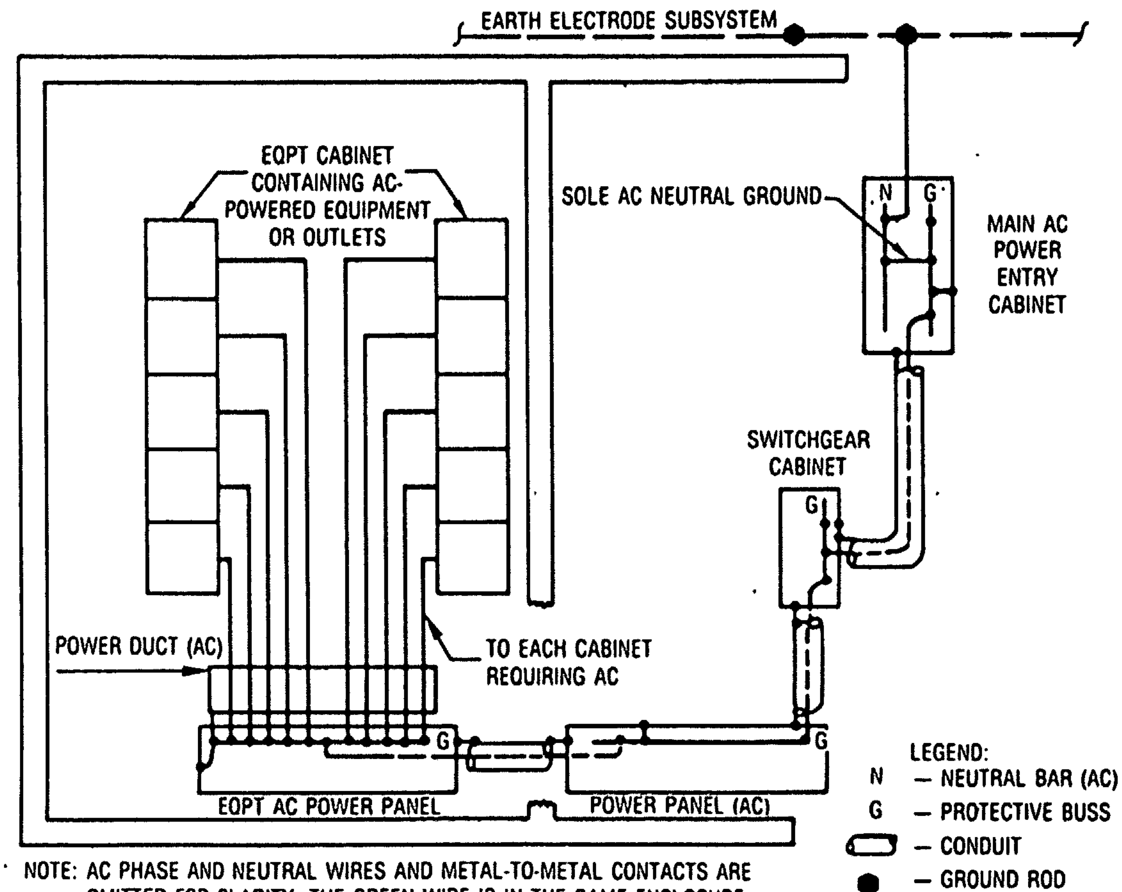


Figure 7. Air Terminal Placement on Flat-roofed Structure



NOTE: AC PHASE AND NEUTRAL WIRES AND METAL-TO-METAL CONTACTS ARE OMITTED FOR CLARITY. THE GREEN WIRE IS IN THE SAME ENCLOSURE OR CABLE WITH THE POWER CONDUCTORS

Figure 8. Typical Fault Protective Subsystem

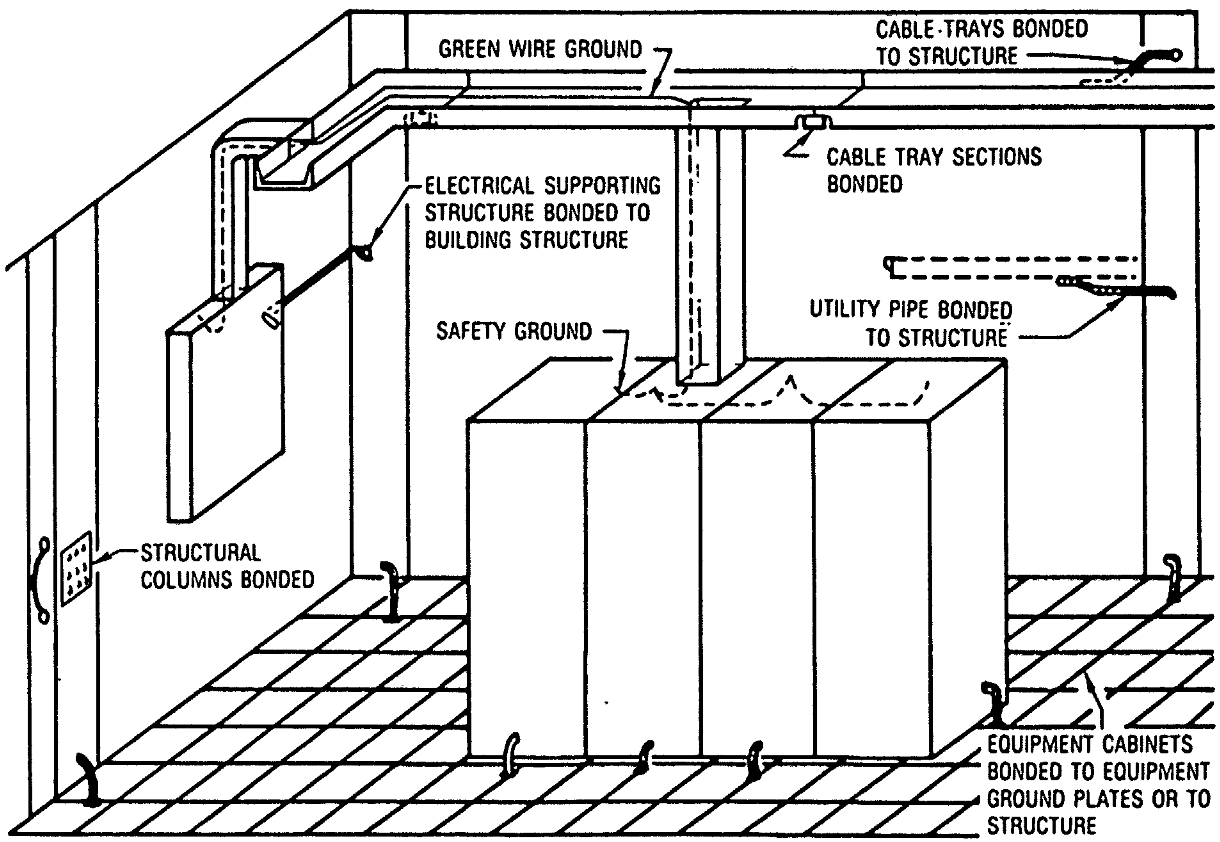


Figure 9. Elements of the Facility Ground Subsystem (with grid)

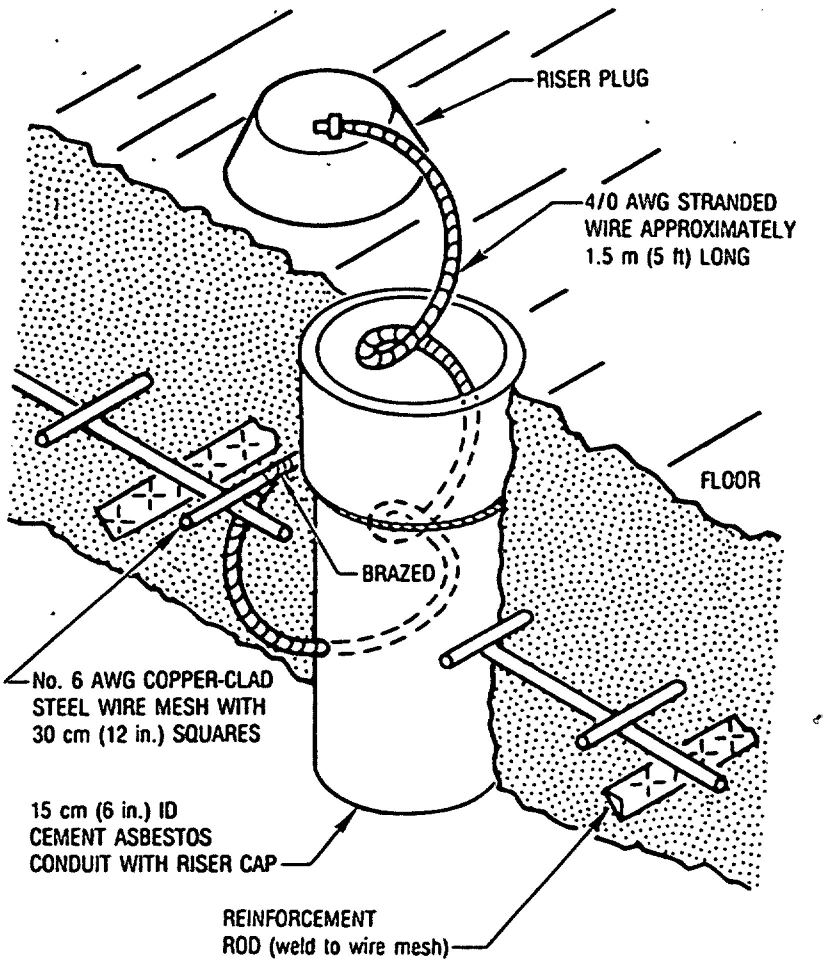


Figure 10. Typical Equipotential Ground Plane for New Construction - High Frequency Facilities Installation

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MIL-STD-1542A (USAF)	Electromagnetic Compatibility and Grounding Requirements for Space System Facilities

3a. NAME OF SUBMITTING ORGANIZATION	4. TYPE OF ORGANIZATION *(Mark one)*
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