MOTOROLA

Standards and Guidelines for Communication Sites

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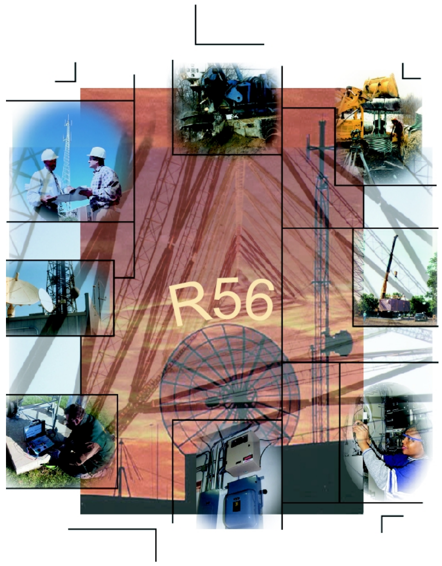

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STANDARDS AND GUIDELINES FOR COMMUNICATION SITES

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Applicability

The standards and guidelines in this revision of this manual shall apply to new communication sites built after the publication date of this revision of the manual. Standards and guidelines in this manual are not required to be implemented at sites built prior to publication of this revision.

TABLE OF CONTENTS

CHAPTER 1: INTRODUCTION

CHAPTER 2: SAFETY SUMMARY

CHAPTER 3: SITE ACQUISITION

CHAPTER 4: SITE DESIGN AND DEVELOPMENT

CHAPTER 5: COMMUNICATIONS SITE BUILDING DESIGN AND INSTALLATION

CHAPTER 7: INTERNAL GROUNDING

CHAPTER 8: POWER SOURCES

CHAPTER 9: TRANSIENT VOLTAGE SURGE SUPPRESSION

CHAPTER 10: MINIMIZING SITE INTERFERENCE

CHAPTER 11: EQUIPMENT INSTALLATION

LIST OF ILLUSTRATIONS

LIST OF TABLES

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CHAPTER
1

INTRODUCTION

This manual provides Motorola's internal guidelines and requirements for the installation of communications equipment, infrastructure and facilities.

This manual is an update of Motorola's previous version of its R56 manual released in 1994. Major changes and additions include:

- The manual is now applicable to all sectors of the Motorola Communications Enterprise.
- It now has expanded safety information.
- It has been rewritten for a global audience.
- Generally accepted industry standards are identified and referenced.

1.1 AUDIENCE

This manual is intended for use by Motorola employees and contractors. Motorola recognizes that this manual may be used by the following groups:

- Customers
- Site managers
- Consultants
- Program managers
- System designers
- Contractors responsible for constructing communication sites and installing infrastructure network equipment at the sites.
- Technicians responsible for installing and maintaining communications equipment installed at communications sites.

NOTE: Users of this manual are cautioned to read and understand all disclaimers on the inside front cover before using this manual.

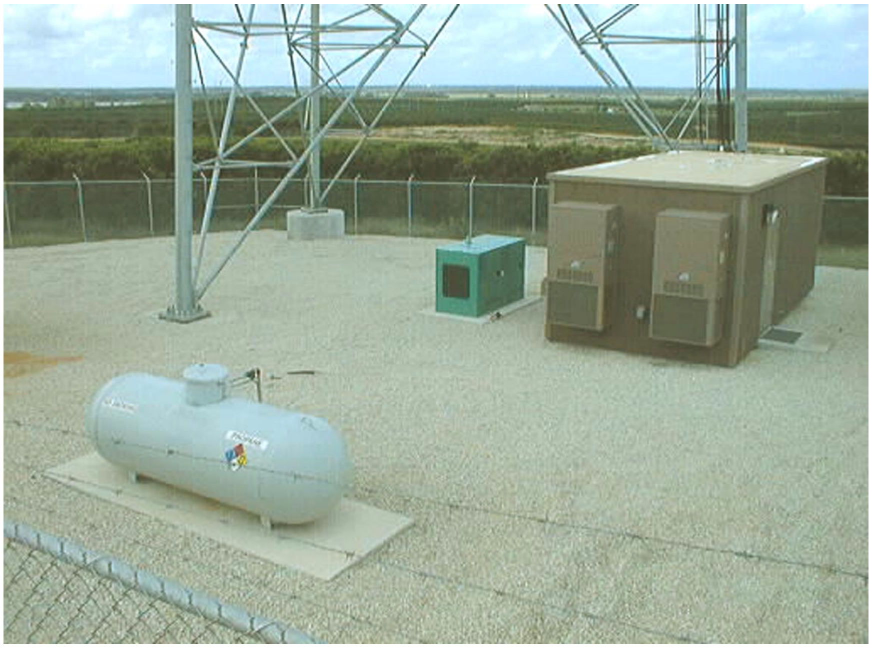

FIGURE 1-1 TYPICAL COMMUNICATIONS SITE

1.2 ORGANIZATION

This manual is organized into chapters, each of which provides guidelines and requirements for a major aspect of site development. Each chapter contains the following information about the subject it covers:

- Requirements that must be followed. Requirements are indicated by the use of the word “shall” in bold (**shall**).
- Guidelines which describe preferred methods, but which are not requirements.
- Useful information about planning, designing, and developing communications sites.

1.3 STANDARDS

Table 1-1 lists all published standards cited throughout this manual.

NOTE: All local and jurisdictional codes and safety standards, whether incidental or superseding to standards specified in this manual, shall be followed while developing a site, installing equipment, or performing maintenance.

TABLE 1-1 RELATED PUBLICATIONS AND RESOURCES

Publication	Title
Publications	
ANSI A10.14	Requirements for Safety Belts, Harnesses, Lanyards, and Lifelines for Construction and Demolition Use
ANSI A14	Requirements for Ladders
ANSI C62.1	Surge Arresters For AC Power Circuits
ANSI T1-313	Electrical Protection for Telecommunications Central Offices and Similar Type Facilities
ANSI Z308.1	Minimum Requirements For Workplace First Aid Kits
ANSI Z359	Requirements for Personal Fall Arrest Systems, Subsystems and Components
ANSI Z87.1	Occupational And Educational Eye And Face Protection
ANSI Z89.1	Protective Headwear For Industrial Workers -Requirements
ANSI/IEEE 80	IEEE Guide For Safety In AC Substation Grounding
ANSI/IEEE 81	Guide For Measuring Earth Resistivity, Ground Impedance, And Earth Surface Potentials Of A Ground System (Part 1)
ANSI/IEEE C95.1	Safety Levels With Respect To Human Exposure To Radio Frequency Energy
ANSI/TIA/EIA-222(f)	Structural Standards for Steel Antenna Towers and Antenna Supporting Structures
ANSI/TIA/EIA-568-A and CSA-T529	Commercial Building Telecommunications Cabling Standard (CSA-T529 is the Canadian equivalent of ANSI/TIA/EIA-568-A.)
ANSI/TIA/EIA-569-A	Commercial Building Standard for Telecommunications Pathways and Spaces
ANSI/TIA/EIA-606 and CSA-T528	Administration Standard For The Telecommunications Infrastructure Of Commercial Buildings (CSA-T528 is the Canadian equivalent of ANSI/TIA/EIA-606.)

TABLE 1-1 RELATED PUBLICATIONS AND RESOURCES (CONTINUED)

Publication	Title
ANSI/TIA/EIA-607 and CSA-T527	Commercial Building Grounding and Bonding Requirements for Telecommunications (CSA-T527 is the Canadian equivalent of ANSI/TIA/EIA-607.)
ANSI/UL 154	Carbon-dioxide Fire Extinguishers
ANSI/UL 299	Dry Chemical Fire Extinguishers
ANSI/UL 711, CAN/ULC-S508-M90	Fire Extinguishers, Rating And Fire Testing of
ASTM 488-90	Seismic anchoring
ASTM A615-68	Specifications for Deformation of Preformed Steel Bars for Concrete Reinforcement
ASTM C150-99a	Standard Specification for Portland Cement
ASTM D1557	Test Method for Laboratory Compaction Characteristics of Soil Using Modified Effort
ASTM D698-91	Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort
Bellcore Technical Specifications AU-434[1]	Earthquake concrete expansion anchors
Bellcore TR-64	Concrete specifications for seismic installations
CAN4-S503-M83	Canadian Standard, Carbon-dioxide Fire Extinguishers
CAN4-S504-77	Canadian Standard, Dry Chemical Fire Extinguishers
Code of Federal Regulations 47	Part 17 - Construction, Marking, and Lighting of Antenna Structures
EIA/TIA-222	Tower Foundation and Anchor Design
FAA Advisory Circular 70/7460-1G	Obstruction Marking and Lighting
FCC/OET RTA 95-01 (NTIS order no. PB95-253829)	Engineering Services for Measurement and Analysis of Radio Frequency (RF) Fields. Technical report for the Federal Communication Commission, Office of Engineering and Technology, Washington, DC
IEEE C62.41	IEEE Recommended Practice on Surge Voltages in Low-Voltage AC Power Circuits.
IEEE C62.45	IEEE C62.45 IEEE Guide on Surge Testing for Equipment Connected to Low-Voltage AC Power Circuits.
IEEE Green Book; *IEEE STANDARD 142*	Recommended Practice for Grounding of Industrial and Commercial Power Systems
IEEE Std. 837	IEEE Standard for Qualifying Permanent Connections Used in Substation Grounding
ISO/TC94/SC4	Personal Equipment for Protection Against Falls (International ISO standard)

TABLE 1-1 RELATED PUBLICATIONS AND RESOURCES (CONTINUED)

Publication	Title
MIL-HDBK-419A	Communications Facilities Design and Construction
NEBS TR-63	Network building standard regarding seismic compliance
NEMA/ANSI Z535.3	Criteria for Safety Symbols
NFPA 1	Fire Prevention Code
NFPA 10	Standard for Portable Fire Extinguishers
NFPA 12	Standard for CO_2 Extinguishing Systems
NFPA 13	Standard for Installation of Sprinkler Systems
NFPA 17	Standard for Dry Chemical Extinguishing System
NFPA 33	Standard for Spray Application Using Flammable or Combustible Materials
NFPA 70[2]	National Electrical Code®
NFPA 101®	Life Safety Code®
NFPA 111	Standard on Stored Electrical Energy, Emergency and Standby Power Systems
NFPA 780	Standard for the Installation of Lightning Protection Systems
NFPA 2001	Standard on Clean Agent Fire Extinguishing Systems
OSHA 1926.104	Safety Equipment
Motorola document 68P09226A18	Frame Mounting Guide
Motorola document 68P81150E62	Grounding Guideline for Cellular Radio Installations (included as Appendix C of this manual)
UL 268	Smoke Detectors For Fire Protective Signaling Systems
UL 467	Grounding and Bonding Equipment
UL 497A	Secondary Protectors For Communication Circuits
UL 497B	Protectors For Data Communication And Fire Alarm Circuits
UL 1449	Transient Voltage Surge Suppressors
ULC-S504-77	Standard for dry chemical fire extinguishers

TABLE 1-1 RELATED PUBLICATIONS AND RESOURCES (CONTINUED)

Publication	Title
Uniform Building Code,	
• Articles 2330 through 2338	Earthquake, Seismic Designs
• Article 1807 (c), (k)	High-Rise Buildings
• Chapter 23, Article 2370	Seismic Isolated Structure Design
ZED 259	Requirements for Personal Fall Arrest Systems (Canadian standard)
Internet	
www.fcc.gov/oet/rfsafety	FCC Office of Engineering and Technology. (RF safety)
http://www.neic.cr.usgs.gov/ http://geohazards.cr.usgs.gov	US Geological Survey agency (Seismic activity in various regions)

1. Bellcore is now known as Telcordia.
2. The National Fire Protection Code® (NFPA) encompasses all National Electrical Code® (NEC) standards. In this manual, NFPA 70 refers to the NEC.

1.4 GLOSSARY

The glossary below contains terms as defined in the context of this manual.

ACI: American Concrete Institute.

ACS: Advanced Conventional Systems.

ADSL: Asymetric Digital Subscriber Line.

AEB (Ambassador Electronics Bank): A central switch that routes and combines all audio sources for SmartZone trunking systems. Also known as Embassy Switch.

AH (Ampere Hours): A measurement of battery current capacity relative to time, normalized to 8 hours. For example, a 320 AH battery will deliver 40 Amperes for 8 hours.

Ambient Temperature: Environmental temperature as typically measured 60 cm (5 ft.) above the floor in the center of an aisle.

ANSI: American National Standards Institute.

Antenna: A device that permits transmission and reception of radio frequency energy through space. Also known as aerial.

Antenna Structure: Generic term describing an antenna supporting system which may be other than a tower (building, monopole, bracket, etc.).

As-Built: A Motorola factory-provided printout furnished with a new system or site development that describes the system’s or sites original factory-built or installed configuration.

ASHRAE: American Society of Heating, Refrigerating, and Air Conditioning Engineers.

ASSE: American Society of Safety Engineers.

ASTM: American Society for Testing of Materials.

Attenuator: A passive device for controlling (attenuating) signal levels. It can be fixed, calibrated, or variable. Where calibrated attenuators are used, the device is typically calibrated in dB of negative gain (loss or attenuation).

AWG (American Wire Gauge): An American standard for identifying the thickness of electrical conductors.

Bandpass Cavity: A high Q resonant circuit designed to pass a narrow band of frequencies with very little loss while attenuating all other frequencies outside the selected bandwidth. When used between a transmitter and the antenna transmission line, it reduces spurious signals and transmitter sideband noise that might otherwise be radiated from the transmitter and degrade the performance of a nearby receiver.

Bandwidth: The frequency spectrum space occupied by a signal of a single channel.

Base station: 1) Station that allows simplex communications between radio units and console positions. 2) A repeater which provides the source of audio received by the console, and the destination of audio transmitted from the console.

Battery: One or more electrochemical storage cells connected together to serve as a DC voltage source.

Blackout: An extended zero-voltage condition (total loss of power) lasting for minutes, hours, or even days at a time. Blackouts can be caused by ground faults, accidents, lightning strikes, power company failures, or other acts.

BNC: Bayonet "N" Connector.

BOCA: Building Officials and Code Administrators International, Inc.

Bonding: The permanent joining of metallic parts to form an electrically conductive path that ensures electrical continuity and the capacity to safely conduct any current likely to be imposed.

Bonding jumper: A reliable conductor that ensures the required electrical conductivity between metal parts required to be electrically connected.

Boot: A protective, flexible sleeve installed around cables that pass through the wall of a communications site building.

Branch circuit: The circuit conductors between the final overcurrent device protecting the circuit and the outlet(s).

Brownout: A long-term under-voltage condition lasting minutes, hours or even days at a time. They are often intentionally instituted by an electric utility company when peak demand exceeds generating capacity.

BTU (British Thermal Unit): A standard measurement of generated energy, typically as heat. (1 BTU equals 1.055 kJoules of energy.)

Building: For the purposes of this manual, a permanent structure capable of regular human occupancy built on a foundation that contains communications equipment and related ancillary support systems, and may contain other unrelated equipment and/or facilities.

Cabinet/enclosure: An enclosure that houses communications equipment and ancillary systems only. It is designed such that equipment contained within can be accessed without the need for personnel to enter the cabinet.

Cable ladder: (Also see Cable runway) An open steel structure (painted or anodized) suspended from the ceiling that provides an orderly means of support and routing for wires and cables throughout a communications site. May be installed inside the building or vertically to guide cables on a tower. All exterior cable ladders should be constructed of galvanized metal.

Cable runway: A structure provided for the routing and management of cabling. May be located below a raised floor, suspended from the ceiling, or mounted on top of equipment racks and/or cabinets. The term Cable Runway is used in this manual to include both cable ladders and cable trays.

Cable tray: (Also see Cable runway) A solid structure, typically constructed of aluminum or fiberglass, suspended from the ceiling that provides an orderly means of support and routing for wires and cables throughout the interior of a communications site.

Caisson: A drilled cylindrical foundation shaft used to transfer a load through soft soil strata to firm strata or bedrock. The shaft is filled with either reinforced or unreinforced concrete. A caisson may either be a straight shaft or bell type of installation.

CATV: Cable Television.

CCTV: Closed-Circuit Television.

CEB (Central Electronics Bank): Electronic equipment that provides the interface between the console dispatch positions and the RF equipment.

Cellular: A multi-site, low-power full-duplex radio system that interfaces to the PSTN.

CEPT: European Committee of Post and Telegraphs.

CFC-free: Denotes a refrigerant which does not use Chlorofluorocarbons.

CRF: Code of Federal Regulations.

Channel bank: A device that places multiple channels on a digital or analog carrier signal.

CIU (Console Interface Unit): An interface device that provides encryption/ decryption of console audio signals.

CO (Central Office): The main switching center of a telephone service provider or local exchange carrier (LEC).

Combiner: A passive device that allows transmitters on different frequencies to use a single antenna.

Console: A system’s dispatch electronics, made up of one or more console operator positions and a Central Electronics Bank (CEB).

Conventional system: A radio system in which resources are dedicated to a specific frequency.

CPR: Cardio-Pulmonary Resuscitation.

Critical Loads: Loads that are required for proper system performance.

CSA: 1) Abbreviation for Canadian Standards Association. 2) Cross-sectional area (as used for cable gauge specification in metric system).

CSI: Construction Specification Institute.

CSU (Channel Service Unit): A digital DCE used to terminate digital circuits (such as DDS or T-1 lines) at the customer site. It conditions the line, ensures network compliance with FCC rules, and responds to loopback commands from the central office.

Daisy chain: Any method of connection whereby the conductors are connected from one chassis, equipment frame or rack connection point to a second chassis, equipment frame or rack connection point and on to a third connection point, creating a series arrangement whereby the removal of the second connection point interrupts the ground path from the first chassis, equipment frame or rack. Daisy chaining of grounding conductors is not an acceptable method of connection.

Demarcation Point: The telephone or utility point of presence at a facility which divides utility assets from customer assets and accordingly assigns maintenance responsibilities.

DOT: Department of Transportation.

Duplexer: An RF filtering system that separates the transmit and receive frequency, so that equipment can transmit and receive simultaneously on a single antenna, without affecting other equipment.

DVM: Digital Voltmeter.

E-1: A TDM digital link which uses 32 time slots with a speed of 2.048Mb/s

Earth: Synonymous with ground.

EAS (Environmental Alarm System): Equipment which centrally receives, interfaces, and processes remote alarms related to equipment environmental conditions and other switch-closure alarms.

Easement: An interest in real property which is owned by another that entitles the holder to a specific limited use or enjoyment of the owner's property.

EBTS (Enhanced Base Transceiver System): Base stations used in the iDEN system.

EGB: (External Ground Bus Bar): A ground bus bar that provides a bonding point for multiple grounding conductors (such as all coaxial connections) and connection to the grounding electrode system.

EHS: Environmental Health and Safety.

EIA: Electronics Industries Association.

Electrolytic ground rods: Ground rods in which the ability to dissipate charge is enhanced by chemical reaction with the soil.

EME: Electromagnetic Energy.

EMT (Electrical Metallic Tubing): Describes conduit tubing used specifically for housing electrical conductors. Several variations are available for specific purposes.

ERP (Effective Radiated Power): The near-field radiated effective power (as opposed to peak envelop power) of a transmitting antenna. Specifies power radiated less any losses inherent in transmission lines or antenna coupling.

ESD (Electrostatic Discharge): A high voltage, low current electrical discharge caused by buildup of static charge between two surfaces.

Ethernet: A Local Area Network (LAN) protocol.

ETSI: European Telecommunications Standards Institute.

Exothermic welding: A process by which two pieces of metal are permanently welded using heat generated by a chemical reaction caused by combining the welding materials.

External grounding system test: A test that measures the effective resistance of the external site grounding system.

External site grounding ring: A ring of conductor wire surrounding an equipment enclosure, building and tower at a communications site. The grounding ring is bonded to the grounding electrodes, so that electrical charges are ultimately dissipated by the earth.

FAA (Federal Aviation Administration): The US regulatory agency responsible for air traffic safety. It also governs height and marking regulations for towers and other tall structures that could pose a hazard to aircraft.

Facility: A complete site environment, including a power system (s), site structure, HVAC system, antenna structure, and boundary fencing (if applicable).

Failsoft: A default communication mode for trunking systems that prevents system shutdown by providing limited communications capability during a system failure. The repeaters operate in conventional mode if the central controller fails.

FCC (Federal Communications Commission): The US regulatory agency responsible for overseeing radiated transmissions in the United States.

Firestop: A cross-member used in walls to inhibit vertical spread of fire.

FM: Factory Mutual.

FMV (Fair Market Value): The approximate worth of a piece of property, based on several factors including location and the actual selling price of similar properties in the area.

FNE (Fixed Network Equipment): Permanently installed communications site infrastructure equipment.

FOTS: Fiber Optics Transmission System.

FRU: Field Replaceable Unit.

GFCI (Ground Fault Circuit Interrupting): A type of electrical receptacle that removes power to the receptacle if a ground fault occurs in the equipment connected to the receptacle.

Gin pole: Construction equipment used for lifting tower sections and antennas during antenna construction.

GPS (Global Positioning System): A system which determines exact locations by utilizing high-precision satellite signals as its reference. The satellite signals can also be used as a timing reference.

Grounding: The connecting of a particular leg of a circuit across multiple equipment of a power system in common. The common connection is then also electrically bonded to the soil. In this manner, the grounded portion of the circuit can serve as a common low-side connection across the system. Synonymous with earthing.

Grounding conductor: A means for bonding equipment to the site grounding electrode system.

Grounding electrode system: A buried system of ground conductors which provides a bonding point between soil grounding at the site and the neutral-ground connection of the incoming AC power. The site master ground bar is also bonded to this point.

Ground loop: A situation where a difference in electrical potential occurs between two different points in a site's grounding system. Usually caused by a conductive object being bonded to the grounding system at more than one point, resulting in a potential between the two bond points.

Ground test well: A buried port that allows inspection of connections to the grounding electrode system.

Gumbo: A soil composed of fine-grain clays. When wet, the soil is highly plastic, very sticky, and has a soapy appearance. When dried, it develops large shrinkage cracks.

Hantavirus: A potentially deadly airborne virus spread by rodents.

Hard-wiring: The practice of direct physical connection of wiring leads directly to a junction device. An example of hard-wiring is the connection of a device's AC line directly to a junction box without the use of a receptacle and line cord.

Harmonic: Regarding power lines, an abnormality in which distortion of the normal utility sine wave occurs. Harmonics can be transmitted back into an AC power line by non-linear loads such as switching power supplies and variable speed motors. If significant enough, harmonic conditions can cause overheating in step-down and three-phase load transformers and neutral conductors.

HAZMAT: Hazardous Material(s).

HMIS (Hazardous Material Identification System): A labeling system for identifying the location of potentially hazardous materials.

HVAC: Heating, Ventilation and **Air Conditioning** equipment.

Hz (Hertz): Frequency measurement unit. One Hz equals one cycle per second.

ICBO: International Conference of Building Officials.

Ice bridge: A protective shield for horizontal cable runs between towers and building cable entry ports or between two buildings, designed to prevent ice from forming and falling on the cables during winter.

iDEN (Integrated Dispatch Enhanced Network): A Motorola-manufactured digital transmit/receive system, operating in the 800-900 MHz range, that combines radio and telephone services in a single subscriber unit.

IEEE: Institute of Electrical and Electronics Engineers.

IGZ (Isolated Ground Zone): An installation configuration where grounding of equipment is electrically isolated and/or separate from general facility grounding.

IPGB: Internal Perimeter Ground Bus conductor.

ITU: International Telecommunications Union. (Also known as CCITT.)

IZGB: Isolated Zone Ground Bar.

Low Pass Filter: Also referred to as “harmonic filter”. Filter that suppresses harmonic frequencies above its specified pass band. It is used with transmitters to prevent intermodulation. Most systems require this type of filter between the isolator and the antenna system to reject second and third harmonic transmitter energy.

LPG: Liquefied Propane Gas.

LTV (Let-through Voltage): Voltage (at a specified current) allowed through a TVSS device when the device is in suppression mode.

LVLD: Low-Voltage Load Disconnect.

Meter pedestal: The base structure for the electric services utility meter at communications site. Typically installed by the local utility company during communications facility construction.

MGB (Master Ground Bus Bar): The single grounding point inside an equipment enclosure to which all other interior ground wires are ultimately bonded. There is one master ground bus bar per building or equipment area at a communications site.

Microwave: Frequencies higher than one GigaHertz (1,000,000,000 Hz) in the frequency spectrum.

Modified Proctor test: A soil compression test that measures the compacted density of soils being used for structural applications. (Refer to *ASTM D1557* for more information.)

MOV (Metal-Oxide Varistor): A two-terminal voltage protection device in which resistance across the device markedly decreases when the voltage across the device reaches a specified threshold.

MPE (Maximum Permissible Exposure): Defines maximum permissible exposure to radiated RF energy to personnel. Several levels exist based upon frequency, power density, and time of exposure.

MSDS: (Material Safety Data Sheet): A manufacturer-provided ingredient and safety hazard description of materials classified as hazardous or containing hazardous elements. It also includes information for handling spills or chemical reactions.

MSO (Mobile Switching Office): Provides central office functions for iDEN mobile units.

MTBF: Mean Time Between Failures.

Multicoupler: An RF device which provides multiple outputs of a single RF input.

Multimeter: A test instrument capable of measuring voltage, current, and resistance.

NEBS: Network Equipment Building Systems.

NEC® (National Electrical Code): A consultative organization responsible for electrical practices standards. It is part of the National Fire Protection Association (NFPA).

NCRP: National Council for Radio Protection and Measurement.

NEMA: National Electrical Manufacturers Association.

NFPA: National Fire Protection Association.

NIU (Network Interface Unit): A T-1 network interface unit.

Noise: Regarding line power, a power line abnormality which collectively refers to various kinds of high frequency impulses that ride on the normal sine wave of AC electrical power. Noise can range from a few millivolts to several volts in amplitude and can create erratic behavior in any electronic circuit. RF noise, when present over power lines, is one of the more troublesome. This noise can be generated by lightning, radio transmissions, or computer power supplies.

Nomograph: An arrangement of axes in which a variable is determined by a line which intersects known points on associated axes.

Notch Filter: A band-reject cavity filter designed with a high Q resonant circuit to attenuate a narrow band of frequencies while allowing all other frequencies to pass through with only a slight loss of signal strength.

Operating Temperature: Temperature within an equipment case, with the equipment operating at a given capacity or load.

ORV permit: Off-road vehicle permit. A permit that grants the holder the right to drive a motorized vehicle through areas inaccessible by road.

OSHA: Occupational Safety and Health Administration: United States federal government regulatory agency responsible for standards regarding personnel safety at commercial and industrial sites.

Paging: A one-way communication system in which the receiving unit is sent a digital message. Paging can be provided as a PCS service.

PANI: (Surge energy Producers, Absorbers Non-isolated equipment and Isolated equipment): A method of bonding conductors to the MGB in a specific order, depending on their origin.

PCS (Personal Communication Services): A digital communications system that provides data services such as messaging and paging as well as digitized voice.

PERT chart: Program, Evaluation, and **Review Technique** chart. A flowchart showing the relationship and sequence of events comprising a project.

Plat book: A document that depicts the legal ownership of specific parcels of land, usually in relation to a county, township, section, or range.

Plenum: A compartment or chamber to which one or more aid ducts are connected and that forms part of the air distribution system.

Point of entrance: The point of emergence through an exterior wall, a concrete floor slab, or from a rigid metal conduit or an intermediate metal conduit effectively bonded to a ground electrode system.

Pulse method: A method for tower guy wire tensioning.

PSTN: Public Switched Telephone Network.

QA/QC: Quality Assurance/Quality Control.

R56: The Motorola committee responsible for enacting standards related to communication site construction and installation practices. R56 also refers to the literature distribution number formerly used for this manual, *Standards and Guidelines for Communications Sites* (PN 68P81089E50).

Rack: A standard equipment rack used for supporting communications equipment installed in an existing Building or Shelter.

RF: Radio Frequency.

RFDS (RF Distribution System): A system that combines RF signals so that multiple transmitters and receivers tuned to different frequencies can use a single antenna.

RFP: Request For Proposal.

RGB (Rack Ground Bus Bar): A single bus bar to which all equipment ground wires are bonded within a single equipment rack.

RH: Relative Humidity.

R-Value: A standardized rating system of thermal insulation effectiveness. Higher values denote greater insulating effectiveness.

SAD (Silicon Avalanche Diode): A two-terminal voltage protection device in which resistance across the device markedly decreases when the voltage across the device reaches a specified threshold.

Safety climb: Equipment that is attached to a tower to safely enable tower climbing.

Sag: A sag is the opposite of a surge (see also **Surge**). It is a multi-cycle, under-voltage condition that can be caused by ground faults, undersized power systems, lightning, or a sudden start-up of a large electrical load.

SBCCI: Southern Building Code Congress International, Inc.

Seismic rating: Any of several standardized systems of rating an area’s probability and intensity of seismic activity based on geological and empirical data. This publication references the Moment Magnitude (MM) rating standard recognized by the Uniform Building Code. Ratings of “0” (least probability with the least intensity) through “4” (greatest probability with the greatest intensity) are accordingly assigned to various regions.

Separately Derived System: A premises wiring system in which power is derived from a transformer or converter winding. It has no direct electrical connection, including a solidly connected grounded circuit conductor, to the supply conductors originating in another system.

Service Entrance: The point at which the utility enters a facility and the utility ground rod is attached.

Shelter: A permanent structure built on a foundation that contains communications equipment and related ancillary support systems, and may contain other unrelated equipment and/or facilities. A Shelter **shall** be suitable for temporary or permanent human occupancy during equipment installation, maintenance, and use.

Simulcast: A system configuration using simultaneous transmissions of information on the same frequencies. This configuration extends communications over a large coverage area. Each repeater on the same frequency has identical transmit parameters to ensure the intended transmission format.

Site: A permanent installation of fixed communication equipment and ancillary items. A site can range from property containing full support capability (such as a collocated building, backup power, and an antenna tower) to an equipment rack. Within these extreme are shelters, vaults, and exterior-installed cabinets.

SmartZone system: A multi-zone, multi-base station trunking radio system that allows subscriber units to travel throughout the system's coverage zones with no loss of service.

Soil resistivity test: A test that measures the resistivity of soil at a prospective communications site. Used for determining whether an external grounding electrode system can be constructed that will provide satisfactory resistance values.

SPD: Surge Protection Device.

Spike: A power line abnormality which manifests itself as a high magnitude transient event that can disrupt computer operations and even damage equipment. A spike can be caused by lightning, utility switching, static discharges, and switching of large electrical loads on and off.

SSGB (Subsystem Ground Bus Bar): A single bus bar to which all equipment ground wires are bonded within a single room or portion of a communications site.

Standard Proctor test: A soil compression test that measures the compacted density of soils being used for structural and non-structural applications. (Refer to *ASTM D698* for more information.)

Surge: A power line abnormality which manifests itself as an over-voltage condition that lasts longer than one cycle or 1/60th of a second. A surge is usually more dangerous than a spike because of the duration, rather than the magnitude of the over-voltage. This type power line abnormality can be caused when utilities switch large loads off-line, or when devices drawing a large amount of current suddenly stops or shuts off. The opposite of a sag (see also **Sag**.)

T-1: A TDM digital leased line that provides 24 multiplexed voice grade channels at 1.544 Mbps.

TDM (Time Division Multiplex): A multiplexing scheme in which data from several sources share a common link. Each source is allotted access to the link on a sequential time access basis. The aggregate of all the time slots for a given period is referred to as a "frame".

TDMA: Time Division Multiplex Access.

TELCO: Telephone company.

Temperature and pulse charts: Documentation that verifies guy wire tensioning test results.

TETRA: Trans European Trunked Radio.

Thrust block: Specialized concrete footing.

TI: Tenant Improvement.

TIA: Telecommunications Industry Association.

Tower: A structure supporting one or more antennas at a communications site. Tower types include monopole, lattice, and can be freestanding or supported with guy wires.

TGBB (Tower ground bus bar): A bus bar located at the bottom of a communications tower to which the tower's down conductors and transmission line ground kits are bonded. The tower ground bus bar is grounded to the external site grounding ring.

Transfer switch: A high-current switch that transfers a site's AC main power connections from utility-provided power to either generator-provided power or UPS-provided power. The switch can be either manually or automatically actuated.

Transmission line: A connection between RF elements (such as a repeater and an antenna) in which the transmission line characteristic impedance at an intended frequency range is considered and matched between the elements. In this manner, a transmission line provides maximum signal transfer between RF elements. Depending on the frequency of the system, a transmission line physically can consist of impedance-matched coaxial cable, or semi-rigid/rigid waveguide structures.

Trunking: The automatic and dynamic sharing of a small number of communication channels between a large number of radio users.

TTA (Tower Top Amplifier): A weatherized RF amplifier/duplexer module that is mounted adjacent to an antenna. It is used to boost receive signal levels while allowing transmit signals to pass unaffected.

TVSS: Transient Voltage Surge Suppression.

UCBC: Uniform Commercial Building Code.

Ufer ground system: A ground conductor (typically a concrete-encased electrode) used to speed dissipation of voltage potentials in an area with less than optimum earth ground characteristics, such as a concrete slab.

UL®: Underwriter's Laboratory.

UPS (Uninterruptable Power Supply): A system that provides AC line power to communications site equipment if primary power fails. A UPS consists of a battery-backup system that converts battery-supplied DC power to AC line power. The UPS also provides filtering to protect equipment from transients and other power irregularities on the supply line.

USGS (US Geological Survey): US agency that furnishes information relating to seismic activity.

Vault: An enclosure that houses communications equipment and ancillary systems only and is fully or partially buried in soil. It is designed such that equipment contained within can be accessed without the need for personnel to enter the enclosure.

Vibratory wand: Equipment used to consolidate aggregate in concrete to help assure removal of air voids.

VPL (Voltage Protection Level): For a voltage protection device, the voltage at which point clamping occurs.

Waveguide: A rigid or semirigid, normally rectangular, hollow transmission line that typically carries microwave signals.

WBS (Work Breakdown Structure): A method of describing the tasks involved in a project by assigning numbers to the major items to be completed, and then assigning subordinate numbers to tasks that are constituents of the major items. The numbers are then used to identify all tasks throughout the project.

1.5 R56 COMMITTEE MEMBERS

The following Motorola R56 committee members contributed to this publication. Each committee member has extensive experience and technical expertise in one or more of the topics included in this publication.

To contact the committee with questions or to offer suggestions for improving this manual, send email to:

R56MAN1@namerica.mot.com

Primary Contributors	
Dave Babbitt	Bill Kouba
Stan Bailey	**Tom Kravcar - committee chairperson**
Bob Batis	Shane Morris
Chris Berbaum	Jim Ostling
Bruce Carpenter	Frank Rasco
Bob Custer	Ron Romano
Ray Grimes	Ron Tatom
Dan Kelly	
Associate Members	
Don Backys, P.E.	Rob MacDougall
Mike Hill	Eddie Phillips
John Kuhl	Leda Quesada

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CHAPTER 2

SAFETY SUMMARY

This chapter provides the following safety-related information:

2.1 INTRODUCTION

This chapter provides an overview of how safety and equipment precaution concerns are addressed in this manual. This chapter also discusses general safety concerns and requirements.

2.2 SAFETY, PRECAUTION, AND NOTE STATEMENTS DEFINED

Safety statements included in this manual alert you to potential hazards to personnel or equipment, and precede the step or text to which they apply. Safety statements in this manual are of the following types:

WARNING

Warnings indicate danger of injury or death to personnel. Warnings can indicate chemical, electrical, or other type of hazard. Warnings are indicated by an exclamation point and the word WARNING.

CAUTION

Cautions indicate the possibility of damage to equipment. Cautions are indicated by an exclamation point and the word CAUTION.

NOTE:

Notes provide information that makes the job or process easier to perform properly.

2.3 FIRE SAFETY

WARNING

The primary intent in suppressing a fire at a communication site is to protect lives. Equipment protection is secondary. If the fire is expected to be entirely suppressed by a manual extinguisher, then the suppression effort can be made, but in no circumstances shall fire suppression be attempted in order to save equipment when personnel safety is at risk. In all cases for occupied shared buildings, the fire department and tenants shall be notified immediately of the fire.

This section describes general fire safety precautions to be observed at sites. For information on requirements for fire protection systems, see “Fire Protection/Safety” on page 5-34.

Fire extinguishers can represent an important segment of any overall fire protection program. However, a proper fire suppression program success depends upon the following general conditions:

- The extinguishers are of the proper type and size for a fire that may occur.
- The extinguishers are properly located and identified.
- The extinguishers are in working order and properly maintained.
- Employees have a clear understanding of their functional operation.
- Safety awareness has been made available.

2.3.1 TRAINING AND PROPER USAGE

Site personnel **shall** be familiar with the proper usage of the fire protection equipment provided at the site. Documentation supplied with the equipment must be made available to personnel. Responsible personnel **shall** fully understand the content of such documentation.

More complicated systems, such as an installed automatic system, should be supported with training supplied by the vendor.

2.4 BATTERY SAFETY PRECAUTIONS

Batteries used for powering equipment pose the following risks:

- Explosion hazard resulting from inherent generation of hydrogen sulfide gas.
- Chemical burn/blindness resulting from sulfuric acid electrolyte.
- Very high current capabilities, with the possibility to burn, start fires, and result in arcing.

All of these concerns are significant and **shall** be observed in accordance with the warning here, and in accordance with all manufacturer documentation and product placard notices.

WARNING

Motorola employees shall not handle hazardous materials unless properly trained. This includes warehouse storage, transportation, and installation of battery systems.

WARNING

Regular site personnel shall not attempt to clean electrolyte spills resulting from battery rupture. Such work is considered a HAZMAT handling incident.

WARNING

Special precautions are required when handling batteries:

To avoid spilling acid, do not tip batteries.

Battery acid can cause severe burns and blindness if it comes into contact with skin or eyes. Wash affected skin or eyes immediately with running water. Seek medical help immediately.

Jewelry shall not be worn while working on batteries.

Installation personnel shall wear necessary safety equipment when installing batteries.

Batteries may require two-person lift. Use proper lifting techniques and equipment to avoid injury.

Insulated tools shall be used when installing battery systems.

WARNING

Appropriate signage must be present on doors leading to battery rooms and within the room itself, notifying personnel of explosion, chemical, and electrical hazards within the area. Appropriate fire extinguisher(s) must be present in battery room, as dictated by local code.

2.5 SEISMIC SAFETY PRECAUTIONS

Proper seismic design of a site helps ensure safety of personnel at the site should an earthquake occur.

WARNING

Seismic activity of a site shall be assessed using maps promulgated from the US Geological Survey (USGS). (See "Related Publications and Resources" on page 1-3 for information on obtaining USGS materials.)

Seismic activity shall be assessed by a certified architect using USGS maps and other recognized geologic or risk history documents descriptive of the location in question.

WARNING

Shipping boxes and other temporary packaging, and cabinet stabilizer supports shall not be used as permanent seismic bracing. Only specifically designed seismic support hardware shall be used for seismic bracing. (Recommended seismic bracing and support is addressed in the respective chapters of this document.)

WARNING

Seismic battery racks, seismic bracing and support, and seismic facility and antenna structure construction practices shall be employed in seismically active locations. Storage cabinets shall be closable and secured to walls. (These requirements are discussed further in the respective chapters of this document.)

2.6 ELECTROMAGNETIC ENERGY SAFETY

Personnel working at a communications site **shall** be aware of Electromagnetic Energy (EME) hazards and corresponding precautions.

WARNING

All Motorola employees and contractors, and other personnel shall be required to wear personal Electromagnetic Energy (EME) monitoring devices when working in the vicinity of fixed transmission sources of Radio Frequency (RF) energy.

WARNING

All Motorola employees, contractors, and other personnel working at communication sites shall be familiar with the information contained in Appendix E, "Electromagnetic Energy Information" and shall follow the appropriate guidelines.

2.7 GENERAL SAFETY PRECAUTIONS

The following are general safety precautions that should always be observed when working at a site.

WARNING

Never service electrical/electronic equipment unless another person capable of rendering first aid is present.

WARNING

To avoid injury or death caused by electric shock, do not wear a grounded wriststrap when working with high-voltage equipment.

WARNING

Objects heavier than 18.2 kg (40 lb.) should be lifted by two or more people

WARNING

On older existing buildings, care should be exercised to ensure surfaces being disturbed do not contain asbestos. Surfaces containing asbestos can result in an inhalation hazard when disturbed by drilling, cutting, sanding, or demolition. Only certified asbestos abatement professionals shall perform asbestos removal. A certificate of occupancy shall be secured where such abatement has been performed.

WARNING

New and existing structures can pose health related problems due to lack of sanitary conditions. Proper personnel hygiene practices and material handling shall be practiced. Personnel performing installation should wash their hands before eating and avoid touching mouth and nose while handling equipment and/or debris.

WARNING

In environments where explosion hazards may exist, non-incendive Intrinsically Safe electrical components shall be used where appropriate. Note that certain locations may be entirely unacceptable for housing electronic equipment.

WARNING

Communications equipment shall not be installed in elevator equipment rooms unless specific, code-allowed measures have been taken to mechanically isolate any wiring from moving equipment.

WARNING

All applicable health and safety codes shall be adhered to when performing tasks discussed in this manual. In the United States, all applicable OSHA standards shall be adhered to.

WARNING

Climbing of ladders and towers poses significant safety risks. Only personnel trained in this practice, and who possess the proper equipment shall perform such work. The Motorola Contractors Fall Protection Program shall be observed.

Ladders shall be OSHA approved for electrical work.

WARNING

In the United States, in installations such as nuclear power plants and processing facilities, rules and regulations of the United States federal government's Nuclear Regulatory Commission (NCR) policy, as well as any customer policy, shall be observed.

2.8 SAFETY SUMMARY

This section lists all WARNING statements consecutively listed throughout this manual.

2.8.1 CHAPTER 3: SITE ACQUISITION

WARNING

Always drive safely. To avoid accidents, never try to drive while looking at a map or computer screen.

2.8.2 CHAPTER 4: SITE DESIGN AND DEVELOPMENT

WARNING

Any area involving tower construction shall be tied-off from non-authorized personnel entering.

WARNING

Fall protection measures shall be observed and implemented at any and all towers and structures, regardless of ownership, where climbing is required.

Any and all regulations regarding tower climbing shall be observed and implemented. In any case, more stringent regulations shall supersede other regulations.

Subcontractors shall be required to submit their written comprehensive Safety Program to Program Management and obtain approval prior to commencing any work.

All tower climbing shall be in accordance with the Motorola Contractor Fall Protection Program (See Appendix B).

WARNING

Follow Ground Resistance Tester manufacturer's warning and caution information when using tester. Follow furnished instructions when inserting and removing test rods into soil.

WARNING

Utility locator services shall be used to locate buried utilities before conducting any subsurface explorations.

WARNING

To ensure personnel safety, all excavations shall be conducted in accordance with OSHA safety and excavation regulations, and/or local safety regulations (whichever is more stringent).

2.8.3 CHAPTER 5: COMMUNICATIONS SITE BUILDING DESIGN AND INSTALLATION

WARNING

Shipping boxing and supports shall not be used as seismic bracing.

WARNING

Aluminum ladders designed for climbing shall not be used as cable trays or runways.

WARNING

Fixed or portable fire suppression systems using water shall not be used in communication sites.

WARNING

Buildings and shelters that may have been open to the elements and animal infestations can pose health risks to personnel working in the structure.

Avoid sweeping dry floors when rodent droppings may be present. To prevent hantavirus infection, the floor shall be mopped in a safe and sanitary manner using a 5:1 water/bleach mixture. Personnel occupying the site shall wash hands before eating and avoid touching mouth, nose, or eyes until site is sufficiently clean.

WARNING

If the building has a sprinkler system, make sure the cable runways do not block the sprinklers. Also, the equipment installation must not alter or block the sprinkler spray pattern or effectiveness.

WARNING

The primary intent in suppressing a fire at a communication site is to protect lives, with equipment being secondary. If the fire is expected to be entirely suppressed by a manual extinguisher, then the suppression effort can be made but in no circumstances shall an effort be made to suppress a site fire to save equipment where lives are at risk through this effort. In all cases for occupied shared buildings, the fire department and tenants shall be notified immediately of the fire.

WARNING

The fire department shall be notified as soon as a fire is discovered. Notification shall not be delayed in order to assess the results of fire fighting effort using on-site portable fire extinguishers.

2.8.4 CHAPTER 6: EXTERNAL GROUNDING

WARNING

When operating any kind of power tool, always wear appropriate safety glasses and other protective gear to prevent injury.

WARNING

Before excavating or digging at a site, have the local utility company or utility locator service locate the underground utilities.

WARNING

Follow manufacturer's warnings and safety requirements!

Heavy clothing, work shoes or boots, gloves, and safety glasses shall be worn when performing exothermic welding.

Exothermic welding shall not be performed unless another person capable of rendering first aid is present. A suitable fire extinguisher shall be close by with an attendant during the process.

WARNING

Wear safety glasses, hard hat, and steel-toe shoes when working with high-compression fittings.

WARNING

Braided straps shall not be used because they corrode too quickly and can be a point for RF interference.

WARNING

Do not attempt to install a separate grounding electrode system without bonding it to the existing grounding electrode systems. A difference in potentials could result.

WARNING

No welding, heating, or drilling of tower structural members shall be performed without written approvals from the tower manufacturer.

WARNING

Procedures in this section shall not be performed by untrained or unqualified personnel, nor are any procedures herein intended to replace proper training. It is required that personnel attempting to measure the resistance of a grounding electrode system receive prior formal training on the subject and on its associated safety hazards. All applicable laws, rules and codes regulating the work on electrical systems shall be complied with at all times.

WARNING

Check for current on the grounding electrode conductor before disconnecting. Never disconnect the ground of a live circuit. Disconnecting the ground of a live circuit could cause death or severe injury.

WARNING

Follow Ground Resistance Tester manufacturer's warning and caution information when using tester. Follow furnished instructions when inserting and removing test rods into soil.

Make certain this procedure is fully understood before proceeding with test.

WARNING

Follow Clamp-on Ohmmeter manufacturer's warning and caution information when using tester.

2.8.5 CHAPTER 8: POWER SOURCES

WARNING

Work practices that help ensure safety shall be observed while performing all electrical work as required by (but not limited to) agencies such as OSHA, NEC, BOCA and local codes.

Throughout the US, the local buried utility locator service shall be contacted before excavating. In other countries, local utility shall be consulted to obtain buried utility location service. Failure to properly locate buried utilities can pose hazards to personnel. Failure to comply with regulations regarding buried utilities can result in penalties.

WARNING

Aluminum conductors shall not be used. Never mix aluminum and copper wire, connectors, panels, or receptacles. These conductors have a different coefficient of expansion which can cause a connection or joint to become loose.

WARNING

Consumer grade AC power receptacle strips shall not be used for permanent installations.

Do not mount extension blocks or receptacle strips on the floor. Damage can result from foot traffic or water, and water seepage or fire sprinkler activation may pose an electrocution hazard to personnel.

WARNING

Motorola prohibits the use of non-plenum rated power cabling for installation within plenums, even if local codes allow otherwise. Failure to use suitable plenum-rated cables in these areas can result in generation of toxic fumes in the event of a fire.

WARNING

Electrical installations installed in hollow spaces, vertical shafts, and ventilation or air-handling ducts shall be installed in a manner such that the possible spread of fire or products of combustion will not be substantially increased. Openings around penetrations through fire resistance-rated walls, partitions, floors, or ceilings shall be firestopped using approved methods to maintain the fire resistance rating. Firestopping such penetrations may be accomplished by using specially manufactured fire seals or fire-barrier caulking. See NFPA 70, Article 300-21, Article 800-52 and ANSI/TIA/EIA-569-A for more information.

WARNING

Motorola employees and contractors shall not handle hazardous materials unless properly trained. This includes warehouse storage, transportation, and installation of battery systems.

WARNING

Wet cell battery failure involving large-scale electrolyte leakage may constitute a Hazardous Material (HAZMAT) condition. Under no circumstances shall regular site personnel perform HAZMAT handling.

Special training and HAZMAT certification, spill mitigation and reporting, and cleanup techniques/monitoring is required under the Federal Clean Water Act and NFPA regulations.

WARNING

Appropriate signage shall be present on doors leading to battery rooms and within the room itself, notifying personnel of explosion, chemical, and electrical hazards within the area. Appropriate fire extinguisher(s) shall be present in battery room, as dictated by local code.

WARNING

To avoid spilling acid, do not tip batteries.

Battery acid can cause severe burns and blindness if it comes into contact with skin or eyes. Wash affected skin or eyes immediately with running water. Seek medical help immediately.

No jewelry shall be worn while working on batteries.

Installation personnel shall wear necessary safety equipment when installing batteries.

Batteries may require two-person lift. Use proper lifting techniques and equipment to avoid injury.

Insulated tools shall be used when installing battery systems.

WARNING

Battery manufacturer warning statements shall be understood and complied with. The manufacturer's statements shall determine the type and extent of Personal Protective Equipment required in minimizing battery handling hazards for the batteries being installed.

At all sites using wet cell batteries, or gel-cell batteries where manufacturer specifies eyewash or other Personal Protective Equipment, such equipment shall be provided in the battery containment area.

2.8.6 CHAPTER 9: TRANSIENT VOLTAGE SURGE SUPPRESSION

WARNING

Gas Discharge Tubes shall not be used as AC power line surge suppression devices.

WARNING

Common Mode AC power surge suppression devices shall not be utilized. These devices may fail in a short circuit condition. Should this occur, the AC power neutral conductor becomes bonded to the ground or equipment grounding conductor causing undesired currents in the ground or equipment grounding conductor(s). This is a personnel safety hazard and is a violation of NFPA 70. (Common Mode surge suppression devices may be used on telephone or data circuits.)

WARNING

All AC power SPDs used within the United States shall be UL listed or recognized. Devices may conform to the international CE certification mark.

WARNING

Maintenance of SPDs installed within a panelboard requires panelboard cover removal, which constitutes an electrocution hazard. As such, only a qualified and licensed electrician shall perform cover removal and maintenance.

2.8.7 CHAPTER 11: EQUIPMENT INSTALLATION

WARNING

Use caution if there is Isolated Ground Zone and non-Isolated Ground Zone equipment in the same structure. Isolated Ground Zone and non-Isolated Ground Zone equipment shall be mounted at least 2.4 m (8 ft.) apart to avoid touch potential.

WARNING

Electrical installations installed in hollow spaces, vertical shafts, and ventilation or air-handling ducts shall be installed in a manner such that the possible spread of fire or products of combustion will not be substantially increased. Openings around penetrations through fire resistance-rated walls, partitions, floors, or ceilings shall be firestopped using approved methods to maintain the fire resistance rating. Firestopping such penetrations may be accomplished by using specially manufactured fire seals or fire-barrier caulking. See NFPA 70, Article 300-21, Article 800-52 and ANSI/TIA/EIA-569-A for more information.

WARNING

Facility AC wiring within junction boxes, receptacles, and switches shall be performed by a licensed and bonded electrical contractor. Personnel safety and liability hazards can result from AC wiring performed by installation personnel other than an electrical contractor.

WARNING

Under no circumstances shall consumer-grade power outlet strips be used in any installation. Extension cords of any type shall not be used for connecting line power to communications equipment.

WARNING

Never look into an optical fiber cable. Optical fiber cables use invisible laser light that is dangerous and can cause damage to the eye.

2.9 EQUIPMENT PRECAUTION SUMMARY

This section lists all CAUTION statements consecutively listed throughout this manual.

2.9.1 CHAPTER 5: COMMUNICATIONS SITE BUILDING DESIGN AND INSTALLATION

CAUTION

For Tenant Improvements in existing high-rise buildings, it is critical that the contractor determine if post-tensioning is employed in floor, roof, or wall construction. If so, industrial X-Ray mapping is required to avoid structural damage caused by accidental penetration of a tensioning cable.

CAUTION

Batteries should be cleaned with clear water. Do not use abrasive cleaners, detergents or petroleum-based cleaning products on battery container.

2.9.2 CHAPTER 6: EXTERNAL GROUNDING

CAUTION

Braided ground conductors shall not be used under any circumstances. Braided conductors corrode easily and become a point for RF intermodulation.

2.9.3 CHAPTER 8: POWER SOURCES

CAUTION

For areas with seismic rating of Moment Magnitude rating 3 or greater, appropriate rack design shall be used. Follow manufacturer's installation requirements.

CAUTION

Batteries should be cleaned with clear water. Do not use abrasive cleaners, detergents or petroleum-based cleaning products on battery container.

2.9.4 CHAPTER 9: TRANSIENT VOLTAGE SURGE SUPPRESSION

CAUTION

SPDs using SAD technology may develop an artificial diode bias when subjected to strong RF fields that may be experienced at AM, FM or TV broadcast sties. This bias may cause data circuit errors.

CAUTION

Tower lighting cables shall not be bundled along with transmission lines or other conductors anywhere within cable ladders, or the building interior.

CHAPTER 3

SITE ACQUISITION

This chapter provides guidelines for integrating the site acquisition process into the design and development of a communications system. The chapter contains guidelines regarding on the following topics:

3.1 INTRODUCTION

Historically, the system owner (the "customer") has handled site acquisition as an activity independent of system development. However, although some portions of the process cannot be done by anyone other than the system owner, it has been found that lack of vendor involvement in the site acquisition process can contribute to delays and additional project costs. On some projects, a third party may need to be contracted to perform portions of the site acquisition process.

The tasks described in this chapter are organized into the same sequence as they typically occur in a project and as they should be included in the project schedule.

3.2 VENDOR RESPONSIBILITIES

3.2.1 CUSTOMER INTERFACE

A good relationship with customer staff is imperative. The customer should assign a person to act as the focal point for the acquisition process. In some instances, customers will insist that the vendor use a particular contractor for site acquisition issues. In these instances, the contractor must also appoint someone to take responsibility for the site acquisition effort. Though neither of these positions may be a full-time job, it is important that someone be assigned responsibility for dealing with everyday issues.

The vendor needs to be intimately involved with the process and should take as much responsibility for the schedule as possible. There are many governmentally regulated aspects of site acquisition that only the customer can deal with. On these aspects, the vendor should act in a consulting role only.

The following status activities are recommended to keep the customer informed on the progress of site acquisition.

- **Meetings**

  Hold scheduled meetings with designated representatives from each of the subcontractors, the customer, and the system vendor to discuss progress on all site issues.

- **Status Reports**

  Establish weekly or bi-weekly meetings with the customer and their contractors to review the status of all sites. Face to face meetings to discuss acquisition issues of each property will save a lot of confusion and keep everyone advised of progress or problems.

- **Status Checklists**

  Create a detailed status checklist and update it before each meeting. Ultimately, the customer must obtain the sites for the system vendor, so the customer should be kept appraised of any impediments to the site acquisition process so they can attempt to keep the acquisition process on track. All subcontractors should provide input and updates to the status checklists.

  Identify all open issues as soon as possible and track them on the checklist. As issues are resolved, they can be removed from the list or otherwise noted as resolved. Each item should be reviewed on a weekly basis.

- **Management Update**

  In addition to the status meeting, some detail must be provided to others involved in the project - keeping them advised as to progress at a high level. Make arrangements to report on finalized sites and elevate issues as necessary at a meeting where management from both organizations are present. Only critical issues should be addressed at this meeting.

3.2.2 STAFFING

Site acquisition should fall within the responsibilities of project management. Because site acquisition can occupy the majority of the project manager's time, effective communication between the customer, the project manager, outside contractors, and those appointed by the project manager to assist with site acquisition is vital.

3.2.3 SCHEDULE

Site acquisition needs to be considered at the earliest stages of the project planning process and dynamic links to the overall project schedule should be tied to the completion of certain site acquisition tasks. The unavailability of a site can have a serious negative impact on the overall project schedule.

It is recommended that the project schedule be managed using a software tool, and that the Work Breakdown Structure (WBS) tasks be directly linked into the master project schedule. The links should be properly assigned and updated regularly. As a minimum, aspects of site acquisition that should be tracked in the project schedule include:

- Preparation of initial site packages for each site
- Preliminary site lock
- Federal Aviation Administration (FAA) approval (or equivalent in nondomestic locations)
- Site released for final design

See foldout Figure G-1 for a sample Program, Evaluation, and Review Technique (PERT) Chart.

3.2.4 PERMITS

The vendor is usually responsible for all permits and other regulatory approvals for the project. If there are permits that the customer must apply for, the vendor should prepare the permit and get it to the customer for its approval, signature and presentation to the requesting agency.

Because obtaining construction permits or zoning changes can be a lengthy process, it should be addressed early in the project. Construction permits are covered in Chapter 4, "Site Design and Development."

3.3 CUSTOMER RESPONSIBILITIES

There are some items that must be provided by the customer in order to complete site acquisition. To keep the site acquisition process on schedule, make the customer aware of these items early in the process so the items are ready when necessary.

3.3.1 LETTER OF INTRODUCTION

Ask that the customer prepare a brief letter of introduction on the customer's stationery, describing your activities and providing a contact to call if there are further questions. The Site Acquisition manager should keep a copy of this letter with them as they conduct field investigations.

3.3.2 RIGHT OF ENTRY

The site owner should provide the contractor and other subcontractors with written permission to enter sites for pre-construction activities such as surveys and soils work. If the site is being purchased from a private individual, the option to purchase should grant the right to conduct site investigative work necessary to determine the usability of the proposed site. The right of entry should extend from the time of option until the title has transferred to the system owner. Typically, permanent alterations to the property are not permitted during right of entry.

3.3.3 POLITICAL CONSIDERATIONS

The system owner must take a firm stance regarding its position on public objections to the construction of towers. Without a comprehensive approach to the politics of developing the system, significant schedule delays and additional costs can result if there is organized objection to tower construction.

If the customer is an agency of a state government, one very helpful tool to the customer is the passage of legislation making the state and its agencies exempt from local zoning requirements specifically for the construction of the project.

> **EXAMPLE**: In one state in which Motorola installed a statewide radio system for the state police and other state agencies, the state's governor proposed and succeeded in having a state law passed that allows the state to build towers as necessary for its 800 MHz statewide radio system. The legislation requires that the state notify the local unit of government that has zoning jurisdiction that a new tower is being proposed at a specific location. If the local zoning authority opposes the state's proposed tower location, it has 30 days to propose an equal alternate location that has clear title, no wetlands and a completed ASTM Phase I environmental study. The site must meet the coverage requirements of the system and in all aspects be satisfactory to the state. If the local unit of government fails to offer an alternate location for the site, the proposed site may be developed by the state without regard to local zoning ordinances.
>
> In this state, new tower locations have been challenged several times and all have been successfully defended by the state due to this legislation.

Regarding the above example, note that the probability of obtaining the passage of such legislation often depends upon the scope of the project, and whether the project is deemed important enough to warrant such an exemption from local zoning controls.

To minimize delays associated with public objections and public hearing processes, explore the possibility of using utility rights-of-way. In many states, utilities are exempt from local zoning regulations and processes.

Utility right-of-way are typically long strips of land located adjacent to highways. It may be possible to obtain standard leases for identical sites as needed to cover an area. The leasing process is simplified by requiring dealings with a single landlord (the utility company) instead of with multiple property owners.

In certain jurisdictions, the zoning process may be simplified by the use of underground vaults, partially buried vaults, or "cabinetized" sites. Cabinetized sites are sometimes viewed as "utility cabinets" and not buildings. In many jurisdictions, if cabinets are less than 1.82 m (6 ft.) high, they do not typically require full zoning permits/approvals.

3.3.4 PROPERTY APPRAISAL

When determining the offering price for private parcels, governmental agencies will need to know the fair market value (FMV) of the parcel before an agreement is signed. A FMV may also be required for interagency title transfers (Dept. of Natural Resources transfer to state police, for example). The customer should engage the services of an appraiser available to provide FMV for all sites.

3.3.5 REAL PROPERTY TITLE ISSUES (CURING DEFECTS)

The following title-related items are the responsibility of the customer:

- **Legal Description; Conveyance**

  The property owner and the customer should be responsible for determining the proper legal description of the sites, as well as conveying legal title for all sites. The vendor should provide a preliminary description of the desired location based on coverage and other site investigative activities.

- **Title Insurance**

  Most customers require a title insurance policy be issued for parcels which comprise part of its radio system. The title insurance policy provides some assurance to the customer that there are no adverse title problems that will render the site unusable in the future. Generally, obtaining title insurance on the property underlying the site should be used as another method to ensure the condition of title to the property, and not as a final statement regarding its worthiness.

- **Surface Releases**

  Some customers will not be concerned with the subsurface mineral rights of their properties and some will. The most important concern when locating tower sites is that the customer has control of the **surface** of the property together with the right to lay any necessary utility lines.

  In many cases, the owner of a parcel of property does not own minerals, gas, or oil that may be located beneath the parcel. In these cases, the mineral rights have been severed from the real estate and a third party has the right to the minerals. Though your customer need not acquire the right to the minerals, it is important that a surface release be obtained from the owner of the mineral rights so they will not ask to come onto the property to mine the minerals or interfere with the use of the property as a communications site.

  For oil and gas, surface releases are rather easy to get because the gas and oil can be reached using directional, or “slant”, drilling from another location. Conversely, if there are minerals or gravel near the surface of the property and someone else holds the mineral rights, it is unlikely they will release their surface rights.

3.3.6 PROJECT FINANCING

In some cases, the source of project funding can have a great deal of impact on the requirements of the procurement process. For example, if your customer is a public entity that intends to fund the project through the sale of bonds, the issuer of those bonds will usually have strict restrictions as to the condition of the title to the property (i.e., the site) being used as partial collateral for the bonds. Most bond covenants do not allow collateral properties to be burdened with surface use restrictions, exclusive easements granted to others, encumbered title, or with other restrictions to use that in any way may diminish the ability of the bond holders to recoup their investment in the event of default on the loans secured by the bonds.

As a result, for projects financed by public bonds, this places a greater need to properly cure title defects than if the customer were to finance the project with its own funds. Be aware of the means of financing and be ready to adjust your process.

3.4 SITE SELECTION PROCESS

Site selection and acquisition consists of five stages:

- Customer / Vendor Understanding
- Initial Site Selection
- Preliminary Site Selection
- Final Site Selection
- Final Site lock

Each stage is described below.

3.4.1 CUSTOMER/VENDOR UNDERSTANDING

Hold a meeting with the customer to set goals for the site acquisition process and to establish responsibility for each stage of the process. Site acquisition is dependent on the customer's coverage requirements; therefore, ensure that the design team thoroughly understands these requirements. Acceptance of the site by the customer is dependent on whether the coverage requirements have been met. Site acquisition personnel should work closely with the system design team to assure complete understanding of the customer's coverage requirements.

3.4.2 INITIAL SITE SELECTION

Once the coverage requirements are identified and agreed to by both the customer and the vendor, various coverage prediction tools can be used to locate target areas. These target areas are then investigated by the Site Acquisition (SA) manager and evaluated as to their suitability.

Site acquisition for multi-site systems begins with office work to identify potential locations. The manager responsible for site acquisition should work closely with coverage and microwave engineers to locate target areas that will meet the coverage requirements of the system. The search should be coordinated so that the site acquisition manager is confident that the preliminary site locations will meet the coverage and microwave paper path survey requirements. It is important to identify several potential locations for each site. Only a field visit can determine the suitability of a location as a final prospect.

Much of the preliminary investigation work can be done from the office using the following resources:

- Use available taxing authority plat books to determine property ownership and parcel size, as well as the accessibility of the property to a public road.
- Use U.S. Geological Survey (USGS) or other terrain-related maps to determine general land cover, topography, vegetation, site accessibility, and to identify larger wetland areas.
- Use FAA or equivalent aeronautical maps and data to determine the site's proximity to airports and to eliminate areas that will likely be rejected by the FAA during the application process.
- Global Position System (GPS) reception is required for certain systems. Use topographical maps and/or a handheld GPS receiver to determine whether a site receiver can be oriented properly to receive the satellite signal. Also verify that any local RF interference does not render a GPS receiver inoperative at a proposed site location.
- Contact the local power companies to determine availability of power near the site and costs to bring power to the site.
- Contact the local telephone company to determine availability of standard local telephone service as well as T-1 lines to the site.

3.4.3 PRELIMINARY SITE SELECTION

After sites have been determined suitable using the tools available from the office, each site should be visited to further assess its suitability. Visit several locations for each site to determine the best location. Secondary locations for each site or optional locations should also be identified in case the first choice cannot be obtained.

After all locations for each site are evaluated, the location meeting the greatest number of criteria is chosen as the preliminary location for the site.

The initial site selection described above is done in the office. When a site meets the criteria that can be evaluated from the office, conduct a site inspection to confirm whether it merits further consideration.

One of the most important responsibilities of the site acquisition manager is the preliminary site inspection. This field visit captures as much information as possible to make a good evaluation of a site and its level of compliance with your proposed system design requirements.

During the field visit, the Site Acquisition manager should go to the local governing agency and gather information on the ownership of the potential property. The governing agency that maintains the tax roll information can provide basic legal description and ownership information. The local zoning restrictions which apply to the property should also be identified as early as possible. Note that differing local governmental agencies may have different responsibilities and authority (and therefore, information) relating to the property. For example, tax roll information is generally maintained by county governments; while zoning information is maintained by a municipality (if the site is located within the boundaries of a municipality). This is usually adequate data for preliminary site selection purposes. Once the site is selected as a final location, title work will be ordered from a title company to resolve any ownership problems.

If the system to be installed requires the installation of GPS receivers, it is critical that a GPS survey be made in and around the location of the proposed site.

Exterior RF interference (broadcast, military, etc.) may preclude use of the new site, regardless of its other qualities. Chapter 10, “Minimizing Site Interference,” provides an overview of methods for reducing RF interference from other sources.

3.4.4 FINAL SITE SELECTION

Before the preliminary location can be classified as a final location, the following must be done:

- Title search
- Topographic and boundary survey work
- Environmental and wetlands studies
- Zoning considerations
- Curing defects in title

Once the topographic survey is finished, soil borings are ordered to determine the site’s suitability for a tower. FAA applications (or equivalent) are filed to seek out any restrictions on the eventual height. Field path surveys are conducted to assure microwave reliability is within the required specifications.

If any of these items cannot be completed satisfactorily, the site may have to be abandoned and the search for a new site started. These topics are discussed in further detail below.

3.4.5 FINAL SITE LOCK

Final site lock can have different meanings to different customers. If there is any outstanding issue that could result in the site being rejected, it should not be considered as "final." However, in many instances, it is not practical to wait until all issues are resolved before continuing with the system's implementation. It is necessary to balance the customer's comfort level against the risks associated with site rejection.

3.5 CHOOSING A SITE

New communications systems can use several types of antenna locations:

- Existing, developed communications sites
- Existing, undeveloped sites
- New antenna structures
- A combination of these three types

Cost may dictate the use of existing sites, while security concerns may steer the project toward using customer-owned sites. This section will help you assess and compare costs of improving and maintaining an existing site to the cost of constructing and maintaining a new site.

3.5.1 EVALUATING EXISTING SITES

An existing site consists of either (or a combination of) the following:

- Developed RF site
- Undeveloped site

3.5.1.1 EVALUATING DEVELOPED RF SITES

Many urban (as well as some rural) areas have stringent zoning and other restrictions on the development of new structures. This may restrict your search for sites to existing structures. These existing structures may be buildings or towers, and they may already be developed as antenna sites or they may be undeveloped. If you decide to use an existing site in your system, its development should be tracked and managed with the same attention to detail afforded to new sites.

Factors to consider when evaluating a developed RF site are listed below. Because these sites are typically leased from the site owner, the customer must resolve lease-related issues with the site owner; the vendor can only assist the customer.

Gather and present lease forms and documents required for lease preparation to the customer for preliminary review. The lease itself should be negotiated between the site owner and the customer, since issues that may arise can only be resolved by the principal parties.

- The site must meet the system's coverage requirements. Be sure that the antennas specified in the coverage predictions can be mounted on the existing structure and that any required microwave antennas can be accommodated.
- If the existing tower structure has a combining system, RF engineering must be involved to be sure the system can share the combining scheme.
- Most tower structures constructed to accommodate leases are capable of supporting many antennas. Verify that the addition of equipment does not surpass the ratings of the tower without requiring additional engineering.
- Check with the Federal Communications Commission (FCC), or equivalent, for a history of any violations of lighting or obstruction marking over the last 5 years related to the site.
- Determine whether there is a tower or building monitoring system for obstruction lighting or whether the site lessor accepts responsibility for FCC (or appropriate licensing authority) citations due to failure to notify.
- Check that the coordinates, height, lighting, and obstruction marking meet the latest FAA (or appropriate regulatory authority) filing. If they do not, a re-filing is necessary. Verify that the site owner is willing to make the required changes and determine who will be responsible for notifying other users of the site.
- Verify whether the site has a grounding system. If so, verify that it meets the requirements of this publication. Refer to Chapter 6, "External Grounding," for information on assessing the condition of the site ground system.
- Verify that the site has a documented maintenance schedule and that it is followed.
- Verify that the equipment room environmental conditions are adequate for the addition of your equipment as well as future expansion.
- Verify that convenient access to the equipment room is available for installing and servicing equipment.
- Verify that site security is adequate for the equipment room as well as for the rooftop transmission systems.
- Check for established site requirements for RF interference protection evaluation and verify that they meet the needs of the system being installed. Refer to Chapter 10, "Minimizing Site Interference," for more information on RF design considerations.
- Check the site management or owner's lease expiration date. If it is due to expire in the near future, the implementation of your system could be jeopardized.
- Check to make sure that the customer lease with the lessor includes appropriate provisions to help ensure that the customer's lease rights are adequate to maintain equipment operation seven days a week, 24 hours a day in the event of an emergency or other site-related problem.
- Check that the lease has an exit clause dealing with natural disasters and liability.
- Verify that a disaster recovery plan exists.

- Check for and evaluate the potential impact of Electromagnetic Compatibility (EMC) sources at the site.
- Verify that site management will allow posting of workplace safety warning signs for personnel protection.
- Compare the cost of leasing space at the site to that of other sites in the same area.
- Have the lease agreement reviewed by the customer's legal advisor before giving serious consideration to the site.
- If required, verify that the system operator will be permitted to install an exclusive RF distribution system (RFDS) and antennas. An Integrated Dispatch Enhanced Network (iDEN) system will not work with many of the current analog transmit and receive combining systems that may exist on a shared site.
- Verify that the antenna structure can accommodate future antenna growth.
- Check to see if the site location is at risk for natural disasters such as forest fire, flood, or earthquake.
- Check for potentially incompatible activities in the vicinity, such as schools, hazardous manufacturing, storage of hazardous materials, or corrosive atmospheres.
- Verify whether the new site tenant can perform tower work or must hire an owner-approved third party contractor.
- If tower work is required, investigate the site owner's EME hazard policy relative to pre-notification and transmitter shut-down.

3.5.1.2 EVALUATING UNDEVELOPED EXISTING SITES

In addition to the considerations for existing developed sites, the following items must be considered for potential new sites located in buildings or on rooftops:

- Verify that the floor or roof structure is adequate to support the equipment to be installed, including heavy cabinets and/or large battery banks.
- Contact the building engineer to coordinate the logistics of transporting and installing system equipment and antennas.
- Verify that the site will be accessible to system installation/maintenance personnel 24 hours a day, seven days a week.
- Verify that the area and/or building has adequate, reliable electrical and phone service available.
- Verify that backup electrical power can be provided, if necessary (as supplied by batteries, UPS, or standby generator).
- Check for environmental conditions in the building that could jeopardize personnel safety or equipment operation, such as flammable or toxic material (including, but not limited to, asbestos).
- Verify that the building has an emergency alarm system.
- Check whether special equipment such as cranes or hoists will be required to install the system equipment. There may be restrictions on where and when equipment can be lifted to building tops.

- If the installation requires a self-contained rooftop shelter, check whether the roof itself requires re-engineering and strengthening.
- Check for motors in the surrounding area that will produce carbon dust.
- Check for restrictions on mounting outside antennas on the building.
- Check that there is a clear view of horizon and check mounting restrictions for microwave or satellite dishes and GPS antennas.
- Verify that all appropriate engineering studies have been completed.
- Verify GPS receiver acquisition and performance.
- Research incompatible or challenged uses.
- Check to ensure that an RF transmitting/receiving use does not violate applicable zoning regulations; or if so, whether an appropriate zoning variance may be available.

3.5.2 EVALUATING NEW SITES

Selecting a new tower site requires that a number of factors be considered. There will be various levels of compliance with each of these factors and the balance between all of them determines the suitability of a site. Some of the points are more critical than others. In some cases, a seemingly insignificant factor can cause difficulties that may render the site unusable.

As a minimum, these factors include:

3.5.2.1 CONSTRUCTION ISSUES

- **Customer-Owned Properties**

  The customer may already own properties suitable for use as tower sites. Every attempt should be made to use properties currently owned by any agency or department within the jurisdiction of the customer. Always investigate deed and zoning restrictions that may prohibit the property from being used as a tower site. Be sure to investigate all properties thoroughly and early in the site acquisition process, even if they already belong to the customer.

- **Grounding Systems**

  Assess the effort and cost to develop an adequate grounding system at all potential sites. See Chapter 6, “External Grounding.”

- **Site Expandability**

  Assess the customer’s predicted expansion needs and verify that the location can support them.

- **Government-Owned Lands**

  When dealing with governmental agencies, meet with their local foresters or representatives in the tower's area early in the process to let them know what is being planned. They may help you find a good tower location on public land. Note that some of these agencies may also be charged with advancing certain public interests which are contrary to the construction of communication towers. For example, one public safety agency may desire to place antenna towers on property administered by another governmental agency which is required to adhere to established forest management plans or environmental standards. Discussions with your customers can alleviate such intergovernmental disputes.

- **Site Accessibility**

  Communications sites must provide adequate access to equipment. Access roads and satisfactory rights of ingress are critical to the overall suitability of the site. Balance a site's desirable characteristics against the potentially high cost of building adequate access roads to it.

  If a site has good coverage, microwave connectivity, utilities, no wetland or environmental issues, and is already owned by the customer – but has no legal access, it probably cannot be used. This is particularly true if the purchase site must be financed. If access is inadequate, the lending institution will likely reject it as collateral.

  Access roads should be constructed to specifications outlined in the typical site development drawings included in Appendix F.

  Consider the weather, even for sites accessible by existing roads. Site investigation during the summer months can be deceiving. A remote hilltop might provide excellent radio coverage, but access to it may be nearly impossible to acquire or maintain, especially in winter. Check with the local road commission or agency responsible for road maintenance prior to final determination.

- **Climate Considerations**

  Unusually harsh climates must be taken into account when selecting a site. For example, in locations where permafrost exists, care must be taken to isolate the building from the surrounding earth. Even the small temperature differential presented by an equipment shelter may be sufficient to cause the surface soil to melt, leading to major structural and foundation damage. Workable solutions include building the structure on stilts or insulated pilings. A local construction contractor should be consulted for expertise and guidance in this area.

- **Microwave Paths**

  Systems requiring microwave links between sites require that tower sites have an unobstructed path between them. Determine the height at which the microwave antennas can electrically "see" each other, then determine the cost of constructing a tower large enough to support the antenna at the required height, and the cost of obtaining the necessary approvals from regulatory agencies such as local zoning authorities, the FAA (or equivalent), FCC (or equivalent), and/or tall structures authority.

- **Permits**

  Consider conflicts in obtaining all necessary permits required to build the site, such as zoning certificates, building permits, wetland mitigation plans, etc.

- **Cost**

  Be aware of the costs associated with a potential site. While exact costs are not available at this point in the process, track estimated costs and risks in a format that can be conveniently provided to management and the customer. It is only necessary to track the costs that may be higher than normal. The site acquisition manager should establish the method of tracking based on specific contract requirements.

  Another cost is one of time. If a permit is likely to be challenged by neighbors or environmental groups, the permitting and public hearing process can be extended until the project is no longer viable.

  Sometimes property located near a target is reasonably priced. In other cases hilltops are scarce and therefore expensive. Keep property cost in perspective. Though a hilltop that meets coverage, microwave, AC power and accessibility requirements might be priced at 150% of market value, it may still be more affordable than constructing two alternate sites to provide the same coverage. The following is a partial list of costs that should be tracked:

  - Property Cost
  - Access Road construction cost
  - Zoning and permit process costs
  - Wetlands resolution/restoration cost
  - Hazardous waste mitigation cost
  - Utility construction costs
  - Utility supply costs
  - Soils issues

- **Clear Title/Ownership**

  Assume that there will be some title clearance issues to resolve in most real estate transactions. If the resolution of the problems could delay the project, consider finding a site with a “cleaner” title.

- **Utilities**

  Verify that the required utilities are available for a newly developed site. Some rural telephone carriers cannot provide T-1 service. This may require the purchase, installation, and appropriate FCC licensing of a 2 GHz spread spectrum microwave short-haul carrier.

  Reliable AC power is required at most radio communications sites. Construction of utilities can be very expensive and must be considered when selecting tower locations. Determine the location and distance to existing AC utilities when conducting field visits. In some locations, power can be miles from the tower site and the cost of installing it may be prohibitive.

  In some cases, local authorities may require that all new commercial utility construction be buried. The cost of buried electrical service may be more than double the cost of overhead service. Balance the cost of utility construction against the realized gain of a few feet in elevation.

  Get a price quote for the cost of power from the local utilities. There may be several utility suppliers for large, wide area systems. Make contacts at each of the utilities and try to provide all the information they need.

3.5.3 ENVIRONMENTAL ISSUES

The following environmental considerations may affect project cost and schedule if they are not taken into consideration early in the site acquisition process.

- **Wetlands**

  The site investigation process should include a wetlands delineation to indicate the location of wetland areas so the final design may either accommodate the areas or the necessary permits can be applied for. The wetlands delineation **shall** be conducted by a qualified contractor.

  > **NOTE:** Typically, regulations mandate that where wetlands are modified, the entire wetland must be replaced with wetlands of equal quality, usually of greater size, in another area.

  If a potential site contains wetland areas, in some cases, a simple permit may be granted that allows work in the wet areas. In other cases, regulations mandate that the entire wetland area must be replaced with wetlands of equal quality in another area. This may increase project cost considerably. Balance the cost of wetlands work against the need for the site. Construction within a designated wetland area requires extensive permitting and additional cost. In many cases, it is simply impossible to construct in a wetland due to regulatory issues.

- **Protected Species**

  Attempt to determine if a proposed site is the home of any protected plant or animal species, since their presence may render the site unusable. Also consider whether the site is located in the pathway of migratory birds.

- **Hazardous Waste**

  If there has been disposal of hazardous waste or other toxic material on or near a potential site, it is very important to determine the extent and liability for the disposal. An ASTM Phase I environmental assessment should be conducted at each potential site to adequately make this determination. If the ASTM Phase I assessment discloses potential problems, additional steps may be taken before the site is finally approved.

- **Soils Testing**

  Though a formal soils study will be prepared for each site later in the process, the Site Acquisition manager should note any obvious soil conditions such as exposed rock, hardpan, or shale, and bring them to the attention of the construction manager as soon as the site is selected as a preliminary location. Heavy or rocky soils require special equipment to reliable obtain soil samples.

3.5.4 POLITICAL ISSUES

Public resistance to communications towers is on the increase. Some citizens are forming coalitions to stop their construction. Many municipal zoning plans now specifically restrict the proliferation of towers. To help prevent the project from becoming a target of these efforts, try to work within the guidelines of existing zoning regulations from the outset of the project. Generally, it is **significantly** easier to obtain zoning approval for potential antenna sites which are located in areas with less restrictive zoning regulations.

While a parcel of property may be available in a residential area, construction of a tower might not be in the best long term interest of your customer. Towers and RF transmission equipment which don't "fit in" with the surrounding neighborhood may be a constant reminder to all that your project is insensitive to the public good.

As more and more people move to rural locations, objection to the construction of new towers increases. Consider these objections when evaluating a potential site. Opponents of sites are often willing and have the resources to take necessary legal action to prevent site construction. Long court battles may delay site development, and the entire project, for months or longer. To avoid a potentially long and costly delay, consider developing an alternate location preferable to the local residents.

3.6 PROCESS CHRONOLOGY

This section lists and describes the basic steps in the site acquisition process and generally identifies responsibility for completion. Every project is different, so this chronology may have to be adapted to meet the unique needs of each new system. Steps are numbered for reference only and may not always occur in the order listed.

1. Investigate Airspace Regulatory Agency Requirements

   Responsibility: Site Acquisition Manager

   The FAA or equivalent government agency that regulates airspace may have a significant impact on the eventual location of towers in your system. Spend time with the engineering coverage team to determine the impact of FAA regulations on individual tower locations. Knowledge of the location of airports and restricted areas near a proposed site is required.

2. Investigate Regional RF Plans / Frequency Coordination

   Responsibility: Site Acquisition Manager

   Some RF frequency bands are subject to regional coordination plans that restrict the signal that can be radiated outside a particular jurisdictional boundary. This may have a dramatic effect on the number and location of required sites.

3. Investigate System Coverage Requirements

   Responsibility: Site Acquisition Manager

   Coverage patterns vary between sites due to terrain and land cover. A thorough understanding of the coverage for an area helps to determine how far a potential site can be moved before it becomes unusable from a coverage standpoint. Engineering will have the final say as to the suitability of a site, but picking a location that will meet their requirements is a tremendous savings in time and resources. Keep in mind that systems requiring portable radio unit coverage need more towers than mobile unit-only systems.

4. Prepare Microwave Paper Profiles

   Responsibility: Vendor Engineering

   Microwave paper profiles will be prepared for all microwave paths in your system to verify that there are no obvious obstructions. It is very difficult to evaluate a microwave path from the seat of your vehicle. Though the maps you carry will help identify ridges between sites and locate high ground for towers, microwave paper field path engineering will be required to evaluate each site's potential.

5. Prepare Submittal Checklist

Responsibility: Site Acquisition Manager

A submittal checklist should be developed to ensure that all required submittals are made on schedule. The checklist should contain the following items at a minimum:

- Process Map / Flow Chart
- Topographical Maps
- Contacts List
- Site Description Form
- Plat Map
- Status Update

6. Prepare Individual Site Packages

Responsibility: Site Acquisition Manager

A package for each preliminary site should be prepared, including all site applications and reports. Report formats should be tailored for each project to show information necessary to make the next level of decisions about each location. Consult with the customer to ensure that all reports capture the information that it and the vendor consider to be important.

The information included in the site packages has to do with initial site investigation and site acquisition only. Site construction details should be documented elsewhere, as described in Chapter 4, “Site Design and Development.”.

7. Conduct Initial Field Review

Responsibility: Site Acquisition Manager

After the individual site packages have been completed and submitted to the customer for preliminary approval, schedule a field review of the sites to gather additional information and further evaluate the site.

8. Review Site Packages

Responsibility: Customer

The customer reviews each site package and approves the sites that they determine should remain under consideration. The customer should identify the sites they wish to have removed from further consideration.

9. Obtain Purchase Agreements for Private sites

Responsibility: Customer

After the customer approves a site, if the site is private, the customer directs its buyer to purchase property on which to locate a site.

The buyer conducts an independent market analysis to determine the range of values for the target area and uses this data to help set the property price. The buyer then approaches several property owners regarding the purchase of a tower site. Buyers usually have several alternatives and typically consider multiple sites.

The parcels are reviewed with the Site Acquisition manager to verify their possible use in the system. Once approved by the Site Acquisition manager, the buyer approaches the property owner and offers a purchase option for the property. Issues such as price, mineral rights, surface rights, and title clearance issues should be addressed in the option agreement. In return for granting the purchase option, the seller typically receives a nominal sum of money.

The option agreement must grant the customer and their subcontractors permission to enter the property for additional site evaluation.

10. Obtain Right of Entry

Responsibility: Customer

A properly drafted, signed option agreement gives the optionee the right to do investigative work without materially disturbing the property in a permanent manner. Soils work, wetlands and environmental surveys are some activities allowed during the option period. When site investigative work has been completed and the site is determined to be suitable, the option is exercised and the customer is committed to purchase the property. When the option is exercised, the subcontractors typically are given the right of entry to the property to begin site construction.

11. Conduct Interagency Property Transfer

Responsibility: Customer

If the site is already owned by the customer (as in a governmental agency) but by a different department, the customer must take steps to transfer the property. Note sometimes this process may take longer than purchasing property outright.

12. Select Preliminary Sites

Responsibility: Site Acquisition Manager

After field visits have been made to all proposed sites, select one site from each target location and identify it as a preliminary site. The site count for the entire system is the number of preliminary sites.

13. Conduct Title Search

Responsibility: Customer

The customer orders a title search on the designated preliminary site property to determine if it can be purchased or transferred with clear title. After the title search is completed satisfactorily, the site is turned over the surveyor for field work.

14. Grant Pre-Construction Authorization

Responsibility: Customer

After the option has been signed or the transfer of the property is approved, the customer authorizes the vendor access to the sites for additional site work by issuing a pre-construction authorization. Subcontractors generally are not allowed onto the property without the pre-construction authorization.

15. Release Site for Field Work

Responsibility: Customer

A signed option or approval to transfer the property results in release of the site for fieldwork such as wetlands and environmental surveys, field path surveys, and soils testing.

16. Conduct Wetlands Survey

Responsibility: Customer

The customer may now order a wetlands survey to determine if there are any areas of low or wet property. If wetlands are found, it must be determined whether the site may be modified or the wetlands mitigated, making the site usable. A final determination will probably not be made until final site drawings are done.

17. Conduct Environmental Study

Responsibility: Customer

An ASTM Phase I environmental study must be ordered to determine the presence of any hazardous substances or other environmental issues. If the ASTM Phase I survey finds nothing, no further work is required. If the study identifies areas of concern, additional studies may be ordered including estimations of the cost to clean up the problem. Unlike the presence of significant wetlands, which may render a site useless, environmental concerns may often be resolved.

18. Conduct Topographical Survey

Responsibility: Customer

The customer’s surveyors prepare a topographic survey showing contours, roadways, waterways, and elevations for the site, and the exact latitude and longitude of the proposed tower center. This information will be used to file applications with the FAA and FCC (or equivalent agencies).

19. Conduct Boundary Survey

Responsibility: Customer

A boundary survey of the property should be ordered. The survey must include all necessary information for it to be recorded according to applicable state statutes. A legal description must be prepared and included with the survey map depicting the property.

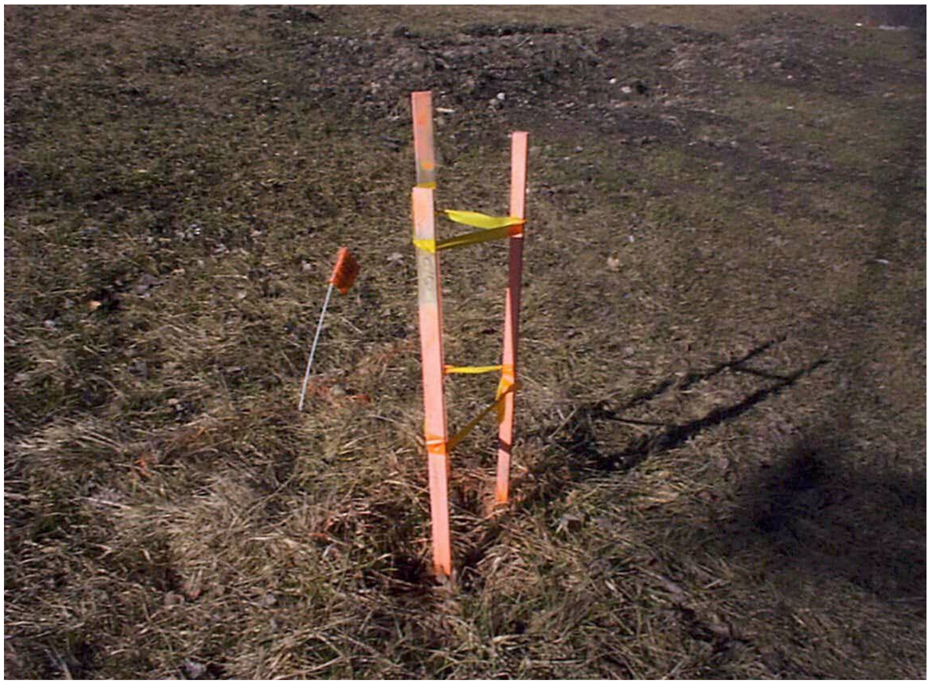


FIGURE 3-1 SITE SURVEY MARKER

20. Complete Title Clearance

Responsibility: Customer

Title clearance work on each of the parcels may take some time to complete. The site acquisition manager should monitor the progress of title clearance work for each site just to be sure there are no items that will eventually render the site useless due to title problems. If title problems arise, be prepared to start the site acquisition process over for a new site.

21. Historical Sites

Responsibility: Site Acquisition Manager

Verify that a site is not an historically significant property or location.

22. File applications with FAA and other applicable governing bodies.

Responsibility: Site Acquisition Manager

The FAA application (or equivalent) requires the exact coordinates of the tower (and its antennas) center point as provided by the topographical survey. File FAA applications as soon as the topographical surveys are completed so the height of the towers can be determined.

The FAA (or equivalent) will analyze your application and the location of the proposed tower in relation to other towers and airports in the vicinity, and respond with a written determination of maximum allowable tower height. You must then evaluate the allowable height to see if it is tall enough to meet system requirements. If the height is inadequate, you may apply for further study and request that a taller tower be considered. The FAA will post the request at all affected airports and ask for comments regarding hazards potentially caused by the proposed tower. If none are raised, additional height may be granted. If objections are made, you may have to re-commence the Site Acquisition for this site in an area which will have a lesser impact on the air space surrounding the nearby airport.

Check for compliance with any local regulations regarding tall structures. The application for tall structures should be submitted at the same time as the FAA.

23. Obtain FAA (or equivalent) Approval

Responsibility: When the FAA (or local aircraft regulatory agency) has approved the tower application, soils work, tower design and site design may start.

24. Check for Compliance with Local Zoning

Responsibility: Customer

One of the most difficult aspects of site acquisition is the need to comply with local zoning ordinances. Some areas have recognized the need for an integrated wide area communications system and have passed legislation to simplify compliance with local zoning statutes. However, many areas have not recognized this need; in such case, opposition can be expected. The customer should obtain appropriate legal advice.

25. Order Microwave Field Path Survey

Responsibility: Site Acquisition Manager

Because there is a significant fee associated with the field path survey, do not order it until you are reasonably sure the site will not be rejected for other reasons. Order the field path survey as soon as the FAA (or equivalent) has granted the tower height and you have secured necessary zoning approvals.

The importance of field path surveys should not be underestimated. A good survey will minimize dish height and ground clutter, eliminating reflection and phasing problems.

In some cases, it may be worth the risk to do the path surveys as soon as the topographical surveys are complete, identifying the coordinates required for the survey.

When the field path surveys are complete, send the data to the tower manufacturer so it can start its design work.

26. Order Soils Survey

Responsibility: Site Acquisition Manager

Order the soils survey as soon as the FAA application (or equivalent) has been approved so the information can be provided to the tower and foundation design engineers and to systems engineering for grounding analysis and design.

27. Release Site for Initial Site Investigation/design

Responsibility: Site Acquisition Manager

At this point, information can be provided to the engineering team to begin site design. Be sure that all work is complete and accurate when turned over to the engineering team. Refer to Chapter 4, “Site Design and Development,” for information on the construction process.

28. Obtain other regulatory agency Approvals

Responsibility: Customer

Local jurisdictional authorities may have additional regulatory requirements. Investigate these requirements and schedule them early in the site acquisition process.

29. Submit Soils Report to Design Team

Responsibility: Site Acquisition Manager

Present the final soils report to the site development design team so they can finalize the tower and site development drawings and specifications. If necessary, persuade the customer to accelerate the authorization of the soils work in order to expedite completion of the tower design.

30. Release Site for Final Design

Responsibility: Site Acquisition Manager

The final design is subject to the soils report for the site. This report confirms soils conditions, which in turn determine the size and shape of the guy anchors, tower base, building foundation and grounding system design.

31. Obtain Customer Approval of Site Design

Responsibility: Site Acquisition Manager, Customer

The vendor and the customer must review the final engineering drawings and approve the site design.

32. Identify Final Site

Responsibility: Site Acquisition Manager, Customer

When the customer approves the site design, other project work linked to Site Acquisition milestones can now be started. For example, once the FAA application (or equivalent) for a site is approved, soils work may begin even though title to the property has not been transferred.

33. Close on Property

Responsibility: Customer

When title clearance work is completed, the sale/transfer of the site property may be closed.

34. Transfer Title

Responsibility: Customer

Title is transferred to the customer at the closing. The site acquisition process for the site is complete.

3.7 SUBCONTRACTING

Third-party contractors may be engaged by the system vendor and/or the customer. Agreements between customer and subcontractor include:

- **Request for Proposal (RFP)**

  The RFP to hire subcontractors is generally the customer's responsibility. A sample RFP is included in Appendix A, "Duties and Responsibilities of Site Development Supervisor".

- **Contract or Consulting Agreement**

  A formal contract should exist defining the terms of the work to be performed by subcontractors. Customers typically prepare their own contracting agreements.

3.7.1 FIRMS REQUIRED

Some of the outside firms that will be required to complete site acquisition work are listed below. Companies that can provide more than one service should be given additional consideration when making the evaluation.

- **Land Surveyors**

  Land surveyors/engineers provide the necessary land services investigation to properly locate the subject parcel and prepare comprehensive survey drawings ready to record in the office of the appropriate keeper of public records. They will provide topographic surveys of the tower location and locate all of the necessary improvements and appurtenances. The topographic survey is vital to the proper engineering of the system and must meet minimum requirements.

- **Civil Engineers**

  Many civil engineering companies provide environmental and wetlands specialists as well as surveyors and engineers. These evaluations are also critical to the success of the Site Acquisition process. An early determination as to the presence of wetlands or environmental problems is crucial to maintain the system installation schedule.

- **Appraisers**

  Customers often require an independent statement of property worth. Appraisers conduct market studies to determine the value of properties in the target area. In some cases a review appraiser is retained to provide a second opinion to ensure studies are consistent with normal practices.

- **Title Companies**

  Some customers have staff to correct title deficiencies. However, if it is subcontracted, it must be closely monitored by the customer to be sure that mandatory requirements are met. Only the customer can determine how “clean” title must be to satisfy their needs. Often, lenders may require that the title meet specific requirements. Some sites will require a higher level of assurance than other sites. Work closely with the customer to be sure that title issued are addressed.

- **Procurement specialists**

  A firm can be contracted to expedite several of the above tasks regarding property purchase and closure.

- **Geotechnical Analysis and Site Engineering**

  See Chapter 4, “Site Design and Development.”

3.8 FIELD EQUIPMENT

The following paragraphs describe equipment recommended for use when conducting visits to potential site locations.

3.8.1 VEHICLE

Because it is necessary to get as close to the site with as much of equipment as possible, having a four wheel drive vehicle is very important during site acquisition, because it provides good ground clearance and the traction necessary to reach remote sites year-round.

Consider installing a winch on the vehicle to extricate the vehicle if it gets stuck, and to remove obstacles like fallen trees in its path. A 9000 pound rated winch that can be quickly moved from the front to the rear of the vehicle by means of a 5 cm (2 in.) trailer hitch receiver fore and aft is recommended.

Some locations may be accessible only by helicopter. Consider the added cost associated with such sites.

3.8.1.1 DRIVING SAFETY

Although not always obvious, driving is probably the most dangerous activity associated with site acquisition. Driving and trying to track your location, as well as a potential site location on several different maps, will only increase the dangers inherent in driving.

WARNING

Always drive safely. To avoid accidents, never try to drive while looking at a map or computer screen.

3.8.1.2 ORGANIZATION

Keep all resource material (plat books, topographic maps, roadmaps, tax roll information, and PC) within easy reach in the vehicle.

Keep as much of the information as possible in an electronic format and store it on your PC. Compile collected data in a relational database for easy retrieval. Street mapping programs can store information about sites visited for future reference.

The vehicle should be equipped with toolboxes to safely carry the tools and safety equipment required for conducting site investigations, and to deter theft.

3.8.1.3 OFF-ROAD VEHICLE PERMIT

During the investigation process, it may be necessary to travel off-road, which may require that you obtain an off-road vehicle (ORV) permit. Each state has different regulations about where vehicles may be driven and what permits may be required. As a rule of thumb, if a standard sedan can travel the trail, an ORV permit may not be required. Many potential sites cannot be reached without four-wheel drive. Check with the local Department of Natural Resources, USFS or other appropriate governmental agency for clarification of ORV permit requirements in the area.

3.8.1.4 INTRODUCTORY LETTER

Area residents will undoubtedly observe site visits. To allay residents' suspicion, always carry identification and a letter of introduction from the customer briefly explaining the project and what you are doing.

The letter should have a phone number for customer and for the contractor. Always carry the Contractor Identification in plain view.

3.8.2 HAND TOOLS

Recommended hand tools and miscellaneous items include:

- compass
- approximately 60 m (200 ft.) cloth tape
- road salt for vehicle traction, especially in winter months
- first aid kit
- single bit axe
- machete
- vehicle battery jumper cables
- tow strap
- wooden marking stakes
- wood lath
- 5-10 rolls orange surveyor's ribbon

3.8.3 COMPUTER AND SOFTWARE

A portable personal computer (PC) equipped with mapping software, topographical maps, email, word processing, database, and spreadsheet applications is critical for gathering and analyzing data during site acquisition.

Obtain a computer that is rugged enough to withstand heavy use in the comparatively harsh environmental conditions of a mobile application. The display should be as large as practical but must be viewable in bright sunlight. A CD ROM drive is required to run mapping software programs.

File transfer among project team members is more efficient if all team members are using the same products and same software versions. The following software tools are recommended:

- Spreadsheet
- Word Processing
- E-Mail
- Database

  Database software that allows the capture and evaluation of site information is critical to the site acquisition process. Contact data can be tracked also. Using a database to store all pertinent data makes it easier to generate project status reports.
- Street Mapping Software
- GPS Interface Software (typically provided with the GPS unit)
- CAD Software

3.8.4 GPS

A handheld global positioning system (GPS) is vital to pinpointing your location on topographical maps or software applications. Purchase a product that will directly interface with your laptop and software applications.

The GPS receiver is also vital in assuring that the proposed location will permit installation of a GPS receiver at the site.

3.8.5 RADIO

Two way radios are useful if immediate communication is necessary with co-workers and supervisors. However, wide area communications is probably not available in areas in which site investigations will be conducted.

3.8.6 CELL PHONE

A cellular phone allows communication with the office and with the customer. Because of the wide areas you may travel investigating potential sites, several cellular carriers may provide your service. Note the cellular coverage area and be aware of additional charges you may incur.

Satellite phones may be the only method of communication available in extremely remote areas.

3.8.7 TOPOGRAPHICAL MAPS

Regional topographical survey maps are available from several sources. Hard copies of maps for an entire region can be rather expensive and you really need only a few of the maps. However, it may be difficult to determine the maps you will need at the time you purchase the maps. If you decide to use hard copy maps, it is advisable to order all maps for the entire coverage area. Order maps with 7 ½ minute or equivalent resolution.

Topographical map software is also available for the PC, eliminating the need for carrying hard copy maps in the vehicle. The map software allows you to locate the appropriate map from an index of names, from an overlay, by coordinates, city and/or towns, zip codes, and other criteria.

Markers of several different types can be placed on the maps and saved to show the site locations and other information.

CHAPTER

4

SITE DESIGN AND DEVELOPMENT

This chapter provides requirements and guidelines for planning and executing safe and successful site design and development. Site development refers to the civil, structural, mechanical, and electrical work; and installation of supporting equipment at a communications site. The chapter primarily discusses new site construction. Adding onto an existing site or installing a site in an existing facility requires that the scope of work, design and drawings be specific to these locations. For other than new construction, it is best to consult with an engineering firm.

This chapter contains information on the following topics:

See Appendix A for a listing of typical site development supervisor responsibilities.

See Appendix B for the following examples intended to supplement the information in this chapter:

- Example of concrete pour checklist
- Example of antenna installation and identification matrix
- Example of utility information form

See Appendix G for examples of typical self-support and guyed tower site design, and typical tower lighting drawings.

4.1 INTRODUCTION

The design and development of communications sites is critical not only to optimal functioning of the communications system, but also to the safety of installation and maintenance personnel involved with building and maintaining the system. The importance of implementing and following safety programs, during construction as well as during the system's useful life, cannot be overemphasized.

All final construction drawings and specifications for a new site should be provided by a properly licensed engineering firm. This ensures that the design is adequate for the site conditions and provides the means of ensuring accurate records of construction are available.

NOTE: All work **shall** conform to applicable codes and regulations imposed by jurisdictional authorities.

All contractors performing work at a site and all equipment vendors must be competent and qualified. It is recommended that each project team develop a list of reputable contractors and vendors. The list should be reviewed with the project director and legal advisors. All potential contractors/vendors **shall** be required to fill out and submit a Pre-Qualification form to the project team. Information obtained from the form and verification of compliance with Safety and Quality Assurance/Quality Control (QA/QC) requirements should be used to determine their bidding status on the project.

The Pre-Qualification form can be obtained from Motorola Environmental Health and Safety (or the project team).

It may be necessary to hire a site development supervisor(s) for large projects. See Appendix A for suggested job qualifications for a site development supervisor.

4.2 PLANNING

Planning the development of a communications site is crucial because the many intricate and parallel activities involved in constructing a site must be effectively organized in order to complete the project efficiently. The following section provides standards and guidelines that should aid individuals in the site development planning phase of the project.

4.2.1 CONSTRUCTABILITY REVIEW

Constructability is the optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve overall project objectives. All project parties should become involved in a constructability program at the onset of a project to ensure there is a maximum influence on overall cost, quality, cycle time and functionality. Constructability programs have proven valuable on large and small projects and are considered to be the reason many projects were successful. Outlined below are some of the basic steps for a constructability review.

- Establish criteria for selection of members
- Establish constructability objectives/concepts
- Establish project objectives (scope) relative to constructability objectives
- Compare contractual scope objectives and constructability objectives with requirements of this manual
- Establish roles and responsibilities
- Establish the importance of teamwork
- Determine level of formality for constructability program
- Define specific constructability procedures
- Integrate constructability into project activities
- Identify appropriate measures for objectives

4.2.2 SITE WALKS

Site walks familiarize involved parties with the development plan for a proposed site. After a site's use has been confirmed, a site walk **shall** be conducted to examine as much detail about the site as possible, and to clearly determine and describe responsibility for all aspects of the site development. It is recommended where practical that all involved parties participate in a site walk.

This includes but is not limited to geotechnical, site engineering, contractor and the customer personnel. This saves time, encourages multiple opinions, and ensures that all parties agree on preliminary layouts.

At a minimum, the following items should be completed during the site walk:

- On existing facilities, perform a preliminary R56 compliance inspection to ensure proper planning and advisement to the customer (if required). Ensure proper testing and measurement of existing ground system integrity, if practical.
- Perform four-point soil resistivity testing if practical. See “Soil Resistivity Measurements” on page 4-13.
- Take subsurface soil core samples for soil resistivity if practical.
- Choose the specific location of the facility. (If survey information is not available or applicable, precise location information is required for future reference and equipment deliveries).
- Note general condition of site and surrounding area, including pre-existing flooding or erosion conditions. Note site characteristics and any notable items from the surrounding properties.
- Discuss site layout. General agreement and concurrence should be reached on preliminary site layout and development with respect to the site and its characteristics.
- Verify the location of the nearest commercial utility/electrical service. If available, note the name of the service provider along with a service pole number or approximate location of nearest service pole.
- Observe accessibility. Access to the site is of the utmost importance and should be thoroughly investigated and noted at this time. Any obvious easement or security issues should be noted and investigated also.
- Observe and investigate weight (load) considerations. Load restrictions, whether on the access road, elevator or floor, should be thoroughly investigated and noted at this time. Obtaining special permits if required to access a site could be time-consuming.

> **NOTE:** Load restrictions can prevent a site from being used if not properly investigated and planned for.

- Note potential environmental concerns such as wetlands, dump site, oil spills, garbage piles, nearby truck stops and fueling stations.
- Note the type of property (existing facility, building top, private, state, or federal property).
- The construction location should be relatively clear of trees and brush. There should be an adequately sized layout/fabrication area adjacent to the construction area; lack of such area may hinder cost-effective construction.
- The construction location should be on level, firm land free of drainage and soil erosion problems.

- In locations where permafrost exists, the building must be isolated from the surrounding earth. Even the small temperature differential presented by an equipment shelter may be sufficient to melt the surface soil, leading to major structural and foundation damage. Workable solutions include building the structure on stilts or insulated pilings. Though it is also possible to construct on bedrock, special methods for anchoring and grounding must be used. Consult a local construction contractor for expertise and guidance in this area.
- If it is recommended or required that an existing tower or structure be used to support proposed additional antennas and transmission lines, then the original designer **shall** perform a structural and foundation analysis.

> **NOTE:** It may be impractical or impossible to add more antennas to an existing tower or structure due to the retrofitting required or the physical limitations of the tower, structure or foundations themselves.

- If it is recommended or required that an existing tower or structure be used to support proposed antennas and transmission lines, an intermodulation study **shall** be performed to determine interference that may exist at the location.

4.2.3 PERMITTING, ZONING, CODE AND REGULATORY CONSIDERATIONS

To assist with permitting, zoning, code and regulatory considerations, it is recommended that a local engineering firm be consulted.

WARNING

Utility locator services shall be used to locate buried utilities before conducting any subsurface explorations.

4.2.3.1 GENERAL CONSIDERATIONS

Obtaining permission and complying to local codes, ordinances and regulations can be complicated and time-consuming. It is highly recommended that this portion of a project be carefully planned and executed with the customer and all involved parties. To avoid unexpected problems, confer with all jurisdictional agencies before beginning construction, and provide them with clear concise execution plans.

4.2.3.2 OVERALL SCOPE OF USE CONSIDERATIONS

Some municipalities require that all communications installations which will share public safety facilities (police or fire stations, hospitals, etc.) must be constructed to standards under the State “Essential Services Act.”

This requires that seismic upgrading and installation practices be met, and emergency power systems be upgraded to handle the new demand for the entire facility, sometimes at considerable additional costs. Even if the shared communications site lease language doesn't specifically identify the need to comply with Essential Services Act standards, there may be "catch all" clauses which state that "all applicable local, state, and federal laws and requirements **shall** be met".

4.2.3.3 AMERICANS WITH DISABILITIES ACT CONSIDERATIONS

> **NOTE:** The following specifically applies to sites located within US jurisdiction. However, other jurisdictions may have similar or more stringent requirements. In all cases, the more stringent requirement **shall** supersede other requirements or standards.

The Americans With Disabilities Act (ADA) is a US federal program signed into law on July 26, 1990 as Public Law 101-336 July 26, 1990 104 Statute 327. Of greatest importance regarding a communications site is the following language contained in *Title I* which requires that:

> "...business must provide reasonable accommodations to protect the rights of individuals with disabilities in all aspects of employment".

As far as site design is concerned, this affects possible changes in work stations and work areas to accommodate required provisions. As local US jurisdictions are under pressure to meet federal ADA requirements, there has been considerable recent activity (particularly in the large cities and counties) to meet ADA requirements, in part through zoning and permit regulation.

Some (but not necessarily all) possible effects on a communication site regarding ADA compliance are:

- Providing extra-wide entry doors
- Providing a ramp for building access, a hand rail, a turnaround place within the building for a wheel chair
- Convenient placement of telephones and light switches
- Dedicated handicap paved parking places

While some domestic municipalities are not yet requiring ADA compliance, many large cities are. Such regulations may significantly affect communications site development. The *Uniform Building Code (UBC), Chapter 31 Accessibility*, addresses these requirements in detail. UBC Chapter 31 most notably, in part, specifies in *Article 3104 (3), Egress,* requires a 1.22 m (48 in.) width doorway, and *Article 3104(4), Article 3105 Facility Accessibility*, which requires that a telephone or other communications system **shall** be available.

4.2.3.4 FEDERAL CLEAN WATER ACT CONSIDERATIONS

Consideration of the Federal Clean Water Act (FCWA) **shall** be given. FCWA programs administered by local governments sometimes vary with different requirements and enforcement for specific locations. The FCWA may require that common HVAC system condensate water be carried to a legal building drain system and may not be disposed of in the ground soil. This can set the requirements to include condensate pumps on HVAC systems and to plumb the HVAC condensate water to a proper sewer system.

4.2.4 SITE DEVELOPMENT DRAWINGS

To help ensure that site development plans are developed in accordance with jurisdictional codes and specifications, it is highly recommended that an engineering firm be consulted.

Typical site development drawings should include (but not be limited to) the following:

- Site Plan, showing the following:
    - General compound and site layout relative to the surroundings
    - Location of access road if applicable
    - Road profiles (cut and fill requirements)
        - Existing road profile
        - New road profile depicting road grade. Attempt to achieve a grade less than 10%. If access road requirements cannot be met, proper planning must be accounted for to ensure accessibility of cranes, concrete trucks, and other heavy construction or delivery shipments.
    - True North/South and East/West Construction baselines as represented from the tower center (or center of site structure). (Refer to Figure G-5 in Appendix G for an example.)

      NOTE: For guyed towers, it is imperative that the final elevation of the anchor head and final grade be coordinated between the foundation tower designer and site engineering firm.

    - Guy anchor location data schedule (if applicable).
    - Typically the bottom of an anchor head should be 30.48 cm (12 in.) to 45.72 cm (18 in.) above final grade.
- Foundation Plan, including:
    - General layout of all required foundations
    - Foundation Schedule depicting applicable foundation elevations
- Grading Plan showing general grade elevation and slope of compound and access areas
- Sediment Control Plan showing location of hay bales or silt fences to prevent soil erosion.

- Grounding system design showing all typical exterior grounding requirements. Soils Resistivity Measurements may also be depicted.
- Typical access road cross section and culvert detail, showing the following:
  - Cross section of access road
  - Drainage requirements
  - Curb cut requirements
- Equipment Shelter Foundation and Details, showing the following:
  - Foundation layout (depth, length, and width of all foundations)
  - Cross-sectional view of foundations for rebar placement
- Utility plan and installation details, showing the following:
  - Layout and installation routes of required utilities
  - Types of instrumentation required if applicable
- Electrical one-line and service installation details, showing electrical service installation.
- Telephone Installation Details, showing type of telephone line installation if required
- Fence enclosure and guy anchor fence plan showing typical fencing installation

4.2.5 LAND SURVEY AND SITE DEVELOPMENT STAKING CONSIDERATIONS

Prior to finalizing site development plans, the site surveying firm should supply the following items as a minimum:

> **NOTE:** Topographic and property boundary surveys **shall** be signed and sealed by a Registered Professional Engineer (or as required by jurisdictional law).

- Electronic (in compatible software version) and paper copies of property boundary surveys clearly showing all easements, rights-of-way and boundaries. The property survey should be overlaid on the topographic survey to show property boundaries with respect to surface conditions.
- Electronic (in compatible software version) and paper copies of topographic surveys showing all relevant surface conditions and characteristics, ensuring proper contour lines to convey relative surface height or depth.
- East/West and North/South construction baseline delineation.
- Latitude, longitude and elevation of proposed center of tower in relation to the tower center.

Upon completion of site development plans and required approval, site development staking should be performed. It is recommended that site development staking be performed by the original surveying firm. The contractor performing the fieldwork and the surveyors should have a kickoff meeting to set expectations, understand and agree to a process that ensures timely execution.

Electronic and paper copies of the completed construction drawings **shall** be transmitted back to the surveyor, to minimize the chance for errors in determining property boundary encroachment or engineering errors. At a minimum site development staking should include (but not be limited to):

- Staking of easement/right of way locations
- Temporary easement locations
- Temporary and permanent roadways
- Roadway curb cut and radius locations
- Center of tower
- Site fence corners
- Center of tower leg locations
- Building foundation corners
- Center of inner and outer guy anchor locations

4.2.6 TEMPORARY FACILITIES

The following items are typically required during construction. Be sure to make provisions for these items before construction begins so that they will be available when needed.

- Staging, fabrication and construction areas
- Drives, walks and bridges
- Public access
- Telephone
- Sanitary and cleanup facilities
- Drinking water
- Light and power
- Heat
- Enclosures and storage
- Dumpsters and trash removal services (do not burn trash onsite.)
- Restrictions on access to equipment shelter (do not use shelter as a workshop)
- Personnel and tool trailers

4.2.7 ELECTRICAL SERVICE

The following list is provided to help organize, manage, and coordinate electrical service installation. Some items may not apply to all projects. Ensure that the electrical installation process is tracked, managed and documented by responsible parties.

- It is recommended that one person from the utility company be established as the point of contact. Ensure that the utility company's work order tracking methods and processes are understood. Typically a customer tracking number is assigned.
- Where practical, keep overhead lines and poles at least 60.92 m (200 ft.) from the site compound area during construction. This helps protect against accidental contact by construction or maintenance equipment and hazards associated with ice falling from the tower while under construction.
- To simplify grounding system installation, request that electrical service enter the site building on the same wall as and near to the entry point for the antenna transmission lines. Proper separation between power lines and transmission lines **shall** be provided (NFPA 70, Article 810). This may require coordination between site development engineer and the shelter manufacturer to ensure consistency in layouts.
- Utility installations are jurisdictional. Ensure that it is clearly understood who the utility supplier will be. This is best achieved with a site meeting.
- Coordinate other utility installations such as closed-circuit television (CCTV) and telephone company.
- Supply the utility with an electrical utility information form. See Appendix B for an example of a typical form.

NOTE: Additional site-specific load or use information, such as type of equipment, generator or UPS information, may be required.

- Obtain an installation cost estimate from the utility company.
- It is imperative that the proper easement paperwork has been obtained and provided to the utility.

NOTE: Governmental agencies transferring land or granting easements may take considerably more time than private landowners.

- Insist on obtaining a copy of the utility site installation sketch, staking sheet or overlay. It is imperative to check that the utility company interpreted your request for service correctly and that they have conformed to easement restrictions. It is easier to correct problems in the design phase than after service installation has started.
- Typically, final electrical service connection to the meter pedestal will not take place until the utility has been paid.
- The utility company usually requires a site address before they will connect power. Utility companies may or may not assign the address. It is more likely the local township will assign the address.

- A jurisdictional electrical inspection is usually required before the utility company connects power.
- The electric meter, but not the meter pedestal, is typically supplied by the utility. Be sure to verify who is responsible for providing the electric meter.
- Electrical service installations in very cold climates are typically much more expensive and likely to slow the installation schedule.

4.2.8 GEOTECHNICAL CONSIDERATIONS

Geotechnical investigations are required for all projects that involve subsurface foundation installations, engineering design parameters and other related aspects of site development. Geotechnical data obtained in these investigations **shall** be provided to the tower and foundation designers and site-engineering firm in a compatible format.

Unless otherwise specified, tower foundation and anchor design **shall** be executed in accordance with the latest revision of ANSI/EIA/TIA-222. It is highly recommended that the customer, tower and foundation designer, site-engineering firm and the appropriate Motorola representative hold a meeting to set expectations, requirements, parameters and the approval process to ensure timely completion of the designs.

NOTE: Some contracts and geographical locations may require additional geotechnical information. Please consult a reputable local geotechnical firm, and the tower and foundation designer to ensure that all required criteria is included in the report.

- Normal soil **shall** be defined as a cohesive type soil with:
  - a vertical bearing capacity of 4000 pounds per square foot
  - a horizontal bearing capacity of 400 pounds per square foot per lineal foot of depth to a maximum of 4000 pounds per square foot.
- Rock, non–cohesive soils, or saturated or submerged soils **shall not** be considered normal.
- Pocket penetrometer tests should not be substituted for unconfined compression tests.

- For each layer of soil encountered, the following items should be determined by field or laboratory testing and summarized in the soils report depending on the types of foundations recommended.
  - Standard penetration values
  - Soil classification and elevations
  - Angle of internal friction
  - Unconfined compression strength and cohesion
  - Tension and compression skin shear (for piles, caissons or drilled piers)
  - In-situ soil density and moisture content
  - Expected ground water fluctuations
  - When drilled piers are feasible, the plasticity index and over–consolidation ratio **shall** be determined.
  - The recommended type(s) of foundations to be considered, and corresponding design parameters for uplift, compression and lateral load
  - Construction techniques to ensure the design parameters are obtained.

4.3 SOIL RESISTIVITY MEASUREMENTS

Prior to the design of a new grounding electrode system, the proposed location **shall** be tested to determine the soil resistivity. (See *IEEE Std. 81* for more information.) Soil resistivity directly impacts the design of a communication site grounding electrode system and is the prime factor that determines the overall site grounding electrode system resistance.

4.3.1 OVERVIEW

4.3.1.1 SOIL RESISTIVITY VARIABILITY

Soil resistivity varies widely by region and can change seasonally due to variations in the soil's moisture and electrolyte content. Therefore, it is recommended that these variations be considered when assessing soil resistivity. To assure that expected soil resistivity is achieved at all times, worse-case conditions should be considered when establishing soil resistivity.

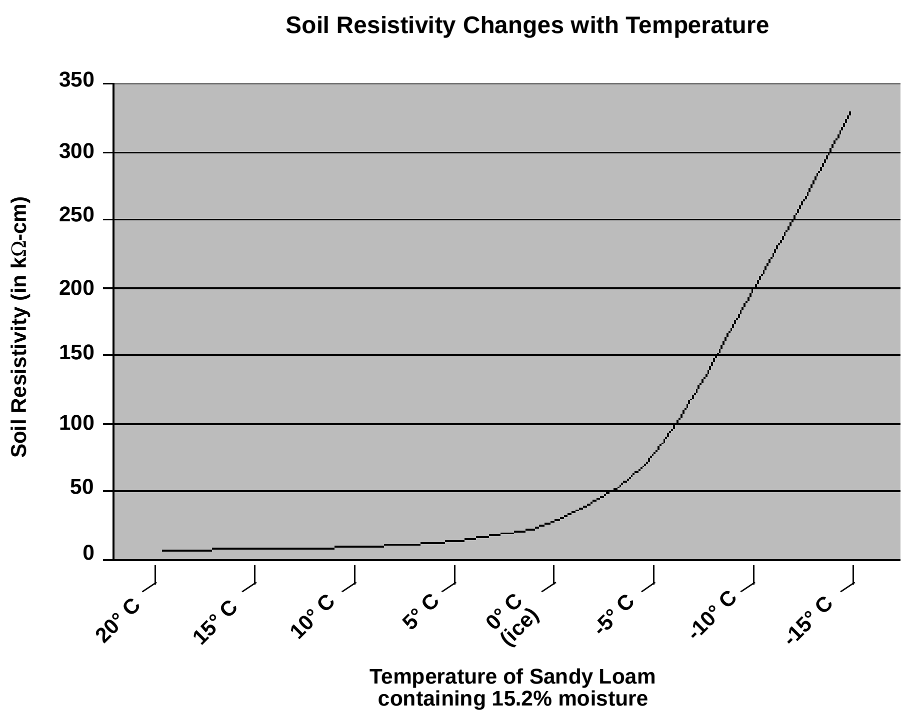
Table 4-1 lists ranges of soil resistivity for various types of soil. The values in Table 4-1 are the expected values that should be seen when measuring soil resistivity.

Figure 4-1 shows soil resistivity changes as a function of soil temperature and moisture content. Noting the soil composition and climatic history of the site under consideration, use Figure 4-1 to assess the optimum time for measuring soil resistivity.

TABLE 4-1 SOIL RESISTIVITY FOR VARIOUS SOIL TYPES

	Resistivity (kΩ-cm)		
Soil Type	**Minimum**	**Average**	**Maximum**
Ashes, brine, or cinders	0.590	2.37	7.0
Clay, gumbo, loam, or shale	0.340	4.06	16.3
Clay, gumbo, loam, or shale with varying portions of sand and gravel	1.02	15.8	135.0
Gravel, sand, or stone with little clay or loam	59.0	94.0	458.0

NOTE: "Gumbo" is soil composed of fine-grain clays. When wet, the soil is highly plastic, very sticky, and has a soapy appearance. When dried, is develops large shrinkage cracks.



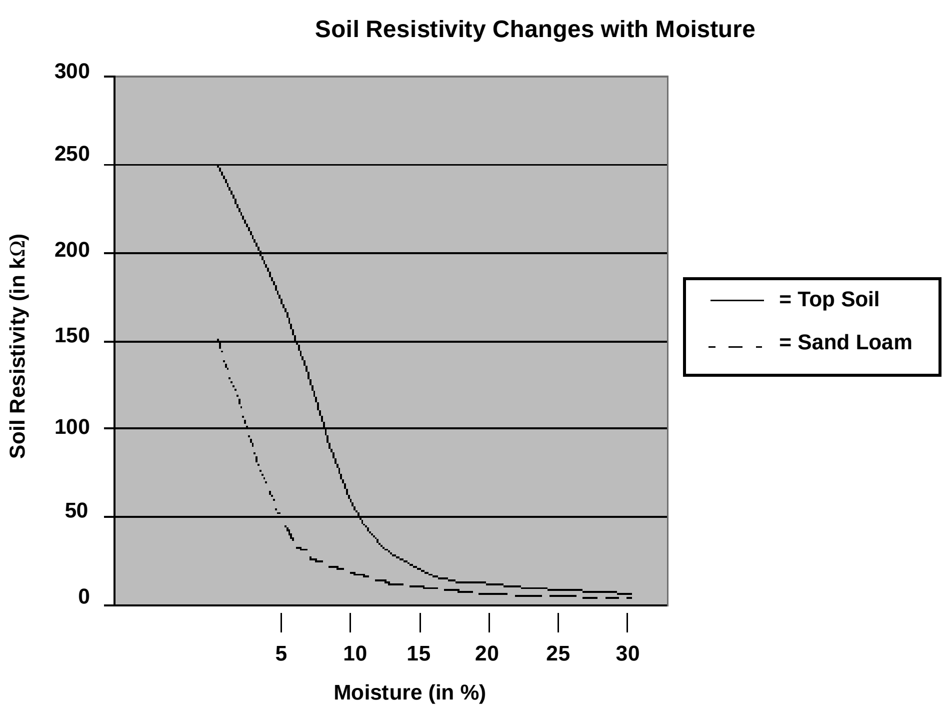


FIGURE 4-1 SOIL RESISTIVITY CHANGES AS A FUNCTION OF SOIL TEMPERATURE AND MOISTURE CONTENT

4.3.1.2 TESTING METHODS

Two methods of obtaining soil resistivity data are typically used, as follows:

- Four-point (Wenner) method (ANSI/IEEE STD 81)
- Random core samples

Where possible, the testing should be performed using the four-point testing method; this is the method described in this specification. The area indicating the lowest soil resistivity will be the optimum location for placement of the grounding electrode system. A suggested best practice is to perform the test during different seasons of the year. The worse-case measured soil resistivity should then be considered in order to design a grounding electrode system that will meet the resistance design year-round.

Random core sampling **shall** be used only when the four-point test cannot be accomplished, such as in metropolitan areas where buried objects may cause misleading readings, or where surface area is insufficient for proper test performance. Random core sampling **shall** be performed by a geotechnical firm. The random core sample test results should then be provided to a grounding design consulting firm so that an effective grounding electrode system design can be developed for the location.

NOTE: The same core samples taken for foundation design can also be used for conducting the random core sample testing.

Core samples should be taken from at least five different test areas as shown in Figure 4-3 at depths of 1.52, 3, and 6.1 m (5, 10, and 20 ft.).

4.3.1.3 SITE PREPARATION CONSIDERATIONS

NOTE: Do not test an adjacent location if the site location is inaccessible when the testing is scheduled. Reschedule the test so it can be done on the site itself.

Soil resistivity tests must be performed on the actual site, after the following preparation and conditions have been met:

- The site has been leveled to where the foundation will be placed.
- Soil added to the site is satisfactorily compressed before conducting the test, so it will behave as undisturbed soil.
- No precipitation has occurred within 72 hours.

4.3.1.4 REQUIRED TEST EQUIPMENT AND SUPPLIES

- Ground Resistance Tester designed for four-point testing, including all necessary manufacturer's accessories. Accessories should include:
  - Four test rods (typically supplied with tester)

    The test rods should be stainless steel, 61 cm (24 in.) maximum length, 1.6 cm (5/8 in.) diameter, utilizing a preferred surface penetration of 22.9 cm (9 in.). Test rods typically come with a four-point testing kit, in lengths from 38 cm (15 in.) to 61 cm (24 in.).
  - Four test leads (typically supplied with tester)

    The test leads connect the tester to the test rods. If the leads do not use labels or different colors to correlate the test lead connections between the rods and tester terminals, use tags or four different colors of tape to correlate the connections.

    NOTE: The connections must be kept in the correct order to maintain symmetry of testing procedures and maintain consistent results.
- Small sledgehammer
- Tape measure
- Safety glasses
- Gloves
- A photocopy of Table 4-3, "Soil Resistivity Worksheet" on page 4-25. This will be needed to record and keep track of several measurements across the site.

4.3.2 PERFORMING SOIL RESISTIVITY TEST

Perform the test at the location where the site will be installed. This procedure describes how to obtain test results for various depths, and how to measure the soil resistivity over the entire site.

4.3.2.1 MEASURING AT VARIOUS DEPTHS

The soil is not homogenous from the surface to the depth being tested. Also, resistivity varies at different depths. Because of this, the four-point test (performed at various depths and at various locations throughout the site) is used to provide a composite result of the soil resistivity.

The testing depth of a soil resistivity test is determined by the spacing between the four test rods which correspondingly connect to tester terminals C1, P1, P2, and C2. The recommended practice is to test the soil at various depths in order to determine the best depth for the grounding electrode system. For example, if the test rods are 1.52 m (5 ft.) apart, the measurement will be an average of the soil from the surface down to 1.52 m (5 ft.). As the spacing between the rods is increased, results for correspondingly deeper samples are directly obtained. Table 4-2 lists the various soil depths measured for various rod spacing distances.

TABLE 4-2 SOIL DEPTH MEASURED AS A FUNCTION OF ROD SPACING

Rod Spacing	Soil Depth Measured
1.52 m (5 ft.)	1.52 m (5 ft.)
3 m (10 ft.)	3 m (10 ft.)
6.1 m (20 ft.)	6.1 m (20 ft.)
9.1 m (30 ft.)	9.1 m (30 ft.)
12.2 m (40 ft.)	12.2 m (40 ft.)

4.3.2.2 ROD ARRANGEMENT

Figure 4-2 shows the rod arrangement required for testing. The test requires inserting four test rods into the test area, in a straight line, equally spaced and all at a depth of 22.9 cm (9 in.). A constant current is injected into the earth from the ground resistance tester through the two outer test rods. The voltage drop resulting from the current flow through the earth is then measured across the inner two test rods. Most testers are designed to provide a direct reading in ohms. This value is then used in one of the following formulas to calculate the Soil Resistivity (ρ) of the tested area.

> **NOTE:** The nomographs furnished in this chapter specify distance in **feet** and resistivity in **Ω-cm**. Where metric measurements are used for distance, these measurements must be converted to feet to work with the formula below and the nomograph.

$$\rho = 191.5 \times A \times R$$

where: ρ = soil resistivity in Ω-cm
A = Distance between test rods (in feet)
R = Resistance obtained from tester (in ohms)

The calculated soil resistivity is the average soil resistivity between the soil surface and the depth of the soil equivalent to the rod spacing.

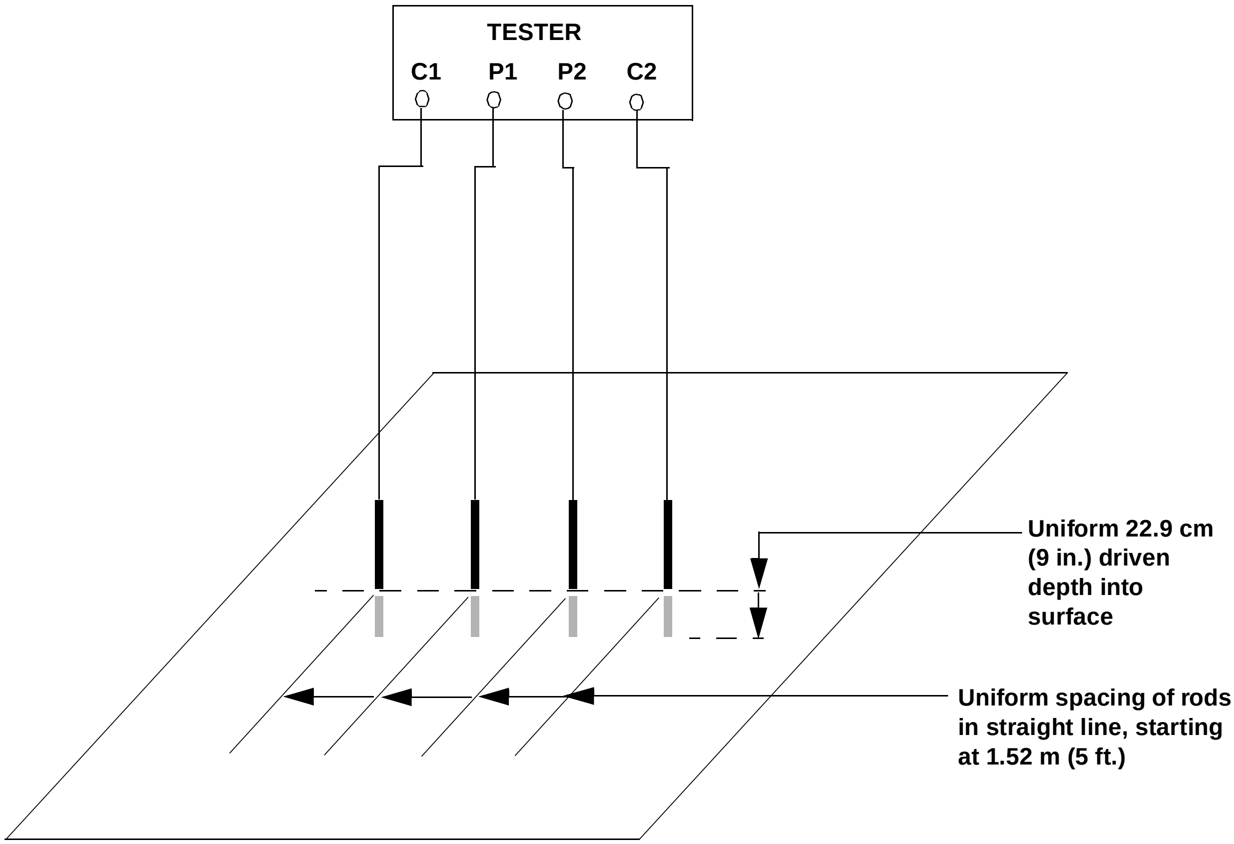


FIGURE 4-2 ROD ARRANGEMENT AND SPACING

4.3.2.3 REQUIRED SAMPLES TO DEVELOP ACCURATE SITE RESISTIVITY PROFILE

Because stray currents, buried water pipes, cable sheaths and other factors usually interfere and distort the readings, measurements should be taken along at least three directions. Figure 4-3 shows the recommended multiple sampling pattern to develop an accurate profile. Note that the more divergent the samples taken, the more accurate the generated soil model will be.

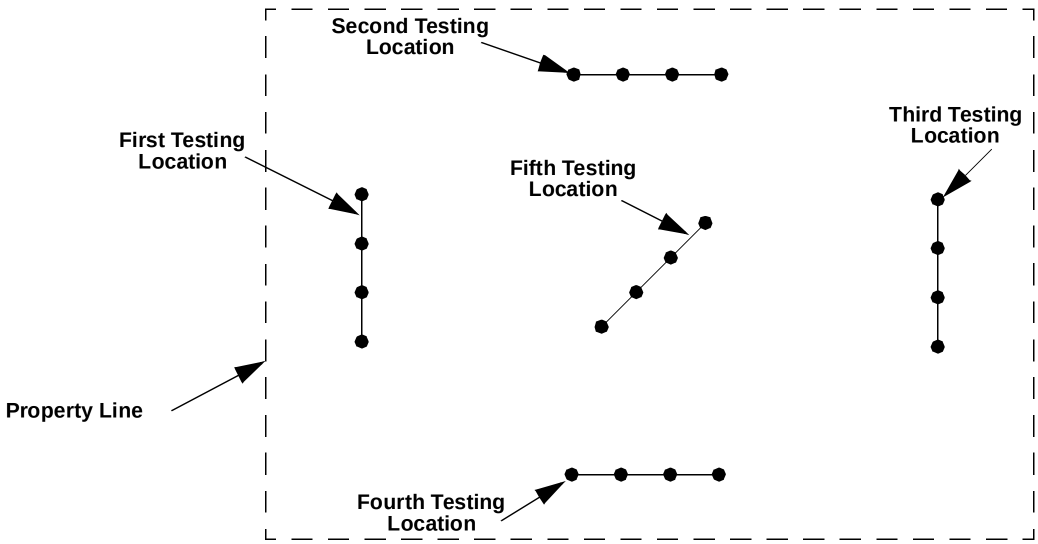


FIGURE 4-3 RECOMMENDED MULTIPLE SAMPLING PATTERN ACROSS SITE

4.3.2.4 SOIL RESISTIVITY TEST PROCEDURE

Perform the following procedure to obtain soil resistivity readings.

WARNING

Follow Ground Resistance Tester manufacturer's warning and caution information when using tester. Follow furnished instructions when inserting and removing test rods into soil.

PROCEDURE 4-1 SOIL RESISTIVITY MEASUREMENT

1	On tester, verify that the jumper strap on tester connected between the **C1** and **P1** terminals is disconnected.
2	Starting at the "First Test Location" shown in Figure 4-3, drive four test rods into the soil at 22.86 cm (9 in.) depth, in a straight line, and spaced 1.52 m (5 ft.) apart (as shown in Figure 4-2).
3	Using test leads, connect the **C1**, **P1**, **P2** and **C2** terminals to their respective test rods, as shown in Figure 4-2. **NOTE:** The test rods must be connected in this order. If the test rods are connected incorrectly an inaccurate reading will result.

PROCEDURE 4-1 SOIL RESISTIVITY MEASUREMENT (CONTINUED)

4	Turn the tester on. Press the test button and read the display. **NOTE:** If the reading is not stable or displays an error indication, double-check the connection and the range that the meter is set to. If the range is correct, try adjusting the test current. Also, an effective way of decreasing the test rod resistance to ground is by pouring water around it. The addition of moisture is insignificant; it will only achieve a better electrical connection and will not influence the overall results.
5	Write down the measurement obtained in the appropriate "Meter Readings" place on the photocopy of the Soil Resistivity Worksheet.
6	Remove the test rods from the soil.
7	In the same location on the site and along the same line as previous test, repeat steps 2 through 6 for remaining spacings listed on the Soil Resistivity Worksheet.
8	See Figure 4-3. Prepare to take measurements for the **next** test location shown in Figure 4-3. Repeat steps 2 through 7 for this location.
9	Repeat steps 2 through 8 for all remaining test locations specified in Figure 4-3.
10	On the Soil Resistivity Worksheet copy, calculate and write down soil resistivity (ρ) for each of the 25 readings taken in the steps above.

4.3.3 INTERPRETING TEST RESULTS

Depending on the type of grounding electrode system to be installed, proceed to the applicable paragraph below. Test results are interpreted in accordance with MIL-HDBK-419A.

- "Single Grounding Electrode System Resistance Calculation" on page 4-21
- "Multiple Grounding Electrode System Resistance Calculation (Electrodes in Straight Line)" on page 4-29
- "Multiple Grounding Electrode System Resistance Calculation (Electrodes in Ring Configuration)" on page 4-34
- "Multiple Grounding Electrode System Resistance Calculation (Ground Rod Grid Configuration)" on page 4-35

4.3.3.1 SINGLE GROUNDING ELECTRODE SYSTEM RESISTANCE CALCULATION

For a single grounding electrode system, the resistance can be easily calculated by use of a Nomograph. Example calculations are shown in Figure 4-4, "Example Worksheet and Nomograph."

If calculations show excessive resistance for a given electrode depth and diameter, calculations can be performed substituting a larger diameter electrode and/or deeper electrode depth. In this manner, the proper size and depth of grounding electrode for a particular site can be determined. An example in Figure 4-4 shows grounding improvement by substituting a larger-diameter electrode at a deeper depth.

Perform the following procedure to calculate the resistance of the single grounding electrode.

PROCEDURE 4-2 CALCULATING SINGLE GROUNDING ELECTRODE RESISTANCE

1	Make a photocopy of Figure 4-5, "Soil Resistivity Nomograph" on page 4-27.
2	On **d** scale of nomograph, plot a point corresponding to the diameter of the grounding electrode to be used.
3	On **L** scale of nomograph, plot a point corresponding to the depth of grounding electrode to be used.
4	Draw a line connecting the **d** and **L** points.
5	Plot ρ value from Soil Resistivity Worksheet on the ρ scale of nomograph.
6	Where line connecting the **d** and **L** points intersects **q** line, draw a new line from this point to the point plotted on ρ scale. Extend this line to the **R** scale. This is the resistance for a single grounding electrode.

4.3.3.1.1 EXAMPLE WORKSHEET AND NOMOGRAPH

Figure 4-4 (sheets 1 through 3) shows example readings and calculations from a filled-in worksheet and nomograph.

- Sheet 1 shows example readings, as entered from field Ground Resistance Tester measurements and the resulting Soil Resistivity calculations.
- Sheet 2 shows a nomograph filled-in with calculations for grounding electrode resistance using a given electrode diameter and depth.
- Sheet 3 shows a second nomograph filled-in with calculations for grounding electrode resistance improvement using a larger-diameter electrode at a deeper depth.

Location "1 of 5" 3 m (10 ft.) spacing is measured on Ground Resistance Tester. In this example, tester reads "2.1 Ω".

"2.1" is written down in "Meter Readings" column for Location "1 of 5" (10 ft. spacing) in Worksheet.

Location	Spacing (Test Depth)	
	1.52 m (5 ft.)	3 m (10 ft.)
Meter Readings (steps 2 through 5)		
1 of 5	4.2	**2.1**
2 of 5	4.5	2.5
3 of 5	4.2	2.3

ρ value for Location "1 of 5" 10 ft spacing is calculated using formula on Worksheet.

ρ value of "4021.5" is written down in "Soil Resistivity Calculations" column for Location "1 of 5" (10 ft spacing) in Worksheet.

1 of 5	ρ= 4021.5	ρ= **4021.5**
2 of 5	ρ= 4308.8	ρ= 4787.5
3 of 5	ρ= 4021.5	ρ= 4404.5

FIGURE 4-4 EXAMPLE WORKSHEET AND NOMOGRAPH (SHEET 1 OF 3)

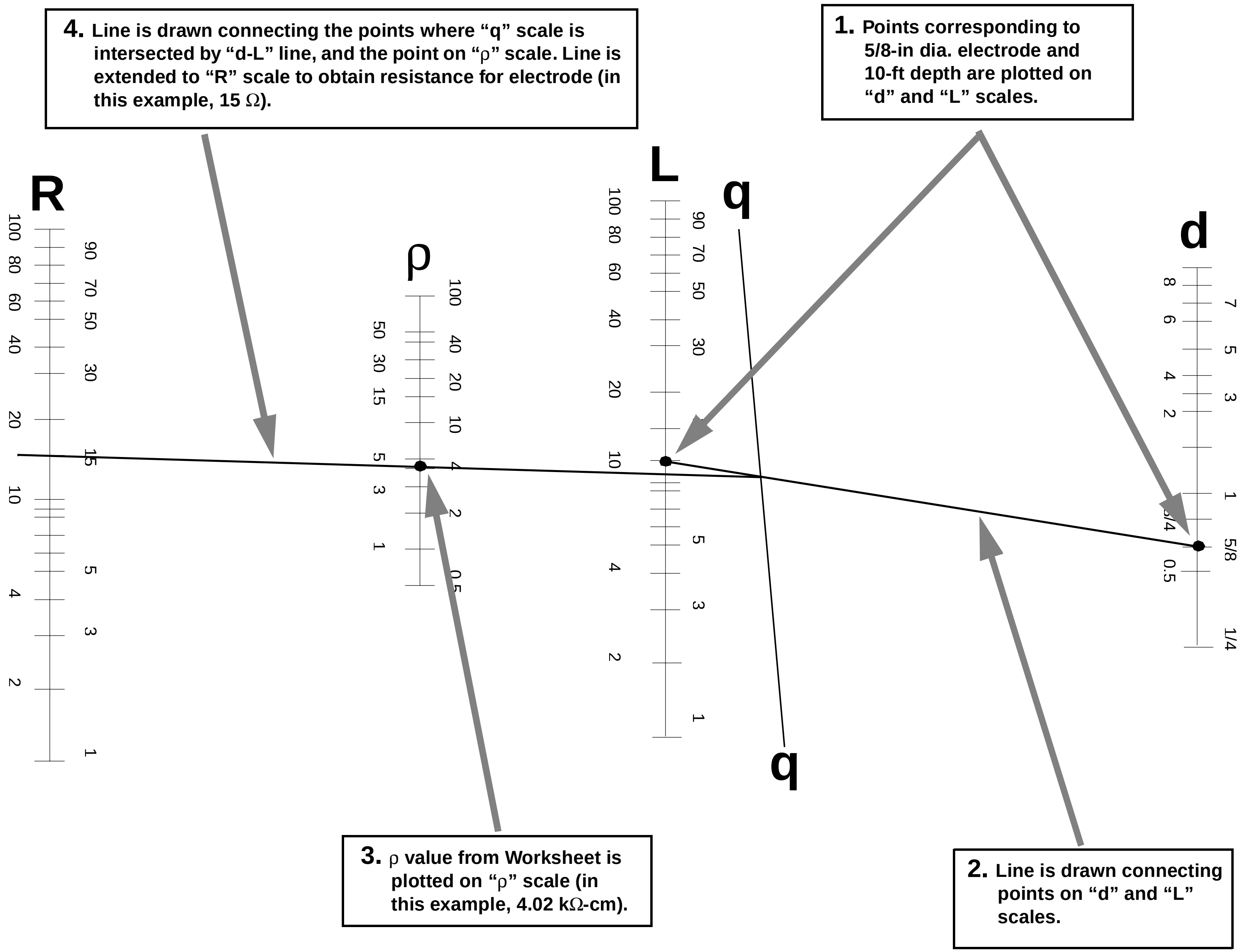


FIGURE 4-4 EXAMPLE WORKSHEET AND NOMOGRAPH (SHEET 2 OF 3)

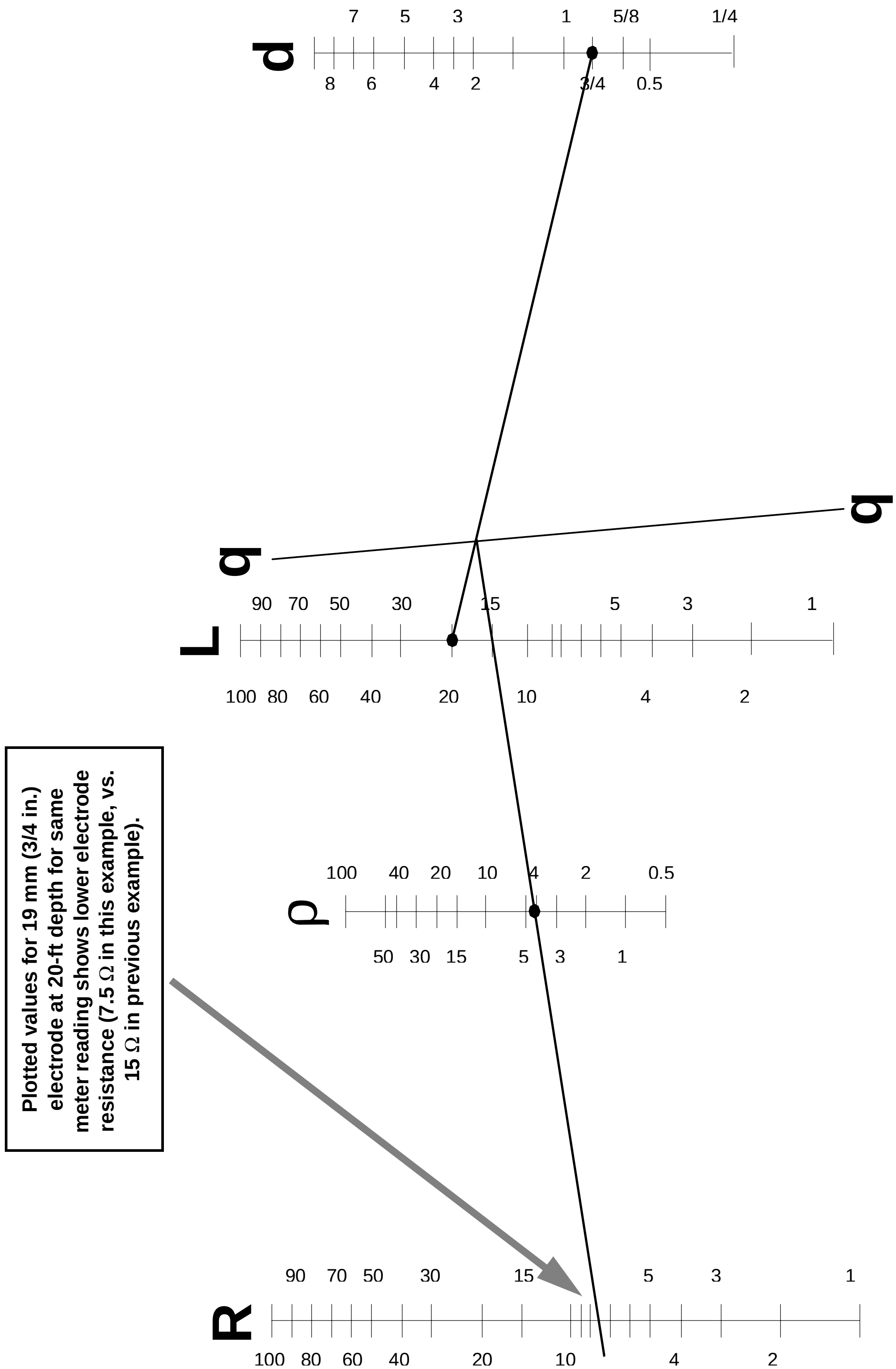


FIGURE 4-4 EXAMPLE WORKSHEET AND NOMOGRAPH (SHEET 3 OF 3)

TABLE 4-3 SOIL RESISTIVITY WORKSHEET

Location	Spacing (Test Depth)				
	1.52 m (5 ft.)	3 m (10 ft.)	6.1 m (20 ft.)	9.1 m (30 ft.)	12.2 m (40 ft.)
Meter Readings (steps 2 through 5)					
1 of 5					
2 of 5					
3 of 5					
4 of 5					
5 of 5					
Soil Resistivity Calculations (step 10) ρ =191.5 x A x R ρ = soil resistivity in Ω-cm A = Distance between test rods (in feet) R = Resistance obtained from tester					
1 of 5	ρ=	ρ=	ρ=	ρ=	ρ=
2 of 5	ρ=	ρ=	ρ=	ρ=	ρ=
3 of 5	ρ=	ρ=	ρ=	ρ=	ρ=
4 of 5	ρ=	ρ=	ρ=	ρ=	ρ=
5 of 5	ρ=	ρ=	ρ=	ρ=	ρ=

Test completed by:	Notes:
Date:	
Client / Project:	
Site Location/ID:	
Ground Resistance Tester Model: S/N: Calibration date:	
Soil Description:	
Ambient Conditions Temperature: Present conditions (dry, rain, snow): Date of last precipitation:	

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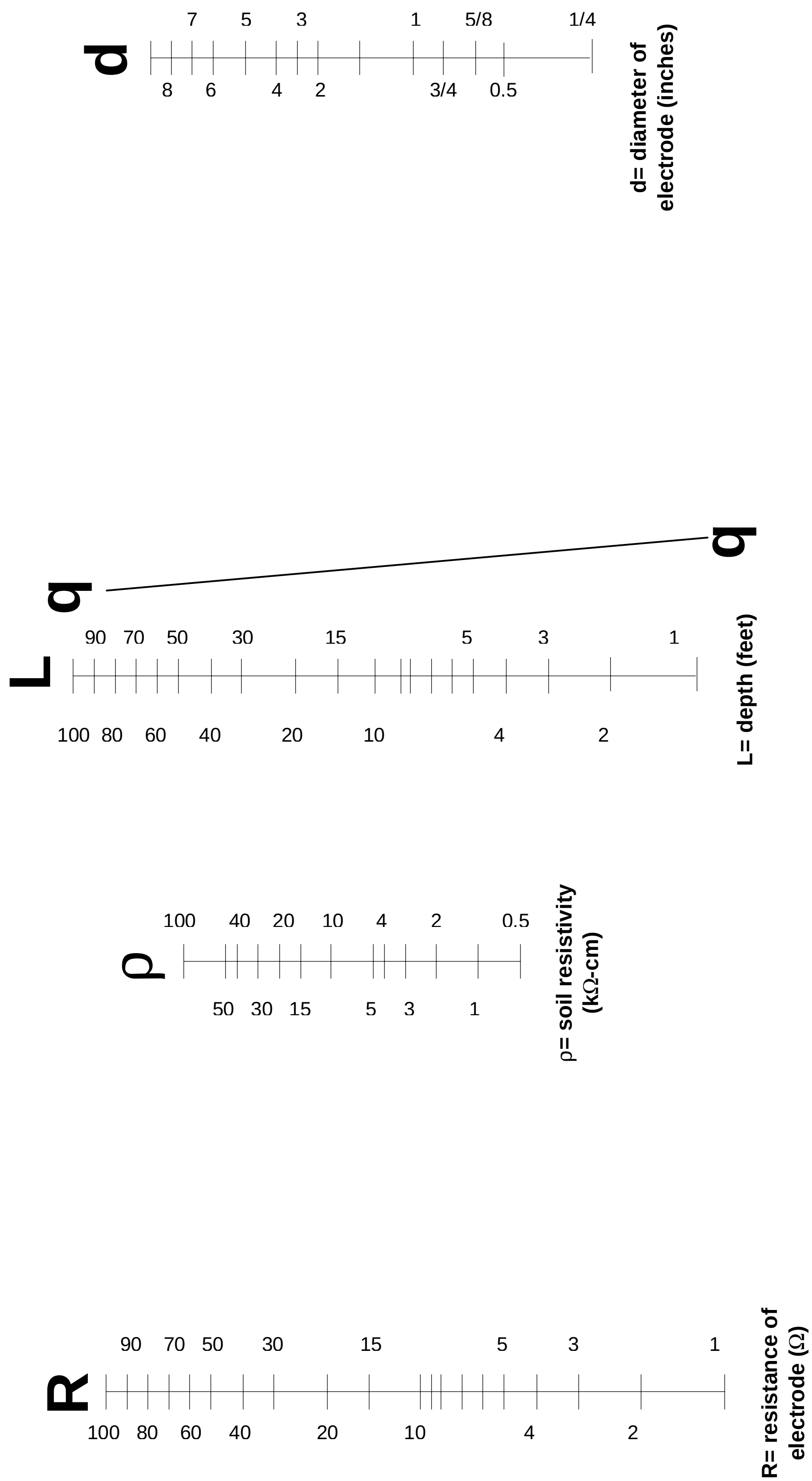

FIGURE 4-5 SOIL RESISTIVITY NOMOGRAPH

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4.3.3.2 MULTIPLE GROUNDING ELECTRODE SYSTEM RESISTANCE CALCULATION (ELECTRODES IN STRAIGHT LINE)

For a multiple grounding electrode system with multiple parallel electrodes in a straight line (as shown in Figure 4-6), the system resistance can be calculated as described in the following procedure.

PROCEDURE 4-3 SYSTEM RESISTANCE CALCULATION (MULTIPLE ELECTRODES IN STRAIGHT LINE)

1 Perform soil resistivity test as described in Procedure 4-1, "Soil Resistivity Test Procedure" on page 4-19.

2 Using the worse-case value obtained, calculate the resistance of one ground rod as described in Procedure 4-2, "Calculating Single Grounding Electrode Resistance" on page 4-21. Write down this number.

3 Sketch a proposed layout of the ground rod arrangement using equally spaced rods in a line.

NOTE: The stipulations regarding rod spacing specified in "Ground Rods" on page 6-6 in Chapter 6, "External Grounding," must be observed when planning rod layout.

4 Make a photocopy of Figure 4-7, "Combined Resistance Graph (Ground Rods Arranged in Line or Ring)" on page 4-31.

5 Using the copy of Combined Resistance Graph (Ground Rods Arranged in Line or Ring), calculate the effective resistance of the proposed layout as follows:

5.1 Noting the number of rods to be used, locate this number on the **Number of Rods** axis of the graph.

5.2 **Note the spacing of the rods in the proposed layout in terms of spacing as related to length of rods. In graph,**
"s=L" is spacing equal to length of rod
"s=2L" is spacing equal to twice the length of rod, and so on.

Locate the spacing line on graph (s=L, s=2L, s=3L, s=4L) corresponding to proposed spacing.

5.3 **At point on graph where Number of Rods line intersects appropriate spacing line, note the Combined Resistance number at the left.**

5.4 **Multiply the Combined Resistance number by the resistance of a single ground rod noted in step 2 of this procedure. This is the worse-case resistance of the proposed ground system.**

4.3.3.2.1 EXAMPLE LAYOUT AND GRAPH

Assuming a layout as shown in Figure 4-6 with the following characteristics:

- Eight rods (each of 8-ft. length) are spaced at 16 ft. points (or “2L” in terms of the graph) along a line.
- Worse-case soil resistivity measurement (step 1 above) is 4021.5 Ω-cm.
- Resistance of single rod tested (step 2 above) is 15 Ω.

System resistance is calculated as follows:

1. (See Figure 4-8) Since eight rods are used, “**8**” line on **Number of Rods** in graph is selected.
2. Since rod spacing is 16 ft., or “2L” of rod length, “**s=2L**” line on graph is selected.
3. At intersection of “8” line and “s=2L” line, draw a horizontal line to **Combined Resistance** axis at left. Note the point where horizontal line crosses **Combined Resistance** axis (in this case, at approximately “**18**” (or 18% of single rod resistance)).
4. Single rod resistance of 15 Ω is then multiplied by 18% (0.18) to obtain effective resistance of system:

   15Ω x 0.18= 2.7 Ω

In this example, effective overall resistance of proposed system would be 2.7 Ω.

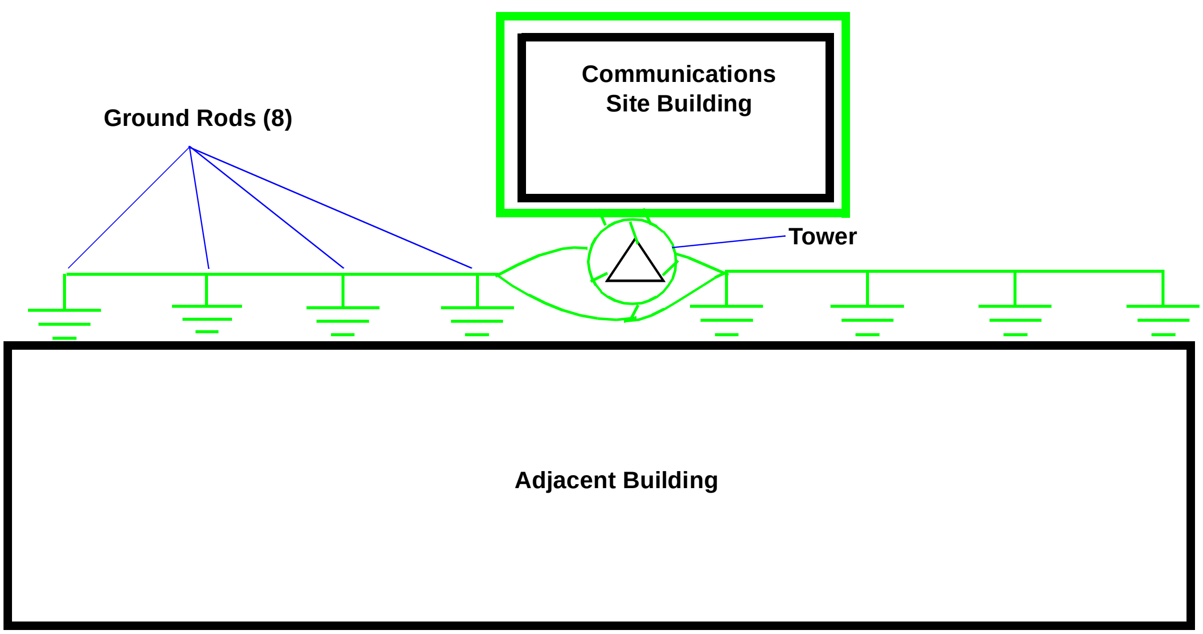

FIGURE 4-6 EXAMPLE OF MULTIPLE GROUNDING ELECTRODES IN STRAIGHT LINE

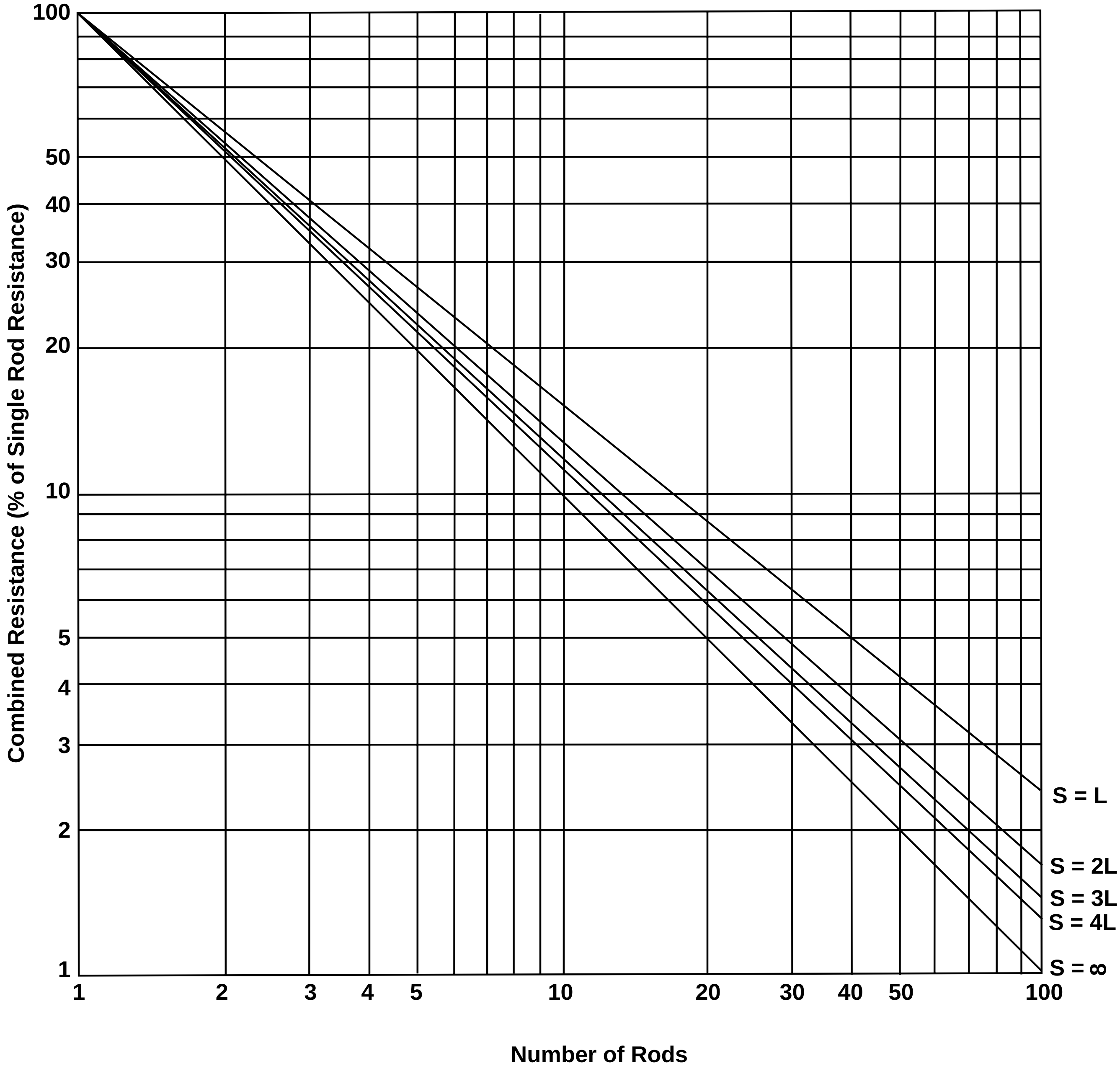

FIGURE 4-7 COMBINED RESISTANCE GRAPH (GROUND RODS ARRANGED IN LINE OR RING)

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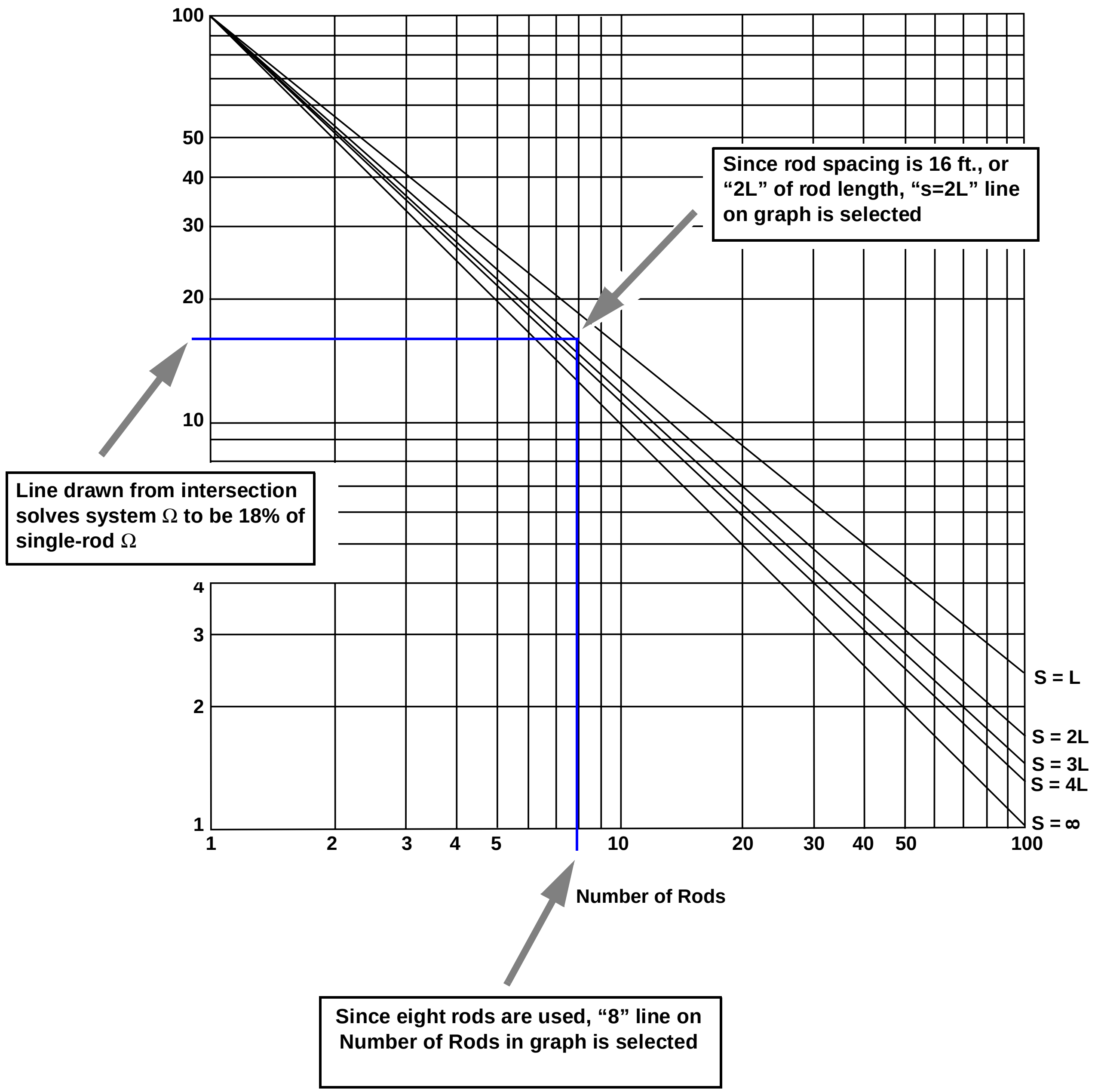

FIGURE 4-8 EXAMPLE CALCULATION OF GROUND RODS ARRANGED IN STRAIGHT LINE

4.3.3.3 MULTIPLE GROUNDING ELECTRODE SYSTEM RESISTANCE CALCULATION (ELECTRODES IN RING CONFIGURATION)

For a multiple grounding electrode system with multiple electrodes installed in a ring configuration (as shown in Figure 4-9), the system resistance is calculated in the same manner as electrodes placed in a straight line (as described in “Multiple Grounding Electrode System Resistance Calculation (Electrodes in Straight Line)” on page 4-29.

When planning a ring configuration layout and performing calculations, note the following:

- All rods in the system **shall** maintain equal or greater separation from adjacent rods.
- The distance between rods **shall** be figured in a direct path to adjacent rods, not the circumference distance of the ring.

NOTE: The stipulations regarding rod spacing specified in “External Ground Ring” on page 6-15 in Chapter 6, “External Grounding,” must be observed when planning rod layout.

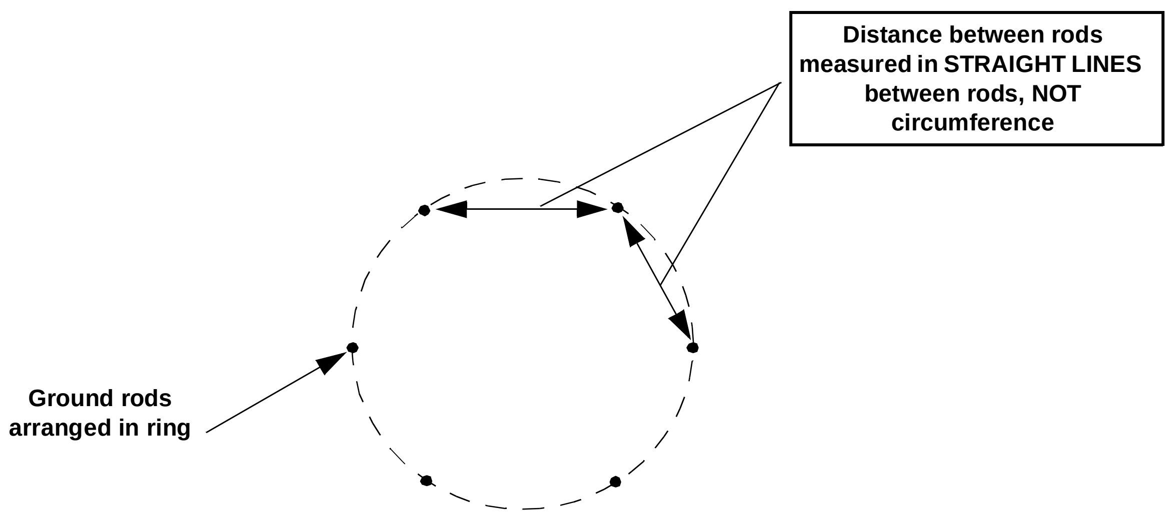

FIGURE 4-9 RING CONFIGURATION PLANNING AND RESISTANCE MEASUREMENT CONSIDERATIONS

4.3.3.4 MULTIPLE GROUNDING ELECTRODE SYSTEM RESISTANCE CALCULATION (GROUND ROD GRID CONFIGURATION)

For a multiple grounding electrode system consisting of a ground rod grid configuration (as shown in Figure 4-10), the system resistance can be calculated as described in the following procedure.

PROCEDURE 4-4 SYSTEM RESISTANCE CALCULATION (MULTIPLE ELECTRODE GROUND ROD GRID CONFIGURATION)

1 Perform soil resistivity test as described in Procedure 4-1, "Soil Resistivity Test Procedure" on page 4-19.

2 Using the worse-case value obtained, calculate the resistance of one ground rod as described in Procedure 4-2, "Calculating Single Grounding Electrode Resistance" on page 4-21. Write down this number.

3 Sketch a proposed layout of the ground rod arrangement using equally spaced rods across the proposed area.

NOTE: The stipulations regarding rod spacing specified in "Ground Rods" on page 6-6 in Chapter 6, "External Grounding," must be observed when planning rod layout.

4 Calculate the area of the proposed grid system in **square feet**.

NOTE: This procedure requires that grid measurements be entered in **square feet**. If metric measurements have been made, the measurements must be converted to feet. (Refer to Appendix D, "General Conversions and Formulas", for conversion formulas.)

5 Make a photocopy of Figure 4-11, "Combined Resistance Graph (Ground Rods Arranged in Grid)" on page 4-37.

6 Using the copy of Combined Resistance Graph (Ground Rods Arranged in Grid), calculate the effective resistance of the proposed layout as follows:

6.1 Noting the number of rods to be used, locate this number on the **Number of Rods** axis of the graph.

6.2 **Note the square footage of the proposed rod layout. Locate the curve on the graph most closely corresponding to the proposed square footage.**

6.3 **At point on graph where Number of Rods line intersects appropriate square footage curve, note the Resistance Ratio number at the left.**

6.4 **Multiply the Resistance Ratio number by the resistance of a single ground rod noted in step 2 of this procedure. This is the worse-case resistance of the proposed ground system.**

4.3.3.4.1 EXAMPLE LAYOUT AND GRAPH

Assuming a layout as shown in Figure 4-10 with the following characteristics:

- 16 rods equally spaced across a 30 x 30 ft. grid (900 sq. ft.).
- Worse-case soil resistivity measurement (step 1 above) is 4021.5 Ω-cm.
- Resistance of single rod tested (step 2 above) is 15 Ω.

System resistance is calculated as follows:

1. (See Figure 4-12) Since 16 rods are used, point corresponding to “16” on **Number of Rods** in graph is selected. Draw line vertically from “16” point on graph.
2. Since grid is 900 sq. ft., a point just below **1,000** sq. ft. curve on graph is plotted on line drawn on graph.
3. At point plotted in above step (intersection of “900” sq. ft. and “16” rods), draw a horizontal line to **Resistance Ratio** axis at left. Note the point where the drawn horizontal line crosses **Resistance Ratio** axis (in this case, at approximately “.17”).
4. Single rod resistance of 15 Ω is then multiplied by 0.17 to obtain effective resistance of system:

   15Ω x 0.17= 2.55 Ω

In this example, effective overall resistance of proposed system would be 2.55 Ω.

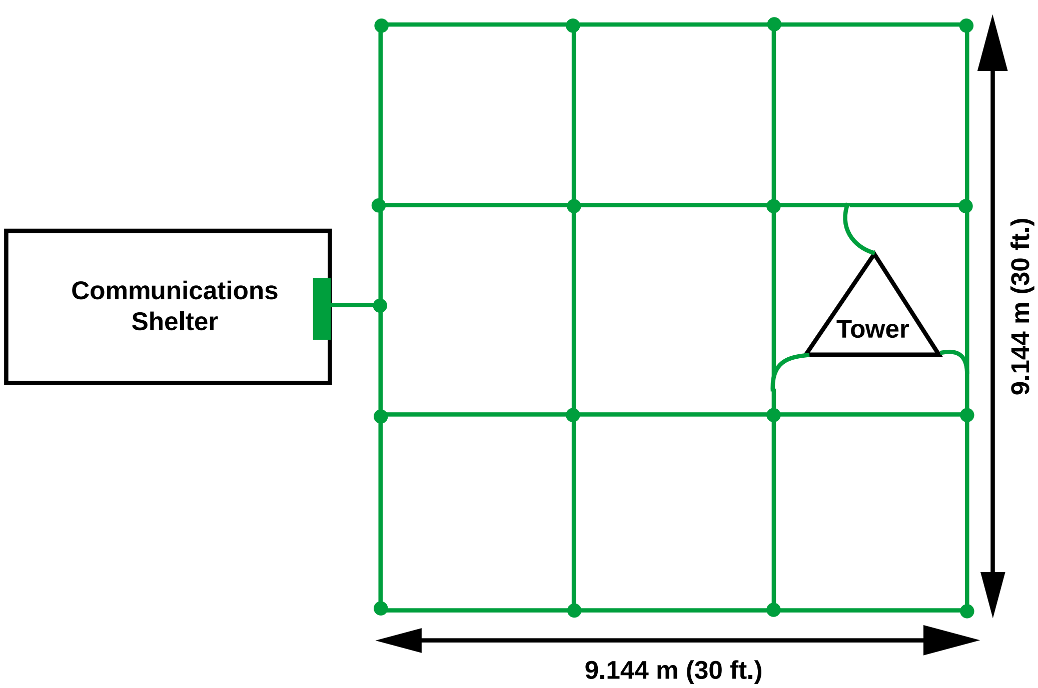

FIGURE 4-10 EXAMPLE OF MULTIPLE GROUNDING GROUND ROD GRID CONFIGURATION

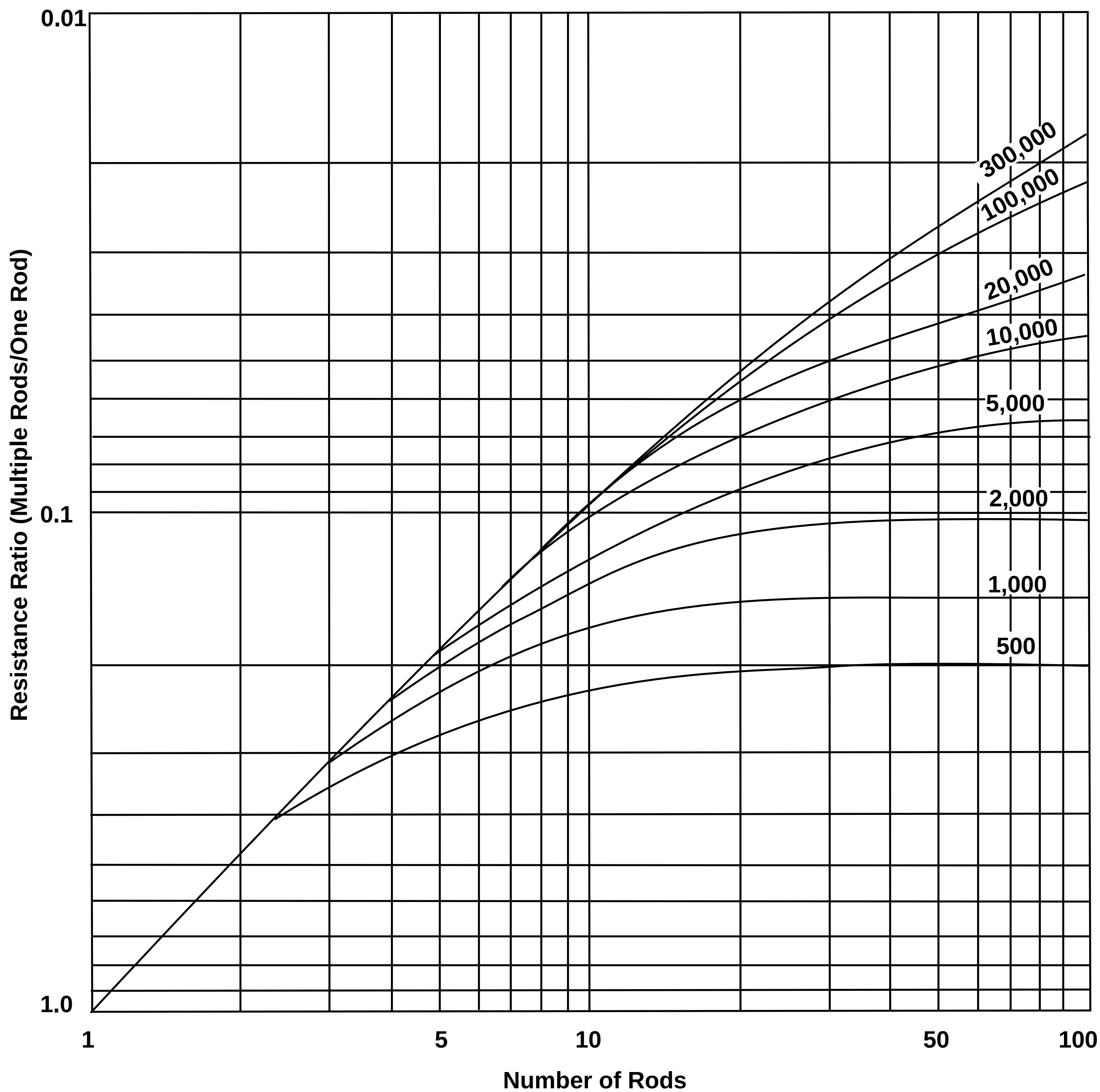

FIGURE 4-11 COMBINED RESISTANCE GRAPH (GROUND RODS ARRANGED IN GRID)

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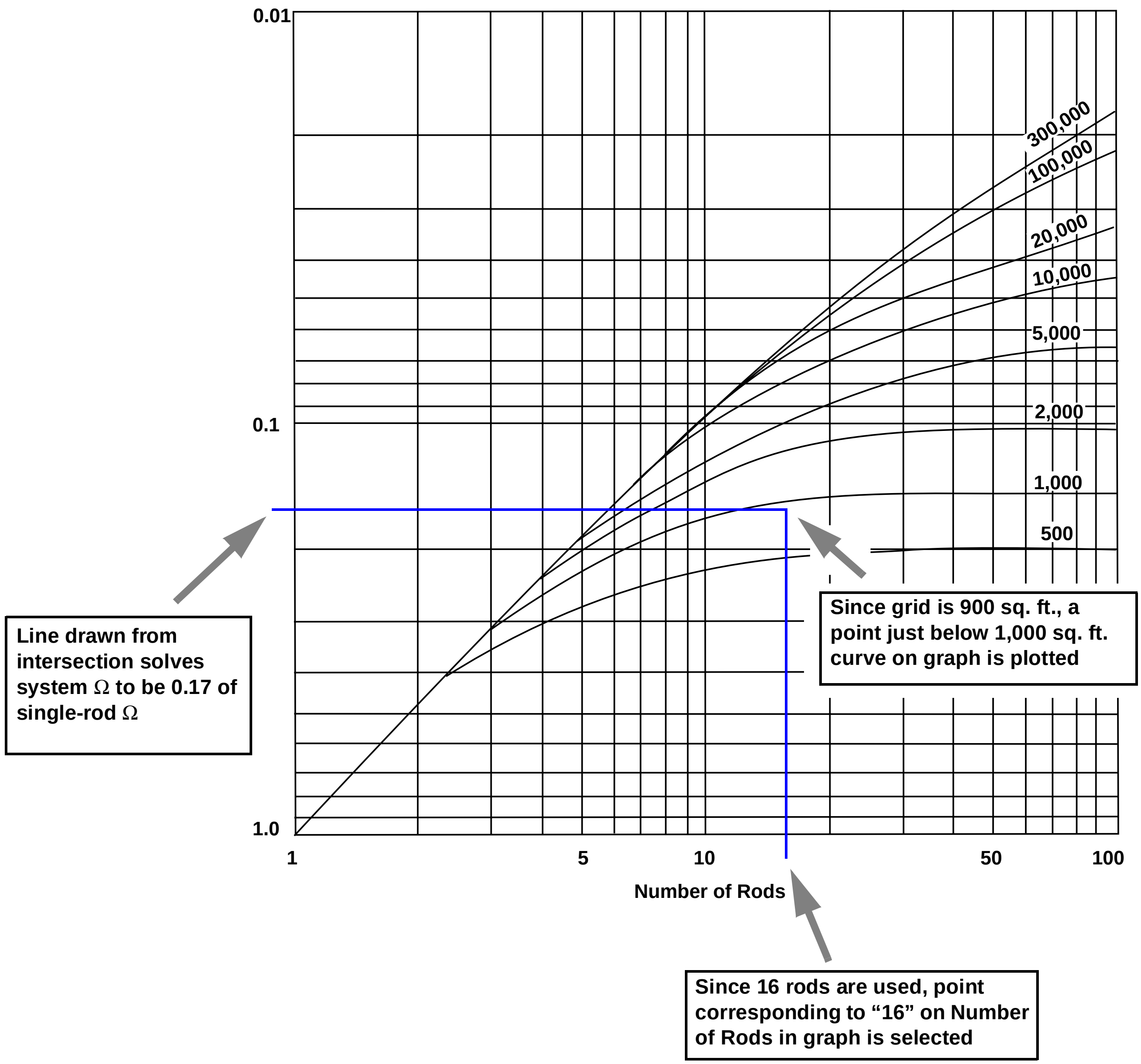

FIGURE 4-12 EXAMPLE CALCULATION OF GROUND ROD GRID CONFIGURATION

4.3.3.5 CALCULATING RESISTANCE OF COMPLEX GROUND ROD SYSTEMS

Complex ground rod systems consist of multiple subsystems bonded together to form an overall site ground rod system. Figure 4-13 shows a typical complex ground rod system.

Resistance of a complex ground rod system can be readily obtained by breaking down the system into its individual subsystems. Typically, a ground rod system can be broken down into the following individual subsystems:

- Building ground ring
- Tower ground ring
- Tower ground radials

For a complex ground rod system consisting of the above subsystems (as shown in Figure 4-13) or similar multiple subsystems, the overall system resistance can be calculated as described in the following procedure.

NOTE: Adjacent subsystems should not be laid out closer than the ground rod spacing distance used within a particular subsystem. This is because as subsystems become closer than this distance, the adjacent subsystems begin to "act" as a single subsystem rather than two subsystems.

PROCEDURE 4-5 SYSTEM RESISTANCE CALCULATION (COMPLEX SYSTEM)

1 Perform soil resistivity test as described in Procedure 4-1, "Soil Resistivity Test Procedure" on page 4-19.

2 Using the worse-case value obtained, calculate the resistance of one ground rod as described in Procedure 4-2, "Calculating Single Grounding Electrode Resistance" on page 4-21. Write down this number; it is needed for following calculations.

3 Sketch a proposed layout of the ground rod arrangement using equally spaced rods across the proposed area.

NOTE: The stipulations regarding rod spacing specified in "Ground Rods" on page 6-6 in Chapter 6, "External Grounding," must be observed when planning rod layout.

4 Calculate the resistance of the **building ground ring** subsystem as described in "Multiple Grounding Electrode System Resistance Calculation (Electrodes in Ring Configuration)" on page 4-34. Write down the result.

PROCEDURE 4-5 SYSTEM RESISTANCE CALCULATION (COMPLEX SYSTEM) (CONTINUED)

5 Calculate the resistance of the **tower ground ring** subsystem as described in "Multiple Grounding Electrode System Resistance Calculation (Electrodes in Ring Configuration)" on page 4-34.

6 Calculate the resistance of the **tower ground radial** subsystem as follows:

6.1 Calculate the resistance of each **individual** tower ground radial as described in "Single Grounding Electrode System Resistance Calculation" on page 4-21. Write down the results for each ground radial.

6.2 **Using the results obtained in above step, calculate the combined (parallel) resistance of the tower ground radials as follows:**

$$R_{total} = \frac{1}{1/R_{radial\ 1} + 1/R_{radial\ 2} + ...1/R_{radial\ n}}$$

7 Noting the resistances determined for the subsystems, calculate the combined (parallel) resistance of **all of the subsystems** as follows:

- subsystem 1 (building ground ring subsystem; step 4)
- subsystem 2 (tower ground ring subsystem; step 5)
- subsystem 3 (tower ground radial subsystem; step 6)

$$R_{total} = \frac{1}{1/R_{subsystem\ 1} + 1/R_{subsystem\ 2} + 1/R_{subsytem\ 3}}$$

NOTE: Total resistance does not include incidental influence from site fencing, buried fuel tanks, or other objects not included in these calculations. More complex grounding systems, or highly accurate results where other objects exist, will require the assistance of an appropriate engineering consultant.

4.3.3.5.1 EXAMPLE CALCULATION OF COMPLEX SYSTEM

Assuming a layout as shown in Figure 4-13 with the following characteristics:

- Worse-case soil resistivity measurement (step 1 above) is 4021.5 Ω-cm.
- Building ground ring (step 4 above) using four rods, each with a resistance of 4 Ω. **Building ground ring subsystem calculates to 4.35** Ω.
- Tower ground ring (step 5 above) using three rods, each with a resistance of 15 Ω. **Tower ground ring subsystem calculates to 5.55** Ω.

- Tower ground radial subsystem (step 6 above) as shown in Figure 4-13. Total resistance of this subsystem is as follows:
  - Radial "A" has four ground rods. Resistance of this radial calculates to 5.55 Ω .
  - Radial "B" has two ground rod. Resistance of this radial calculates to 15 Ω .
  - Radial "C" has three ground rods. Resistance of this radial calculates to 7.95 Ω .

  Tower ground radial calculates to 2.68 Ω , as shown below using the formula provided in step 6:

$$R_{\text{tower radial}} = 2.68\ \Omega = \frac{1}{1/(5.55\Omega) + 1/(15\Omega) + 1/(7.95\Omega)}$$

Overall system resistance is calculated as follows:

1. The individual resistances of the three subsystems are noted:
   - **Building ground ring** = **4.35** Ω
   - **Tower ground ring subsystem** = **5.55** Ω
   - **Tower ground radial** = **2.68** Ω
2. The combined (parallel) resistance of **all of the subsystems** is now calculated as follows:

$$R_{\text{total}} = 1.28\ \Omega = \frac{1}{1/(4.35\Omega) + 1/(5.55\Omega) + 1/(2.68\Omega)}$$

In this example, the calculated effective overall resistance of the proposed system would be 1.28 Ω .

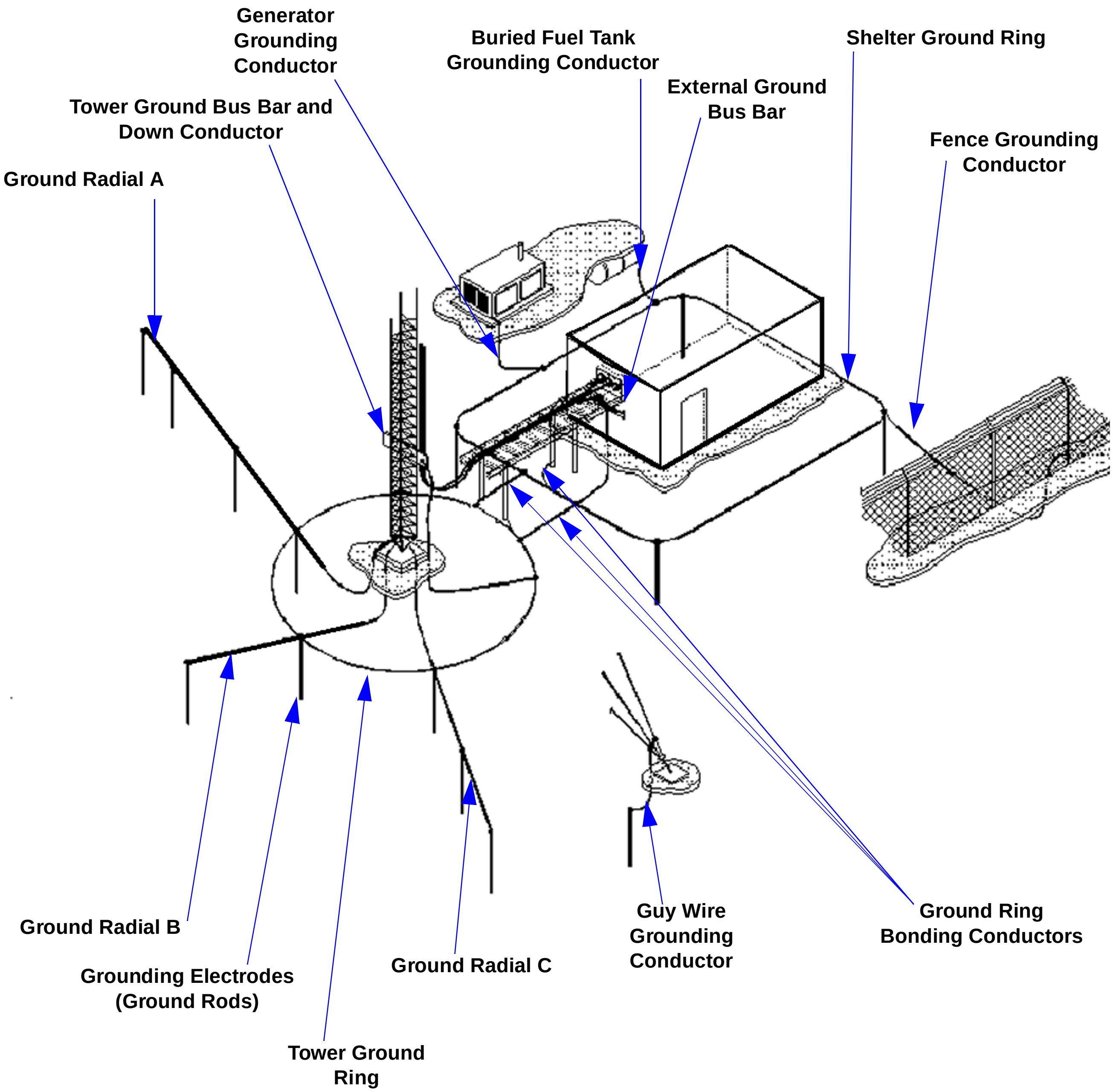

FIGURE 4-13 TYPICAL COMPLEX GROUND ROD SYSTEM

4.3.4 GENERAL OUTLINE OF WORK

The following is a high-level overview of tasks and the typical order in which major site development tasks are performed.

- Clearing land of vegetation
- Installing erosion control barriers
- Excavating and building access road
- Installing utility/electrical metering base
- Excavating and establishing subgrade and drainage requirements
- Excavating and installing shelter and any ancillary foundations
- Excavating and installing tower foundations
- Installing equipment shelter and ancillary equipment, including backup power systems
- Installing electrical conductors and other utility installations
- Energizing equipment shelter
- Installing tower, antennas and RF transmission lines
- Installing tower lighting system
- Installing fencing and gates
- Backfilling, grading, and bringing site up to final grade
- Startup and testing of facility equipment
- Performing final cleanup and obtaining customer approval signatures

4.4 CONCRETE FOUNDATION DESIGN AND INSTALLATION CONSIDERATIONS

This paragraph describes the design and construction considerations and requirements for communications site concrete foundations, including prefabricated communications shelters and tower foundations.

WARNING

To ensure personnel safety, all excavations shall be conducted in accordance with OSHA safety and excavation regulations, and/or local safety regulations (whichever is more stringent).

FIGURE 4-14 SITE EXCAVATION

4.4.1 FOUNDATION AND GEOTECHNICAL SERVICES

Foundation monitoring services are required when structural soils and foundation work is performed. They may also be required for certain other sub-surface and surface work. Monitoring services report whether the soils and concrete conform to design limits specified by either the tower and foundation designer or site engineering firm before, during or after installation. If the specified design limits are not met, the foundation monitoring service **shall** notify the contractor and Motorola to ensure that the noncompliance is corrected. This service is sometimes performed by the geotechnical firm.

NOTE: Firms offering this service may be able to provide a checklist you can use as a guideline for your project.

4.4.2 FOUNDATION DESIGN AND INSTALLATION

- Unless otherwise specified, tower foundation and anchor design **shall** be in accordance with the latest revision of ANSI/EIA/TIA-222.
- Foundation design for prefabricated shelters and other equipment **shall** be based upon site soil conditions as noted in the geotechnical report. These foundation plans for buildings and ancillary equipment **shall** be designed by a licensed Professional Engineer and the design **shall** be included in the site plan. See Appendix G for examples of typical site plans for guyed and self-supporting tower sites.
- Tower foundation drawings **shall** show a minimum of the following information:
    - Reference to the soil/geotechnical report, including file number, date and firm performing report, used in calculations and design.
    - Required concrete compressive strength to be achieved at 28 days
    - Grade and/or type of reinforcing bar
    - Concrete coverage requirements
    - Whether welding of rebar is permitted
    - Whether cold joints are permitted; if so, the joining procedure **shall** be specified.
    - Whether permanent steel casings are permitted for caisson installations
    - Whether temporary steel casings are or may be required due to the expected soil conditions
    - Any recommended concrete installation techniques such as a tremie.
    - References to all codes (and sections of codes) applicable for the design.
    - Plan, elevation and section views depicting a minimum of the following:
        - Length, depth, and width
        - Diameter
        - Finish grade with respect to top of foundation
        - Rebar size and placement
        - Anchor bolt size, type and placement
        - Above finish grade requirement for anchor heads (typically a minimum of 30.5 cm (12 in.)
    - Estimated cubic yards of concrete per pier, caisson, mat, block or other type of foundation

- Backfill requirements such as but not limited to:
    - Material type
    - Thickness of lifts (typically lifts not more than 30.5 cm (12 in.) thick are acceptable)
    - Applicable compaction requirements; such 95% of modified proctor maximum dry density
- Applicable sub-grade compaction requirements; such as for a guy anchor. Upon completion of the excavation the designer may require certain compaction densities.
- Any other pertinent information that may be abstracted from the soils report such as a high water table or large boulders.
- Any other pertinent construction or design information or considerations

- All excavations on which concrete is to be placed **shall** be substantially horizontal on undisturbed and unfrozen soil and be free from loose material and excess ground water. Methods for removing excess ground water **shall** be provided if required.
- Concrete foundations **shall not** be placed on organic material. If sound soil is not reached at the designed excavation depth, the unsatisfactory soil **shall** be excavated to its full depth and either be replaced with mechanically compacted granular material or the excavation be filled with concrete of the same quality specified for the foundation.
- Concrete forms of wood, metal centering, cores, molds, and so forth, **shall** be used as required for the proper execution of the plain and reinforced concrete work. Sufficient quantities **shall** be used to properly execute and expedite work without endangering the safety or strength of any part of the construction.
- All forming **shall** be true and rigid, thoroughly braced, and sufficiently strong to safely carry all dead and live loads to which it may be subjected. The elimination of forming by a monolithic pour against undisturbed soil **shall** be allowed only if approved by a soils engineer and/or a qualified Motorola representative.
- All steel reinforcement **shall** be furnished and installed in accordance with the approved foundation drawing. Unless otherwise specified or shown on plans, reinforcement **shall** consist of preformed bars of intermediate grade, manufactured from new billet stock. Metal reinforcement **shall** conform to the requirements of the latest version of “Specifications for Deformation of Preformed Steel Bars for Concrete Reinforcement”, ASTM A615-68, or applicable jurisdictional code, whichever is more stringent.
- Anchors, bolts, miscellaneous iron work, and so forth **shall** be set as shown in the drawings before pouring cement. Embedded items **shall** be held rigidly in place during placing and curing of concrete. Concrete **shall** be vibrated and thoroughly consolidated around all embedded items. Placing rebar in position as the concrete is placed **shall not** be permitted.
- Prior to all concrete pours, the proposed concrete mix design **shall** be submitted to Motorola for verification of design specifications at least one week before the pour date.
- When concrete is placed, certificates **shall** be furnished for each delivery vehicle or every 7 cu. yds, showing the mix proportions, additives, compressive strength, and the brand name and type of cement.

- Concrete **shall** be so deposited that there will be no separation or segregation of aggregate. Maximum free drop **shall not** exceed 2.43 m (8 ft.).
- Concrete **shall not** be placed when the outdoor temperature is below 4.5° C (40° F) nor when the concrete is likely to be subjected to freezing temperatures before final set, except when adequate provisions have been made for protection. When deposited in the forms, the concrete **shall** have a temperature of not less than 15.5° C (60° F) and not more than 32° C (90° F). A suitable means **shall** be provided to maintain the temperature above 10° C (50° F) degrees for 7 days. The materials **shall** be heated before mixing to prevent concrete from freezing.
- After completion of the foundation and other construction below grade, and before backfilling, all excavations **shall** be clean of vegetation, trash, debris, and inorganic materials.
- A soils engineer **shall** determine if the onsite excavated materials are adequate or suitable for use as backfill material. If the material is not suitable, then engineered soils **shall** be determined by the soils engineer. Backfilling **shall**:
  - use approved materials consisting of earth, loam, sandy clay, sand and gravel, or soft shale
  - be free from clods or stones over 6 cm (2.5 in.) maximum dimensions
  - If excavated material is used, rock **shall** be placed in layers.
- Foundation backfill **shall** be placed in layers no more than 30 cm (12 in.) deep before compaction. See Appendix G for examples of foundation drawings showing typical backfill specifications. The backfill requirements of each site differ based on conditions at the site.
- The foundation area **shall** be graded to provide water runoff and prevent water from standing. The final grade **shall** slope away in all directions from the foundation. See Appendix G for examples of grading plans showing grading and runoff.

FIGURE 4-15 POURING A FOUNDATION

4.4.3 CONCRETE AND SOILS INSTALLATION MONITORING

Test requirements for different types of concrete foundations are provided in Table 4-4.

TABLE 4-4 FOUNDATION AND SOILS MONITORING REQUIREMENTS

Requirement	Type of Foundation			
	Drilled Piers (Caissons)	Deep Mat	Guy Tower Sites	Equipment Shelter and Pads
Confirm and obtain concrete mix design from foundation designer.	✔	✔	✔	✔
Perform penetrometer test at the base of the mat or tower excavation to verify soil bearing conditions. The number of test locations is dependent on soil conditions. The Geotechnical firm **shall** provide bearing values for specific locations. **NOTE:** Penetrometer tests are not required at the bottom of guy anchor thrust block excavations.		✔ minimum 3 to 5 locations	✔ minimum 2 to 3 locations	✔ minimum 2 to 4 locations
Collect bulk sample for Modified Proctor compaction testing – expedite sample to lab to accommodate a 7 day concrete cure period (unless a high early type mix is used) then a shorter turnaround will be required.		✔	✔	
Identify specific caisson(s) being installed and include in daily field log and concrete report. Confirm and note in concrete report caisson diameter and depth.	✔ ✔			
Confirm, note and ensure caisson bottom is clean and free of debris.	✔			
For caissons, confirm and note placement of reinforcement cage and ensure it is centered in caisson pier. For other foundations, confirm and note placement of reinforcement steel with respect to foundation design.	✔	✔	✔	✔
Confirm and note that method of concrete placement is as specified by foundation designer(s).	✔	✔	✔	
Perform concrete field tests (slump, temperature and air content) and cast a minimum of one set of test cylinders (four cylinders per set) for every 19.1 m^3 (25 cu. yd.) of concrete placed. Perform new set of tests and cylinders once five yards beyond the 19.1 m^3 (25 cu. yd.) increment. **Examples:** 61 m^3 (80 cu. yd.) = four sets of test cylinders. 23 m^3 (30 cu. yd.) = two sets of cylinders).	✔	✔	✔	

TABLE 4-4 FOUNDATION AND SOILS MONITORING REQUIREMENTS (CONTINUED)

Requirement	Type of Foundation			
	Drilled Piers (Caissons)	Deep Mat	Guy Tower Sites	Equipment Shelter and Pads
Confirm and note that a working vibratory wand is used to consolidate the upper 3 m (10 ft.) of concrete placed in each caisson or the tower mat foundation.	✔	✔	✔	
Ensure that newly formed test cylinders are placed in an insulated cure box or other heated area to protect against freezing temperatures. Note that other methods of curing may be more acceptable or desired.	✔	✔	✔	✔
Test concrete cylinders in accordance with latest version of American Concrete Institute (or jurisdictional agency) standards and note in concrete test log. (See Appendix B for an example of concrete test log form.)	✔	✔	✔	✔
Note unusual developments such as rejected concrete, weather or construction delays, difficulty in setting anchor bolts, or casings stuck in place.	✔	✔	✔	
Perform, confirm and note density tests on each new lift of tower foundation backfill to verify it is compacted to 95% of the Modified Proctor maximum density value test (ASTM D1557). Make note of type of compacting equipment used.	✔	✔	✔	
Specifically note the anchors or locations worked on and the order in which they were poured.			✔	
Ensure backfill and undercut areas for non-structural applications (such as around pre-fabricated shelter foundations) are compacted to 90% of the maximum dry density value determined by the latest version of Standard Proctor test (ASTM D698).				✔

4.5 EQUIPMENT SHELTER OFF-LOADING

WARNING

To help prevent injury and/or damage to equipment, all appropriate safety precautions shall be taken during shelter off-loading.

The equipment shelter type determines the method and means by which it is off-loaded from the truck that transported it to the site. Typically, shelters require extensive rigging and a large hydraulic crane to off-load and set.

NOTE: It is required that all cranes be inspected and tested by crane operator personnel prior to any lift for Motorola related projects. Construction supervisory personnel **shall** insist that the crane operator demonstrate that the crane has been inspected. Any questions regarding this requirement **shall** be directed to the Motorola Project Manager.

FIGURE 4-16 PREPARING TO OFF-LOAD SHELTER FROM TRUCK

FIGURE 4-17 OFF-LOADING THE EQUIPMENT SHELTER

FIGURE 4-18 MANEUVERING THE SHELTER TOWARD THE FOUNDATION

4.6 SITE AND FACILITY ACCEPTANCE TESTING

When site development, including tower construction, antenna and transmission line installation, utility connection, building or shelter placement or construction, and roadway construction, is complete, all applicable areas of the site **shall** be inspected and tested. This **shall** be done to ensure that all installations and alarms are functioning properly before the site is presented for customer acceptance. All aspects of the inspection and testing **shall** be documented. Items to inspect and test may include but are not limited to the following:

- Site AC power and alarms
- Transfer switch functionality and alarms
- HVAC equipment and alarms (including high and low temperature and high humidity)
- Generator functionality and alarms
- Fire or smoke detection devices
- UPS functionality and alarms
- Tower lighting functionality and alarms
- Dehydrator functionality and alarm
- Security measures such as door alarms and deadbolts
- Antenna and transmission line installations
- Concrete compressive strength requirements
- All aspects of the site, building and tower drawings are met or properly as-built
- General workmanship
- Site and building are clean and free of trash and debris
- Tower installation is in accordance with the latest version of ANSI/EIA/TIA-222

4.7 TOWER DESIGN

NOTE: Twist and sway of a tower affects the performance of microwave links. Therefore it is imperative that the proper loading information for each tower be supplied to the tower designer to help ensure that the tower meets ANSI/EIA/TIA-222 requirements.

All towers **shall be** designed by a registered professional engineer specializing in tower structure design. Tower height is determined from a number of factors, including but not limited to those listed below.

- Required RF coverage
- Required effective radiated power (ERP) coverage
- Location
- Seismic risk probability
- Available area
- Existing structures in the vicinity
- Terrain
- Required antenna height
- Federal Aviation Authority (FAA) or jurisdictional approval

Unless otherwise specified, all towers and foundations **shall** be designed to the latest version of ANSI/EIA-TIA 222 unless jurisdictional laws or codes mandate otherwise. The following tower design requirements apply:

- A minimum of one safety climb **shall** be engineered, supplied and installed on every tower.
- EME precautions **shall** be as described in Appendix E.
- Rest platforms **shall** be designed and installed per OSHA or other jurisdictional codes, or as recommended by the tower manufacturer.

If additional antennas are to be added to an existing tower, or if a structure other than a tower will be used to support a communication system antenna, the original tower designer and/or a registered professional engineer specializing in tower structure design **shall** be contracted to provide an analysis of whether the tower or structure can safely support the additional load of the new antenna.

Figure 4-20 is an example of a Personal Communications System (PCS) antenna, mounted on an alternative structure, in this case a light pole.

FIGURE 4-19 EXAMPLE OF ALTERNATIVE ANTENNA MOUNT

TABLE 4-5 COMPARISON OF TOWER TYPES

Factor	Self-Supporting	Guyed	Monopole
Cost	High More material required Foundation more expensive	Moderate More assembly cost required Land costs may be higher because more area is required for guy wires.	Low
Rigidity	High Self-supporting structure is more stable and able to resist wind loading better than the other types.	Moderate Provide resistance to wind sway, but are susceptible to torquing, especially when dish antennas are installed.	Low - wind resistance less than other types.
Land Required	Low	High - Location of guy anchors must be far from tower, requiring more property. May be unsuitable for populated areas due to land requirements	Low - Well-suited for urban areas with limited land availability.
Height	Moderate	High - Guyed towers may exceed 366 m (1200 ft.)	Low
Growth Potential	High - Heavy loads may be best accommodated by a self-supporting tower	Moderate	Low - Monopoles capable of supporting growth with room to rent space to other users may cost significantly more to build.

4.7.1 REGULATIONS AFFECTING TOWERS

In the United States, the FAA regulates and approves towers, including but not limited to tower height, location, marking, and lighting. Each state or jurisdiction may have specific regulating agencies which may designate specific marking or lighting requirements in addition to FAA requirements. It is highly recommended that the appropriate jurisdictional authorities be identified and consulted before final tower design and construction begin.

CFR 47, Part 17 - Construction, Marking and Lighting of Antenna Structures **shall** be followed to determine required paint markings and lighting for towers. An equivalent standard **shall** be followed for nondomestic installations.

A preconstruction notice **shall** be submitted to the FAA or local authority having jurisdiction at least 30 days before the date the proposed construction or alteration is scheduled to begin. On or before the date a construction permit application is filed with the Federal Communications Commission (FCC). Ensure that the FAA acknowledges receipt of the notice before beginning tower construction. Other notices may be required by the FAA on a case by case basis.

All FAA, FCC, and jurisdictional rules and regulations **shall** be strictly followed throughout tower design and construction, and following tower completion. It is highly recommended that the appropriate jurisdictional authorities be consulted before starting tower design and construction.

4.7.2 ANTENNA AND DISH ANTENNA LOADING

Antenna loading requirements are one of the most critical aspects of tower design. Loading requirements include but are not limited to the following:

- RF antenna quantity, size, type, manufacturer, frequency, and elevation
- If required, future RF antenna loading requirements
- Microwave dish antenna quantity, size, manufacturer, frequency, azimuth, and elevation
- If required, future microwave dish antenna loading requirements
- Transmission cable diameter and type
- Sidearm length and location
- Lighting requirements
- Additional ice or wind loading requirements applicable to the selected site
- Safety apparatus such as climbing ladders and rest platforms
- Miscellaneous optional equipment, such as ice shields

See Figure 4-20 for an example of a tower loading report.

MOTOROLA

Site Designator 7XXX

MSP No 7XXX

Tower Loading Information

City NewTown **Phase** 3

County Charles **District** 7

Tower Type: Self Support *21-Dec-99*

Tower Height: 475

Tower Reference Azimuth: 0

Ant. Engineering File Number:

Microwave Antenna System Information

Path No	Path Destination	Path Density	Radio Capacity	Azimuth	Path Distance	Antenna Height (CL)	Dish Size	Space Diversity	Diversity Ant. Ht (CL)	Div Dish Size	ERIP (dBi)	Polarization
91	7203b	high	28	43	14.8	135	6	☑	95	6	66.8	Vertical
88	7302p4	medium	12	121.4	10.6	142	6	☑	102	6	66.8	Vertical
89	7001b	high	28	160.605	11	160	6.1	☑	99	6	64.8	Vertical
90	7904p1	High	28	237.145	15.8	125	8	☑	80	6	69.3	Vertical
101	7804c	high	28	333.9	11.4	106	6	☑	71	6	66.8	Vertical

MOTOROLA

Site Designator 7XXX

MSP No 7XXX

Tower Loading Information

City NewTown **Phase** 3

County Charles **District** 7

Tower Type: Self Support *21-Dec-99*

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Tower Reference Azimuth: 0

Ant. Engineering File Number:

Microwave Antenna System Information

Path No	Path Destination	Path Density	Radio Capacity	Azimuth	Path Distance	Antenna Height (CL)	Dish Size	Space Diversity	Diversity Ant. Ht (CL)	Div Dish Size	ERIP (dBi)	Polarization

800 MHz Antenna Information

One 800 MHz Rx Ant. Ht: 445

Number of 800 MHz Tx Ants: 2

Mounted at a Height of: 475

Model Number of Antennas: PD100175a

NOTES:

All Line for the 800 MHz Antenna Systems will be 1 5/8" Heliax

1 5/8" Snap in hanger required for the site. 61

Relocated Existing Antenna Systems Loading Requirements

Model Number of Antennas: DB212

Mounted at a Height of: 200

Quantity of Antennas: 3

NOTE:

All Line for the non 800 MHz Antenna Systems will be 7/8" Heliax

If tower is less than 250' mount relocated existing antennas at highest available location.

Tower Marking and Lighting Requirements

- Marked (Painted): ☐
- Medium Intensity White: ☐
- Dual Medium Intensity (White and Red): ☑
- High Intensity White: ☐
- Dual High Intensity (White and Red): ☐
- Conventional Red Lighting: ☐
- Requires No Lighting: ☐

Notes:
1. Compliance with future loading requirements mandates doubling all RF antennas listed above when calculating tower loading.
2. All Microwave Antenna Systems use EWP-63 Elliptical Waveguide.
3. All Microwave Antennas are Solid Dish Antennas with a Solid Molded Radome.
4. EWP63 hangers required at the site. 49 Packs of 10

FIGURE 4-20 EXAMPLE OF A TYPICAL TOWER LOADING REPORT

4.8 TOWER CONSTRUCTION

Tower construction **shall** be performed in accordance with ANSI/EIA/TIA-222 or equivalent or more stringent standard per jurisdiction. Tower construction general requirements are summarized in the following list:

WARNING

All personnel climbing a tower shall be tied off at all times.

- An RF engineer **shall** perform an RF site compatibility study to determine if any interference might occur with existing frequencies currently in use at the site.
- Antenna mounts **shall** be specified and installed as recommended by the manufacturer. Mounting devices **shall** be made of corrosion-resistant material.
- Qualified personnel certified for the correct installation and safety procedures associated with this type of work **shall** perform the installation.
- The highest point of the antenna and/or lightning dissipater **shall not** exceed the licensed height.
- Strain relief in a form similar to a drip loop **shall** be provided between the tower, the ice bridge, and the shelter. A design **shall** be used that allows independent movement between the shelter and tower during an earthquake, thereby minimizing strain on the cables and connectors which will result in transmission line system destruction.

4.9 TOWER TRANSMISSION CABLES

Transmission line installation requirements are summarized in the following list:

- Each transmission line run also requires entry port boots (inside and/or outside), lightning protectors and associated mounting brackets, and any additional jumpering required by the site specific RF configuration. Some manufacturers provide transmission line kits, which include the main line connectors, top and bottom jumpers, line grounding kits (typically three per line), hoist grips, and weatherproofing materials.
- If the installation will require transmission lines that use air or nitrogen as the dielectric material between the conductors, a dehydration system must also be installed to maintain optimum humidity of the dielectric.

- Strain relief devices **shall** be used a minimum of every 60.8 m (200 ft.) during transmission line installation and **shall** remain in place to support the cable after installation. A support cable should be used between the grips to prevent damage to the transmission line caused by lifting from only one point.
- A ground kit **shall** be installed at the top and the bottom of each transmission line vertical run and at the building entry port. If the line run is over 60.8 m (200 ft.), a ground kit **shall** also be installed at the center of the line, or every 60.8 m (200 ft.) towards the ground until the distance is less than (45.7 m (150 ft.).
- To minimize the formation of condensation and ice on transmission lines, a drip loop **shall** be created at the point where the direction of the transmission lines changes from vertical to horizontal. See Figure 4-21.

FIGURE 4-21 EXAMPLE OF ANTENNA TRANSMISSION LINE DRIP LOOP

- The transmission line **shall** enter the building through a transmission entry port.
- To prevent water from entering the cable entry ports, ensure that a drip loop is installed, and is lower than the cable building entry port.
- Transmission lines **shall not** be installed in a way that will impede climbing or safety devices.
- Transmission lines **shall not** be mounted to climbing ladder rungs or climbing pegs.
- Future installations **shall** be considered when installing any transmission line.
- Excess transmission line **shall not** be stored (coiled or looped) on the tower.
- All outside connectors, splices, antenna terminations, and jumpers **shall** be weatherproofed.

- Transmission line **shall** be anchored to the tower using hardware recommended by manufacturer for that type of tower. Spacing of anchoring hardware is also determined by the line manufacturer and is dependent on the type and size of the line. Hangers and/or angle adapters are typically provided for every 91 cm (3 ft.) of line, including any ice bridge paths. All clamps and hardware **shall** be corrosion-resistant.
- Transmission lines **shall** be identified adjacent to each transmission line ground kit in a permanent manner using metal strapping bands, color-coded band, or equivalent method so that it can be determined from the ground which lines run to each antenna (Figure 4-22 shows an example of identification using color-coded bands). See Appendix B for a sample transmission line identification matrix.

FIGURE 4-22 COLOR-CODED TRANSMISSION LINES

4.9.1 ICE BRIDGE AND CABLE SUPPORT REQUIREMENTS

The requirements below apply to installations using ice bridges and/or cable support systems between the shelter and the tower. These requirements help minimize the following:

- Energy directed towards the shelter during lightning strike or other power surge.
- Tower or shelter damage during an earthquake.

General requirements are as follows:

- A self-supporting bridge and cable support system **shall not** be mechanically fastened to the tower. It is recommended that these items be separated by a minimum of 61 cm (24 in.).
- An ice bridge and tower **shall** be bonded to the External Ground Bus Bar, and each support leg **shall** be bonded to the grounding electrode system. (Refer to Chapter 6, “External Grounding,” for bonding requirements.)
- Ice bridges and cable support systems should be constructed from galvanized steel and have a minimum of four support legs. See Figure 4-21 for a typical self-supporting ice bridge.

4.9.2 TOWER SAFETY

WARNING

Fall protection measures shall be observed and implemented at any and all towers and structures, regardless of ownership, where climbing is required.

Any and all regulations regarding tower climbing shall be observed and implemented. In any case, more stringent regulations shall supersede other regulations.

Subcontractors shall be required to submit their written comprehensive Safety Program to Program Management and obtain approval prior to commencing any work.

All tower climbing shall be in accordance with the Motorola Contractor Fall Protection Program (See Appendix B).

WARNING

Towers shall not be overloaded.

Always observe the following safety guidelines when working with towers.

- Towers **shall** be erected and installed by bonded contractor specializing in such work.
- OSHA regulations **shall** be observed in all phases of tower construction and maintenance.

4.9.2.1 SECURING THE TOWER

Unauthorized entry to a tower **shall** be controlled as follows:

- Install a fence around the tower. The fence should be at least 1.8 m (6 ft.) high with barbed wire at the top. Refer to Figure G-7 in Appendix G, "Foldout Diagrams" for details regarding typical fencing.
- The guy piers of guyed towers should also be fenced with a gate and lock to help prevent accidental or malicious damage to the guy wires.
- If the tower has climbing pegs, the pegs should be removed from the bottom 6.1 m (20 ft.) of the tower to deter unauthorized climbing.
- If the tower has a climbing ladder or elevator, it should be appropriately secured.
- Appropriate signage notifying restricted access to the tower area and identification of tower **shall** be affixed to the fence in a conspicuous location.

WARNING

A damaged or weakened guy wire could cause the tower to fall.

4.10 SITE DRAWINGS OF RECORD

All drawings developed in the process of site design **shall** be accurately maintained so that they reflect not only the intended design of the site, but also the way the site was actually built (as-built drawings). Drawings should be marked up to indicate modifications made at the site during construction. A map of the tower installation should also be maintained. COPIES of all drawings and other pertinent information to support as-built site design & construction should be provided to the customer.

It is recommended that the party responsible party for future installations or upgrades to the site maintain and update the drawings to accurately show all subsequent modifications to the site.

CHAPTER 5

COMMUNICATIONS SITE BUILDING DESIGN AND INSTALLATION

The chapter discusses the following topics:

5.1 INTRODUCTION

This chapter provides requirements and recommendations for designing communications site buildings, including equipment shelters and cabinets.

5.2 SITE CATEGORIES

5.2.1 TYPICAL SITES

The list below describes typical configurations that could comprise a communications equipment site. For each category, certain conditions may or may not apply based upon the site category. Also for each site category, special concerns are discussed below and in detail within this chapter.

- Modules within a single rack
- Several frames of radio and support equipment within a general-purpose room, containing other telecom or broadcast equipment
- Dedicated radio room within a new or existing building
- Self-contained outdoor cabinets (land or rooftop), or semi/fully underground vaults. These are often used where zoning or site availability are issues, sometimes in conjunction with camouflaged towers or antennas.
- Pre-fabricated building of concrete/fiberglass construction

  Pre-fab buildings, cabinets, and vaults may have equipment fully or partially installed prior to building shipment, requiring additional building specifications to allow lifting with equipment installed. Weight and size become a consideration if the site has limited access. For shipping, these structures must meet strict dimensional requirements, including protrusions such as HVAC, RF entry assemblies, or AC entrances. In the United States, state certification may be required if pre-fab buildings are manufactured in a different state than deployed. (Similar requirements regarding out-of-state or province manufacture may also apply in non-domestic situations.)
- A "shipping container" that has been outfitted as a self-contained radio site. These must meet strict dimensional requirements, including protrusions such as HVAC, RF entry assemblies, or AC entrances, and must conform to applicable shipping requirements.

WARNING

Shipping boxes and supports shall not be used as seismic bracing. Only specifically designed seismic support hardware shall be used for seismic bracing.

- Renovation (Tenant Improvement (TI)) where the interior or sometimes the exterior of an existing structure is modified to suit the party for whom the communications site is being installed.
- A dedicated new site utilizing a previously unimproved lot and a new structure.

5.2.2 SITE GROUNDING ELECTRODE SYSTEM DESIGNATIONS

Although not directly related to the type of site structure, an important detail related to a site is the grounding electrode system designation. Two distinct categories exist, as follows:

- **Type 'A' Site**

  This site will have a grounding electrode system resistance of 25Ω or less. This relatively high resistance is typically only suitable for smaller installations involving less critical links within an overall system. An example of a site where a Type 'A' designation would be appropriate is a standalone base station housed in an enclosure.

- **Type 'B' Site**

  This site will have a grounding electrode system resistance of 5Ω or less. This relatively low resistance is recommended for large installations involving critical links within an overall system. An example of a site where a Type 'B' designation would be appropriate is a Central Office or dispatch center where disruption could cause a system-wide outage.

NOTE: Refer to Chapter 6, "External Grounding," for more information regarding grounding electrode systems and designations.

5.2.3 DEFINITIONS OF COMMUNICATIONS EQUIPMENT SITES

Important distinctions exist between the various methods of housing the communications equipment that comprise the site. This manual defines and distinguishes various sites as described in Table 5-1.

TABLE 5-1 STANDARD DEFINITIONS OF COMMUNICATIONS EQUIPMENT SITES

Site Type	Description	Notes
Building	A permanent structure built on a foundation that contains communications equipment and related ancillary support systems, and may contain other unrelated equipment and/or facilities. A Building **shall** be suitable for human occupancy during equipment installation, maintenance, and use. A Building would typically not have equipment or supporting systems (cable runways, antenna ports, etc.) already installed before general installation. **Example:** (See Figure 5-1.) A dedicated dispatch center and communication equipment site within a dedicated, permanently occupied facility.	Consists of dedicated site structures as well as interior installations such as shared commercial space in existing buildings, dispatch centers, central office installations, and other sites occupied, on a regular basis, by operations-related and possibly other personnel.
Shelter	A permanent structure built on a foundation that contains communications equipment and related ancillary support systems. A Shelter **shall** be suitable for temporary or permanent human occupancy during equipment installation, maintenance, and use. **Example:** (See Figure 5-2.) A prefabricated building located with a tower which houses equipment related only to over-the-air communications. The shelter supports personnel only on a limited basis for installation and maintenance functions; a dispatch center would be located elsewhere in this case.	Consists of smaller buildings or prefabricated shelters containing only equipment directly related to the function of the site. A Shelter is intended for human occupancy only during equipment installation and maintenance.
Cabinet/Enclosure	An enclosure that houses communications equipment and ancillary systems only. It is designed such that equipment contained within can be accessed without the need for personnel to enter the cabinet. An enclosure typically is pre-wired and pre-installed with its equipment. **Example:** (See Figure 5-3.) A weather-tight enclosure mounted to the rear of a billboard that houses a cell site. The site is completely unmanned.	A Cabinet/Enclosure can be indoor or outdoor installed, placed on a small foundation or wall/pole mounted.

TABLE 5-1 STANDARD DEFINITIONS OF COMMUNICATIONS EQUIPMENT SITES (CONTINUED)

Site Type	Description	Notes
Vault	An enclosure that houses communications equipment and ancillary systems only and is fully or partially buried in soil. The vault supports personnel only on a limited basis for installation and maintenance functions. **Example:** Similar to a cabinet/enclosure, except the enclosure is buried below ground level.	
Rack	A standard equipment rack used for supporting communications equipment to be installed in an existing Building or Shelter. **Example:** (See Figure 5-4.) A radio rack installed in an existing building or shelter to provide an added function to the existing site. A standard rack is intended for indoor installation only in buildings or shelters.	

FIGURE 5-1 TYPICAL SITE BUILDING

FIGURE 5-2 TYPICAL SHELTER

FIGURE 5-3 TYPICAL ENCLOSURE

FIGURE 5-4 TYPICAL RACK

FIGURE 5-5 METAL SHIPPING CONTAINER ENCLOSURE

5.3 BUILDING/SHELTER DESIGN AND LOCATION CONSIDERATIONS

5.3.1 DESIGN CONSIDERATIONS

The following are general considerations regarding sites utilizing a new building or shelter capable of human occupancy.

- Consideration **shall** be given to the amount and type of equipment to be housed, along with adequate space for movement and expansion within the structure. The extent of equipment housed will typically determine the suitability of prefabricated structures (if desired).
- Equipment configuration typically dictates the structure design. The desired size for a prefabricated shelter **shall** be considered against weight and size concerns in transporting the shelter to the site.
- All sites utilizing a constructed structure or a prefabricated structure with manned access **shall** utilize exterior lighting to some extent. Refer to "Exterior Lighting" on page 5-34 for specific details on requirements for various categories of structures.
- Always consider not only the initial equipment loading of the site, but also future growth, which may double or triple the equipment or necessitate additional cabinets at a site. A three-year product life has different investment trade-offs than does a ten-year installation. Whereas a full room design can accommodate change-outs of updated equipment racks, a self-contained, miniaturized cabinet might require replacement if equipment is changed. It is therefore prudent to design in the flexibility to replace some equipment with reasonable ease.
- (See Figure 5-6.) A "single point" or "window" grounding concept is recommended. This includes all of the outside penetrations (RF, AC power and generator, GPS, tower light controllers, equipment and phone lines, and outside grounding connections) into the building or shelter being located within a single "window" area. This window organization accordingly will affect the overall equipment layout. DC power systems should also logically be located close to this window. Though this uses up some wall and floor space, it permits the systematic growth of communications equipment outward.

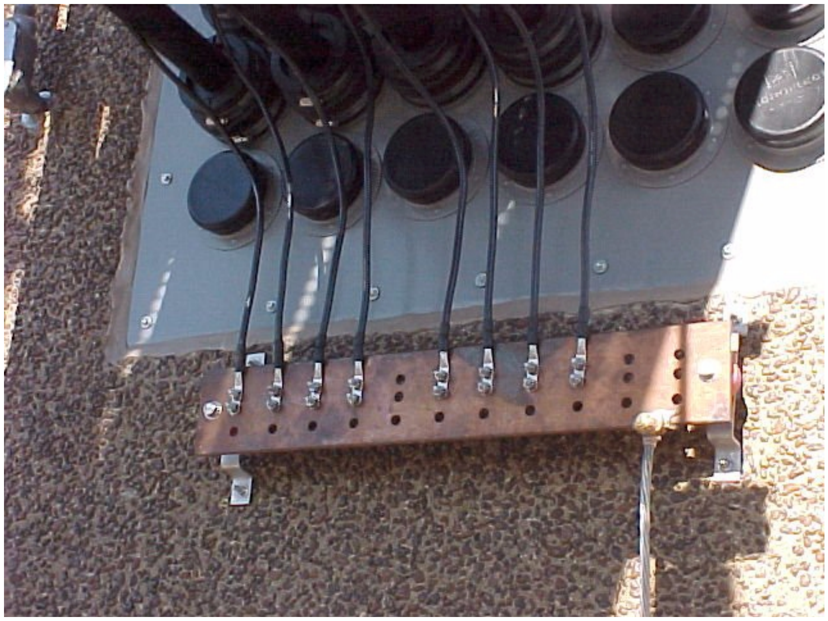


FIGURE 5-6 SINGLE-POINT GROUNDING AT ENTRY TO BUILDING

- Though not usually required for building foundations, some sites with unique soil conditions may require soil boring tests. Soil borings reveal the soil strength and water content, which are used to design a suitable foundation.
- In earthquake-prone areas (Moment Magnitude rating 3 or greater), foundation design **shall** address seismic requirements.
- Where poor soil results in a poor grounding system, an Ufer ground may be constructed within the concrete building pad. This serves two purposes, being a concrete floor surface and a specialized grounding system. See Chapter 6, "External Grounding," for more details.
- All buildings and shelters **shall** be designed or use features that prevent entry of animals and insects into the structure. Design should help discourage nesting of birds and small animals on exterior features of structure.
- Buildings may require compliance with human accessibility standards, such as Americans with Disabilities Act (or equivalent where required). These requirements must be considered during layout and procurement of facility.
- Buildings and shelters **shall** utilize a locked chain-link fence and appropriate deadbolt locks on standardized steel doors. Shelters and outdoor equipment cabinets **shall** be of the type designed for electronic equipment housing and accordingly fitted with locking doors.
- Buildings and shelters **shall** utilize an alarm system capable of notifying a remote location of tampering, cable breakage, power outage, or system failure.
- When installing equipment racks, it is recommended that those located furthest from the access door be installed in the shelter first, so other equipment can be installed without having to fit it behind existing equipment.

- The current and reasonable future needs of the customer should be understood when considering available equipment enclosures. The customer should be made fully aware of the types of enclosures available from the sourcing enclosure manufacturer.
- Shipping a prefabricated structure to a site may require special road use permits and/or special transportation methods (crane, double-length truck, helicopter, and so forth). Be sure the customer understands the shipping costs associated with a given building or shelter when specifying the site.

5.3.2 LOCATION CONSIDERATIONS

A site should be selected that requires little preparation for construction. Refer to Chapter 3, "Site Acquisition," and Chapter 4, "Site Design and Development," for more information on selecting a suitable site.

5.3.3 SEISMIC CONSIDERATIONS

In some locations, seismic design factors may need to be incorporated into building or shelter construction or layout. Where buildings or shelters are to be constructed in geographical locations having a Moment Magnitude (MM) rating of 3.0 or greater, seismic design standards **shall** be considered as described below and in respective sections of this manual.

> **NOTE:** US seismic activity maps are available in *Uniform Building Code, P. 194, Dia. 23-2, US Seismic Map*. Also, US and global maps and graphs are available on the following USGS web pages:
> http://www.neic.cr.usgs.gov/
>
> General seismic information can be found at:
> http://geohazards.cr.usgs.gov

In general, observe the following considerations when designing to accommodate seismic risks of MM 3.0 or greater:

- Note that a seismic zone map is not absolute; a qualified architect **shall** be contracted to determine seismic structural needs for a specific location and buildout. Earthquake risk can also change dramatically within a few miles, depending on soil composition, rock outcropping, liquification soil presence (typically uncompacted sand and water), and seismic standing waves of a particular earthquake event. History has shown that while one block of buildings may have been destroyed, the very next block may have survived with minimal damage.

- Shelters **shall** incorporate a steel door frame and a steel door for security and seismic integrity. In an earthquake a structure may deform, preventing doors from being opened from the inside. As most communication sites do not have windows, this becomes a serious issue for trapped occupants. (Some concrete prefabricated shelter manufacturers also cross-brace the door frame area to prevent deformation during an earthquake.)

5.4 FOUNDATION CONSIDERATIONS

- All foundation designs **shall** be approved by contracted Professional Engineer or contracting firm prior to commencement of work.
- A concrete foundation is typically used for building and shelter installations. If a foundation is used, the foundation **shall** be appropriate for the structure.
- All foundation design and construction **shall** be performed by a qualified contractor specializing in this work (or the entity authorized by the shelter supplier).

NOTE: If a site is to use concrete-encased grounding electrodes within the foundation or other concrete structures, appropriate measures **shall** be taken to accommodate the grounding system within a concrete structure before the concrete is poured. (Refer to “Concrete-Encased Electrodes” on page 6-11 for more information.)

- The concrete contractor **shall** determine if unique soil conditions require soil boring tests. Soil borings reveal the soil strength and water content, which are used to design a suitable foundation.
- A foundation for a prefabricated shelter **shall** be in accordance with manufacturer’s specifications. (Prefabricated building manufacturers usually provide typical foundation specifications for their particular model of building.)
- A foundation for a cabinet **shall** be level and sealed.
- (See Figure 5-7.) Design of foundation **shall** consider any special precipitation conditions unique to the installation locality. These considerations include (but are not limited to) elevated (pier type) platforms used in low-lying areas prone to regular flooding and elevated foundations to prevent burial of site due to snowfall. Special foundation designs include:
    - Footings
    - Piers
    - Columns

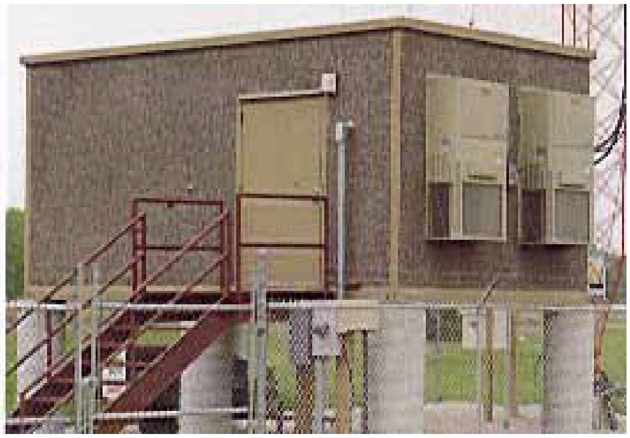


FIGURE 5-7 TYPICAL SHELTER MOUNTED ON ELEVATED PIERS

5.5 FLOOR LOADING

When determining equipment placement in an existing structure or when developing building specifications for an equipment shelter, attention **shall** be given to the Structural Live Load capacity of the building. Standard commercial construction specifications will, in most cases, provide substantial floor loading capacity. However, stacking and/or back-to-back placement of some equipment may exceed structural load limits. The weight and footprint dimensions of each piece of equipment to be installed **shall** be used to calculate floor loading.

The minimum floor loading standard for current Motorola manufactured equipment is 635 kPa (300 pounds per square foot (PSF)). Calculations of the weight of the proposed equipment in PSF **shall** be compared to the rated load carrying capacity of the structure.

Battery configurations can sometimes be specified with either feet, rails, or specialized load spreading devices which can facilitate deployments in high-rise structures. It is often necessary to specify a battery's location within a pre-fabricated shelter, such that if the building is staged (fully equipped and optimized) before shipment, the building has enough structural strength to be lifted and transported fully loaded.

Rooftop shelters require a structural engineering analysis for both initial and final configurations. Verify that all portions of the access route to the installation site, including stairways and elevators, are also capable of supporting the weight of the enclosure. If the equipment must be lifted to the rooftop by a helicopter it will add significant cost to the project.

NOTE: Remember to plan for expansion when calculating floor loading.

The civil engineering firm, contractor, or architect responsible for designing and/or constructing the site will need data relating to expected floor loading. Typically, the following initial information will be required:

- Establishing the weight of the equipment to be installed by adding the individual weights of all electronic equipment, racks, and other ancillary support equipment to be installed.
- Supplying a diagram showing the amount, weight, and proposed location of the equipment planned for installation.

The engineering firm will determine whether the existing floor is adequate, and if not, how the floor can be reinforced to safely support the weight.

The distributed weight **shall not** exceed the rating of the existing floor and **shall** conform to jurisdictional building codes. If an engineering firm is designing the structure, ask their assistance in calculating floor loading.

Some of the practices used to distribute a Structural Live Load can prove to be counterproductive in an earthquake. For example, steel I-beams are sometimes used to support a modular shelter between parapet walls of a high rise building, where the roof itself could not handle the weight without costly retrofit. In an earthquake, the I-beams will flex to their limits with the moment of the shelter movement. This can all but destroy a shelter and its contents. Rooftop isolators attached between the roof surface and the I-beam supports can dampen the movement of the shelter, absorbing the energy of an earthquake.

5.6 CEILINGS AND FLOORS

CAUTION

For Tenant Improvements in existing high-rise buildings, it is critical that the contractor determine if post-tensioning is employed in floor, roof, or wall construction. If so, industrial X-Ray mapping is required to avoid structural damage caused by accidental penetration of a tensioning cable.

5.6.1 CEILINGS

In general, the following considerations need to be observed when designing a site building, selecting a prefabricated shelter, or installing equipment in an existing structure or room:

- Ceiling height **shall** conform to applicable jurisdictional building codes.

- Minimum acceptable ceiling height for communications sites utilizing 2.2 m racks (standard “7 ft. rack”) are recommended to be 2.75 m (9 ft.).
- When adding equipment to existing sites, ensure that the ceiling is high enough to accommodate the planned additional equipment, including stacked cabinets.
- Determine the height of the tallest rack that could be deployed at a site, and then provide additional height to accommodate cabling, working room, and ventilation.
- Consider the size of the cable that might be attached to the top of the rack and that cable’s bending radius.
- The cable runway **shall** be installed to provide at least 30 cm (12 in.) clearance between the cable runway and the ceiling (per ANSI/TIA/EIA-569-A).

5.6.2 FLOORS

In general, the following considerations need to be observed when designing a site building or selecting a prefabricated shelter:

- Floor construction **shall** conform to applicable jurisdictional building codes.
- Except for access flooring, floors should be constructed of concrete or wood. Normally if the building floor is at ground level, the floor is concrete. If the building is elevated from ground level, the floor is normally constructed of heavy duty floor joist and plywood.
- Concrete used as communications site flooring **shall** be properly mixed to ensure adequate tensile strength when under load.
- Concrete **shall** be poured and reinforced in accordance with applicable jurisdictional requirements. Where an earthquake-resistant structure is specified, additional considerations may apply.
- Floors **shall** be level before equipment is installed.
- If a wooden floor is to be used, ensure that the contractor’s floor loading calculations take into account the type of equipment that will be installed, plus any future equipment. (Refer to “Floor Loading” on page 5-13).
- Floors **shall** be sealed to minimize the generation of airborne particulates. This is extremely important for a long equipment service life. Concrete and wooden floors can be finished in vinyl flooring. Concrete floors can also be sealed with an epoxy coating or equivalent.
- Anti-static vinyl flooring is available for installations where equipment is vulnerable to electrostatic discharge (ESD). Care **shall** be taken when installing this type of flooring to ensure the integrity of the anti-static properties. Consult a contractor experienced with this type of flooring.

5.7 WEATHERPROOFING/SEALING

5.7.1 TRANSMISSION LINE ENTRY PORTS

Appropriate methods for entry of transmission lines into a building or shelter are as follows:

- An entry port specifically designed for cabling
- PVC conduit, typically 10 to 13 cm (4 to 5 in.) diameter, allowing 5 cm (2 in.) protrusion at ends. If PVC is used, it **shall** be sealed using an appropriate all-weather silicone sealant. The free space between the cables and the inside of the conduit should be packed with fiberglass insulation.
- Roof/wall feed-through

In general, observe the following considerations for sites utilizing transmission line connections from an interior area to the exterior of a building or shelter:

- The entry of antenna transmission lines into a communications building or room requires a weatherproof, commercially made port assembly specifically designed for this purpose. These assemblies typically consist of a transmission line entry plate and boot assembly.
- A boot **shall** be used even if the cable is run through conduit. To avoid inconvenient rework in the future, it is recommended to select a transmission line entry plate with enough ports to accommodate the number of transmission lines at the site and allow for expansion.
- (See Figure 5-8.) Entry plates should have 10 cm or 12.7 cm (4 or 5 in.) diameter openings. The plate is usually made of painted aluminum, with from one to 12 ports per plate. A single entry plate mounted on the outside wall or bulkhead is sufficient.

FIGURE 5-8 TYPICAL ENTRY PLATE

- Cable boots corresponding to the cable diameter(s) **shall** be used. Cable boots are sized for the transmission line they will carry and can be round, oval or rectangular. Some cable boots allow up to three small (1.27 or 2.22 cm (0.5 or 0-.875 in.)) transmission lines to enter through one boot. The boot is usually made up of a two-piece cushion jacket, cushion (sized to cable diameter), and clamp set.
- To reduce heat loss from the building, two entry plates should be installed inside and outside, with rigid construction foam insulation between them. (Two sets of boots are then required.)
- The entry plate **shall** be installed per the manufacturer's instructions.
- The building/shelter and the port attachment to the building/shelter, **shall** be designed to prevent animals or birds from nesting in and around the entry ports.
- Transmission line entry ports **shall not** be used to feed through tower light power, building ground, or control cables.
- Boots **shall** be made of a material unaffected by ozone, sunlight, extreme heat, and cold.
- All unused ports in the entry plate **shall** be sealed with blank caps supplied by the port manufacturer.
- If a metallic port is used, it **shall** be bonded to the electrode grounding system. An integrated cable port **shall** be bonded to the external electrode grounding system.

5.7.2 SEALING OF BUILDINGS AND SHELTERS

To maintain optimum system performance and to avoid unnecessary HVAC costs, it is important to keep the communications site weather tight.

WARNING

Buildings and shelters that may have been open to the elements and animal infestations can pose health risks to personnel working in the structure.

Avoid sweeping dry floors when rodent droppings may be present. To prevent hantavirus infection, the floor shall be mopped in a safe and sanitary manner using a 5:1 water/bleach mixture. Personnel occupying the site shall wash hands before eating and avoid touching mouth, nose, or eyes until site is sufficiently clean.

Animals and insects pose a threat to equipment and can cause health hazards to personnel. Accumulated rodent droppings can harbor hantavirus and other diseases. Hantavirus is a deadly airborne virus spread by rodents. This threat **shall** be considered even more significant at remote sites in rural areas. To prevent the spread of disease and to prevent damage to equipment caused by nesting wildlife, observe the following requirements:

- All buildings **shall** be weather tight and **shall** deter entry by animals, birds, and insects.
- If rodents are present within a site building or enclosure, the affected area **shall** be appropriately cleaned in a manner that is safe to personnel. Appropriate preventive measures **shall** be taken to remove and prevent further infestations.

5.8 HEATING, VENTILATION, AND AIR CONDITIONING

One of the major considerations in site development is to maintain an environment in which the equipment can operate efficiently. A properly designed Heating, Ventilation, and Air Conditioning (HVAC) system provides the proper environmental conditions. Ambient temperatures inside the building or equipment room **shall** be maintained in a range within the specified requirements of each equipment. (Each Motorola-manufactured product, as well as out sourced items that are dropped-shipped per Motorola orders, has temperature, humidity, and cleanliness requirements, as listed in their respective manuals.)

NOTE: Equipment manuals may specify either *operating* or *ambient* temperature. Operating temperature refers to temperature within the equipment case, with the equipment operating at a given capacity or load. Ambient temperature refers to the environmental temperature as typically measured 60 cm (5 ft.) above the floor in the center of an adjacent aisle.

NOTE: In lieu of manufacturer environmental standards, HVAC system **shall** be capable of maintaining interior conditions of 17.8º to 24º C (64º to 75º F) at 30 to 55% relative humidity (RH) (per ANSI/TIA/EIA-569-A).

The variables involved in maintaining ambient temperatures include, but are not limited to, the following:

- Building construction
- Building size
- Type and amount of equipment installed at the site
- Ambient outside temperature
- Room size
- Number of entry ports (windows, doors, transmission line entry ports)
- Insulation
- Roof type (slope and construction material)
- Surrounding structures
- Use of a forced fresh air system
- Geographical location of the site

Design considerations should be done for some equipment deployments and locations concerning operating limits of the equipment should the HVAC provisions fail. The facility back-up generator **shall** be sized to accommodate the HVAC system.

With generator systems, a start-up delay kit is recommended on the HVAC system so that site AC power cycling or emergency generator cut-over does not present a drop-out/brown-out condition which could stall and damage HVAC compressors.

The type and number of HVAC units to be utilized **shall** be calculated accurately. Due to the large number of variables involved, a single HVAC specification cannot be applied to all situations. Sizing of the HVAC system **shall** be performed by a HVAC engineering firm or the equipment shelter manufacturer's engineer.

5.8.1 HVAC DESIGN CONSIDERATIONS

The HVAC requirements for each site **shall** be evaluated on a site-by-site basis. It is advisable to include an expansion factor of at least 25% in the planning calculation, with consideration given to the final growth potential. With pre-fab buildings, provisions in the wall structure can sometimes be made such that another unit can be added in the field for additional growth.

Consider the following when working with the HVAC contractor to design the HVAC system:

- Obtain thermal loading for each item of equipment from the appropriate engineering personnel and provide it to the building manufacturer HVAC engineering or HVAC contractor. System Planner documentation typically provides heat generation information in both BTUs and Watts.
- Obtain site specifications for construction materials, insulation type and R values, size, existing conditions, and predicted growth.
- In areas with a history of Moment Magnitude rating 3 or greater, seismic considerations for the HVAC system **shall** be addressed by the HVAC engineering firm or contractor. Typically, additional flexible bracing can be provided to prevent HVAC equipment from falling over or shifting position. Flex hoses or semi-rigid hoses with strain relief should be provided to prevent mechanical stress failure.

NOTE: Only CFC-free air HVAC equipment **shall** be used for new installations.

NOTE: It is recommended that the HVAC system be alarmed. Each HVAC unit installed at a site **shall** be connected to the building alarm system so that the total shutdown of any HVAC unit results in an alarm.

5.8.1.1 WALL MOUNTED HVAC UNIT

Figure 5-9 shows a typical commercial wall-mounted HVAC unit. In general, the following considerations need to be observed:

- Self-contained wall mounted HVAC units are acceptable in most applications, but use care in selecting the proper unit size for the projected BTU heat load. If more than one unit is required, be sure to plan for wall mounting space.
- Only commercial-grade HVAC units **shall** be used. Consumer-grade household units or window-mounted units **shall not** be used.
- To reduce operating costs and prevent the compressors from freezing during cold weather, all units should be equipped with heating elements and an economizer which allows the site to be cooled by outside air if the outside temperature falls below a predetermined value.

NOTE: HVAC systems using outside air circulation features may not be suitable for environments having unusually high dust or particulate emissions.

- A redundant HVAC units **shall** be installed and available as a backup in case one unit fails. All redundant HVAC units should be designed in a lead-lag configuration to cycle with the primary unit in order to subject all units to equal wear.
- If two HVAC units are required to provide sufficient cooling, one additional unit should suffice for redundancy.
- Seismically active locations (Moment Magnitude 3 or greater) will require seismic bracing or strapping on wall-mounted or free-standing HVAC units to prevent movement and damage during earthquakes or hurricanes (or staged building transport).
- Local fire codes may require an automatic shutdown circuit for HVAC units should the smoke/heat alarm activate.

FIGURE 5-9 TYPICAL COMMERCIAL WALL-MOUNTED AIR CONDITIONING UNIT

5.8.1.2 EXHAUST FANS

It is advisable to install a thermostatically-controlled exhaust fan at some sites, to remove excessive heat buildup if air conditioning units are disabled or fail.

- Locate the exhaust fan as high as possible in the structure to remove the maximum amount of heat.
- A corresponding filtered exterior cold air inlet vent with motorized louvers should be installed low on an opposing wall to allow unobstructed air flow through the site.
- The inlet of the fan **shall** be protected with a screen barrier to prevent the entry of insects, birds, or animals.

NOTE: To prevent excessive dirt and/or humidity from entering the building, the exhaust fan is intended to be used only as an emergency backup.

Battery and generator rooms require special concerns regarding exhaust requirements. Refer to Chapter 8, “Power Sources,”for more information.

Louvered entries into building or shelter can produce a security risk due to ease of unauthorized entry through the louver assembly. This concern should be considered in the overall security plan for the site.

- Design of motorize louver system **shall** comply with NFPA shutdown requirements. Exhaust fans and HVAC systems **shall** automatically shut down and the exterior wall vents automatically close during fire alarm activation and fire suppressant release. Refer to NFPA 12 for additional information.

5.8.1.3 HEAT PUMPS

In sites where heat levels are too high for the use of wall-mounted unit, commercial-grade heat pumps may be used. The need of using a heat pump system **shall** be determined by the contracted HVAC engineering firm or contractor. Heat pumps are also used in shared sites or where an exterior wall is not available for installation of a stand-alone HVAC unit. The compressor is separate from the control units and **shall** be mounted on either a pad on the roof of the structure or on a concrete pad outside the building.

NOTE: Per NFPA 70, a servicing disconnect is required for maintenance of the heat pump. A GCFI receptacle is also required within 3 m (25 ft.) for maintenance. All units should be equipped with a start control option to avoid compressor damage during short power outages.

5.8.1.4 THERMOSTATS

Thermostats **shall** be installed in locations where room ambient temperature can be best and most evenly controlled. The placement and number of thermostats should be determined by the contracted HVAC engineering firm.

5.8.1.5 TEMPERATURE ALARM

To avoid down time and possible equipment damage due to temperature extremes, it is recommended that all sites be equipped with high and low temperature alarms. These alarms should be interfaced with the site security system and monitored around the clock. The sensors **shall** be accurate enough to detect temperature variations within the range of 5° to 33° C (40° to 90° F).

5.8.1.6 MAINTENANCE

It is recommended that the customer establish a preventive maintenance program with an authorized local HVAC service company to provide service and repair. The agreement should include periodic cleaning and filter replacement.

The back-up unit should be periodically exercised, or alternatively, an equal-sharing duty cycle can be used.

5.9 SPECIAL CONSIDERATIONS FOR TELEPHONE CENTRAL OFFICES AND SWITCHROOMS

The same building design requirements for general communications sites apply to switchroom, iDEN Mobile Switching Office (MSO), major dispatch centers, or central office (CO) design, but on a more critical scale. For example, a CO may contain a cellular or Personal Communications Services (PCS) switch and/or centralized base station controllers. Good design is even more critical for a CO because the CO can be the overall controlling entity of an entire system, and thus can cause system-wide failure if there is a problem.

5.9.1 LIGHTNING DAMAGE PREVENTION

Although perhaps more costly, the single most effective way of protecting the CO switch from lightning damage is to locate it separately from a communications site and accompanying tower at the same facility. Not only is the CO switch much more expensive to replace than typical communications equipment, but the whole system will fail if the CO switch fails. The initial extra cost of building a separate communications site at the central office location is far less expensive than revenues lost if the entire system fails due to a lightning strike to the radio tower that damages the CO switch.

5.9.2 POWER SOURCE PROTECTION

If at all possible, it is preferable to have separate, redundant power feeders from the power company serving the switchroom. These should be fed from two different substations, so that the failure of one substation will not cut off power to the CO.

Co-located business office function may also be considered with priority. Since most CO equipment is served by DC power systems, a large battery system, perhaps even in a redundant configuration, should be considered. This not only provides backup power in case of generator failure, it also provides a means of absorbing surges on the DC circuits that may occur if the site has to switch to generator power.

Terminals communicating with the switch can be served by either individual UPS plants, or a centralized, overall system. This keeps switching transients from interrupting terminal operation.

Surges transferred over the power lines during normal operation **shall** be drained by primary and secondary surge suppressors installed in a configuration that accommodates the generator circuits. Refer to Chapter 9, “Transient Voltage Surge Suppression,” for more information.

It is recommended to have a CO served by fiber optic T-1, T-3, OC-3, and higher capacities. This provides lightning protection by removing the copper connection from the phone company to the switch and provides optical isolation from surges that can occur on the copper connections.

5.9.3 CENTRAL OFFICE LAYOUT

When first installing equipment into a new large switch room, the equipment layout **shall** be planned to allow for sufficient aisle space, but be efficient so future expansion capacity is maximized. The initial layout should be designed to accommodate the absolute maximum number of equipment racks while allowing adequate space between aisles and at end of aisles.

Minimizing the overall distances of the DC power system and the grounding layout should be a priority.

The control room housing the switch terminals should be isolated from the rest of the equipment to provide noise reduction for those continually working in this environment. This room should also be configured as an Isolated Ground Zone (IGZ). See Appendix C, “Cellular Grounding Information Manual”, for more information regarding IGZs.

5.10 CABLE RUNWAYS

NOTE: This section discusses only the installation of cable runway structures. Refer to Chapter 11, “Equipment Installation,” for requirements regarding installing cabling within cable runways.

This section describes requirements for cable runways. Cable runways should be used to support communications cabling within buildings and shelters.

The primary function of a cable runway is to manage cable support which includes proper support of the cables, as well as maintaining adequate separation between the cable groups. The orderly separation and support of cable also eases maintenance. Cable interconnection between cabinets, relay racks and bays of equipment should be properly supported by means of a cable runway system. Cable management over relay racks and equipment cabinets can be accomplished by utilizing cable runway systems. These runway systems are designed to provide support, routing, parallel separation and securing of wires and cables as defined in “Equipment Cabling” on page 11-11. As defined in NFPA 70, Article 318-2, a cable runway or tray system is a unit or assembly of units or sections and associated fittings forming a rigid structural system used to securely fasten or support cables and raceways.

WARNING

Aluminum ladders designed for climbing shall not be used as cable trays or runways.

5.10.1 CABLE RUNWAY SELECTION

Two types of overhead cable runway systems which are suitable for use as cable support are:

- Steel stringer style ladder
- Aluminum or steel ladder style cable tray

Steel stringer style ladders come in various designs and styles. Typically they are available in C-channel, tubular and solid bar in painted or yellow zinc dichromate finishes. Stringers are typically 38 mm (1.5 in.) to 51 mm (2 in.) in depth, and vary in length. Rungs should be spaced at least 22.9 cm (9 in.) apart. Simple hardware is used to make "T" and cross connections.

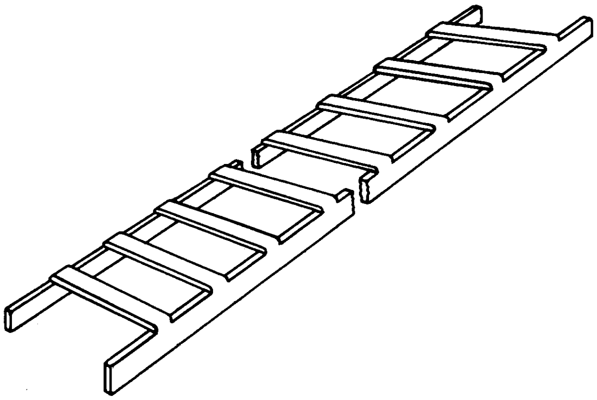
NOTE: "J-bolts" (threaded, formed metal rods which are bent into a "J" shape) **shall not** be used as fasteners for cable runways. These rods typically deform when stressed, possibly allowing cable runways to drop. Captive hardware such as threaded bolt, washers, and nuts are recommended.

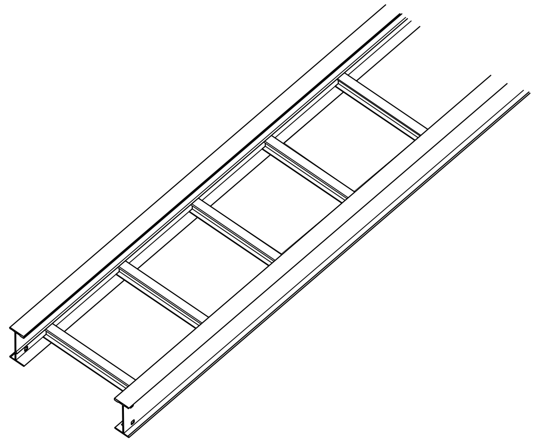
Aluminum or steel cable tray systems also come in various designs and styles such as ventilated trough, solid trough and ladder type with "I" beam or C-channel siderails. The most practical is the ladder type. The major difference between the stringer style ladders and tray runway systems is that a tray has a siderail or wall height from 10 cm (4 in.) to 18 cm (7 in.). This load depth may be desirable for large bundles of cables or transmission line routing. Be aware that this siderail height will impact overall rack to cable tray to ceiling dimension restrictions as outlined in this chapter. A rung spacing of 22.9 cm (9 in.) is also recommended for this runway type. This type of runway system requires prefabricated "T"s, bends, crosses and reducers. These must be factored into the design of the system.

Both runways come in various widths ranging from 10.2 cm (4 in.) to 1.06 m (42 in.). Typically, widths of 45.7 cm (18 in.) and 61 cm (24 in.) are used. Stacking of 45.7 cm (18 in.) wide runways is allowed, but ceiling height requirements and clearances **shall** be adhered to. Design **shall** provide for maintaining a spacing of 45.7 cm (18 in.) between runways. Figure 5-10 shows typical cable runways.

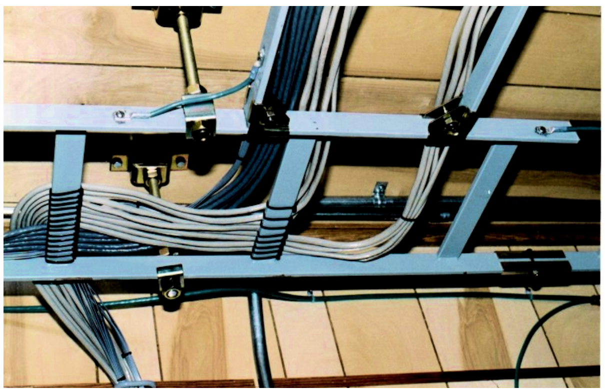
NOTE: The overall sizes of cables, numbers of cable, and number of cable groups required in a run **shall** be considered when specifying runway width. Account for a minimum of 15.3 cm (6 in.) loss of width for cable group spacing in itself.

Extruded Aluminum Types





Solid Steel Painted Type



Flexible Steel Wire Type

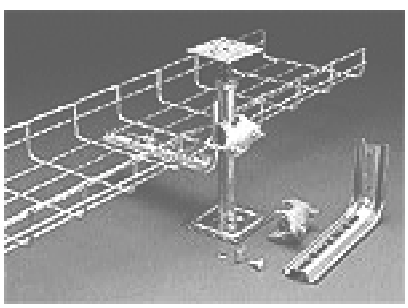


FIGURE 5-10 TYPICAL CABLE RUNWAYS

NOTE: Do not mix aluminum and steel metal runway types at a facility installation.

For wire management under raised computer floors, a welded wire mesh cable tray system is recommended. This type of tray system can be mounted to, or suspended from, raised floor pedestals or sub flooring. This tray system typically consists of high strength steel wire in the form of a 50 x 100 mm (2 x 4 in.) mesh. The finishes can be electro-plated zinc galvanized or stainless steel that are suitable for all environments. Bends can be fashioned by cutting the mesh with a bolt cutting tool and simple hardware connections to the wire mesh. Manufacturers can supply bonding terminations and outboard ground cable supports for proper tray system grounding.

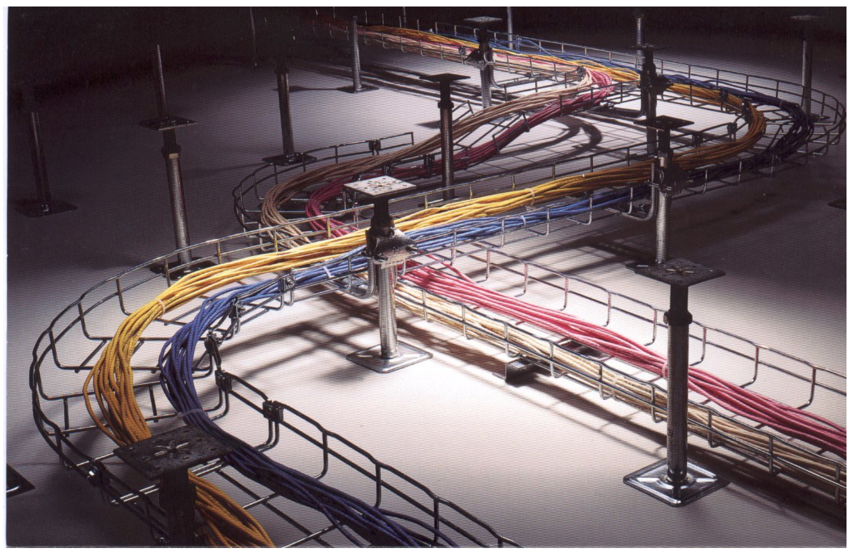


FIGURE 5-11 TYPICAL WIRE-MESH RUNWAY

In general, the following considerations need to be observed in selecting cable runways:

- Refer to Chapter 7, “Internal Grounding,” for proper cable tray grounding practices.
- Noting the amount of cables to be supported by each run, cable runway width **shall** be selected to provide 5 cm (2 in.) minimum separation between cables or cable groups. 46 cm (18 in.) runways or double-deck ladders may have to used in some cases.
- Steel stringer and steel tray systems **shall** utilize an extended post to attached grounding conductors. This post should extend 10.2 cm (4 in.) to 15.2 cm (6 in.) either horizontally or vertically from the siderail of the runway, with no less than 46 cm (18 in.) of spacing between posts.
- If AC power cables are to be run directly in runways, cable separation **shall** be maintained.
- The size, weight, and projected expansion of the system **shall** be considered to ensure proper runway usage.

- The number and function of conductors to be placed within a cable runway **shall** be considered before procuring cable runways.
- It is recommended that only cable runways specifically designed for communications purposes be used (as opposed to standard electrical cable runways).
- A rung type cable runway may be more suitable in instances when only a single line of supports is available and cables can be laid in from a specific side.
- A solid bottom cable tray with a hinged cover may be desirable for use between a tower and building, to provide complete enclosure of the cables and minimize potential damage and vandalism. Unless specifically designed to also function as an ice bridge, a cable tray **shall not** be used instead of a standard ice bridge.

5.10.2 CABLE RUNWAY LAYOUT AND DESIGN

In general, the following considerations must be observed when preparing the layout of cable runways:

WARNING

If the building has a sprinkler system, make sure the cable runways do not block the sprinklers.

- The cable runway system **shall** be designed to accommodate cable distribution throughout the equipment area. Continuity of the cable runway system and support for the cables **shall** be maintained.
- The cable runway system **shall** use the proper sections as designed by the manufacturer. Straight sections, elbows, tees, dropouts, and expansion connectors **shall** be used as required within the system.
- The cable runway system **shall** be designed with suitable strength and rigidity to provide adequate support for all contained wiring.
- Due to thermal contraction and expansion, cable runway systems may require the use of expansion connectors.
- Cable runways and troughs may extend through walls or floors providing the installation is made so that the possible spread of fire or products of combustion will not be substantially increased.
- Openings through fire resistant walls, partitions, floors, or ceilings **shall** be firestopped using an approved method to maintain the fire resistance rating.
- Cable runway systems **shall** be designed for installation at heights that provide clearances adequate to install the necessary equipment with provisions for expansion.
- Factors such as ceiling height, light fixture locations, cable entry ports, equipment location and minimum cable bending radius must be considered during design and layout.
- Cable runways **shall not** be placed under smoke detectors or sprinkler heads.

- Cable runways should not be placed under lights or electrical fixtures or boxes.
- A minimum of 15 cm (6 in.) between the top of an equipment rack/cabinet and the bottom of the cable runway **shall** be maintained.
- A minimum of 30 cm (12 in.) above the top of the cable runway and the ceiling **shall** be maintained.
- When AC power distribution is to be combined with the cable runway system, the AC power raceway **shall not** be supported by or supported from the cable runway system unless the cable runway system is manufactured and approved for this purpose. The AC power raceway may be supported by a trapeze arrangement with the cable runway attached to the top of the trapeze and the AC power raceway attached to the bottom of the trapeze. The trapeze arrangement is supported from the ceiling and/or sidewalls.
- The entire system **shall** be rigid, immovable and properly secured in place. Manufacturer's specifications as well as the NFPA 70, Article 318 and any other applicable national, state, jurisdictional, and local codes **shall** be followed.

5.10.3 CABLE RUNWAY INSTALLATION

In general, the following considerations need to be observed in performing the installation of cable runways:

- Cable runways **shall** be securely supported to the ceiling and/or wall such that they are immovable. These supports **shall** provide a strength and working load capacity sufficient to meet the load requirement of the cable runway system.
- Horizontal and vertical supports should provide an adequate bearing surface for the cable runway and should have provisions for hold-down clamps or fasteners. There may be additional requirements for active seismic areas (Moment Magnitude 3 or greater), such as wooden headers at wall connections. It is recommended in these cases that cable runway ends be attached to walls using a 5 cm x 10 cm (2 x 4 in.) wooden header. The header can be nailed along the wall approximately 31 cm (12") below the ceiling. This provides a blunt attachment point which will prevent the somewhat sharp ends of cable runways from penetrating the walls. Seams between multiple cable runway sections run across a room should be staggered so that if a seam fails, the entire cable ladder system will not fail.
- A support **shall** be located within 61 cm (2 ft.) of each side of an expansion connector. Cable runway systems **shall not** be used as incidental support for other raceways or equipment.
- Cable runways **shall** be positioned such that they are easily accessible with sufficient space provided above and around the cable runway to permit adequate access for installation and maintenance of cables.
- Cable runways **shall not** have any sharp edges, burrs or projections that may damage cables.
- All cable runway sections **shall** be electrically bonded together by an approved method and connected to the building ground system. (See Figure 5-12.) Refer to Chapter 7, "Internal Grounding,"for more information.The cable runway system **shall** be grounded to the room ground system to help ensure safety of service personnel. (Refer to Chapter 7, "Internal Grounding.")
- Manufacturers' specifications relating to the installation of cable runways as well as NFPA 70, Article 318 and any other applicable national, state, jurisdictional, and local codes **shall** be followed.

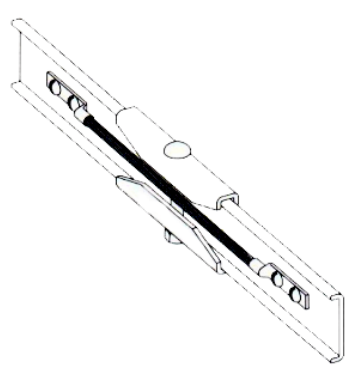


FIGURE 5-12 CABLE RUNWAY BONDING CONDUCTOR

5.10.4 RUNWAY SAFETY CONSIDERATIONS

- Cable runway systems **shall not** be installed at heights or in positions that **shall** pose a hazard to service personnel working within the site.
- At no time **shall** the cable runway system be used as an incidental support or walkway.
- Threaded support rods **shall not** extend below the runway bottom further than the required fittings and **shall** include appropriate protective end caps.

5.11 LIGHTING

All lighting **shall** follow the applicable requirements of NFPA 70, Article 410, and any other applicable national, state, jurisdictional, and local code requirements. Interior lighting requirements are based upon a number of considerations, including:

- Adequate lighting for a safe and efficient work environment. Placement should assure illumination behind tall rack cabinets.
- Energy efficient design
- Low heat generation characteristics

Exterior lighting requirements are concerned with lighting for points of entry and exit from the building and for perimeter security.

Lighting on remote sites can be seen for miles at night and in some cases, could cause neighbor objections. to address these issues, on-demand systems such as infrared proximity sensors and twist-knob timers are highly recommended. Bright lights (including lights used on photocell controllers) can, in some cases, produce neighbor and environmentalist complaints.

In all cases, incandescent or fluorescent lighting may be used.

5.11.1 GENERAL INTERIOR LIGHTING SPECIFICATIONS

- In locations that are considered hazardous because the atmosphere does or may contain gas, vapor or dust in explosive quantities, special application fixtures **shall** be used. These fixtures **shall** be rated for use in Class I, II and III, Division 1 and classified areas. These fixtures **shall** comply with NFPA 70, Article 516-3(c) and NFPA 33.
- In applications where fixtures are susceptible to dislodgment, or where tube breakage may represent a hazard to personnel or equipment, shatterproof fluorescent tubes or safety tubes **shall** be used. Seismic and industrial practices require that fluorescent lamp protectors be installed over lighting to prevent falling glass or accidental damage to lamps.
- If incandescent lighting is used, industrial-grade protective covers **shall** be used.

5.11.2 INTERIOR LIGHTING QUALITY

Interior lighting **shall** produce a minimum of 540 Lux (50 foot candles) measured 1 m (39.4 in.) above the finished floor in the middle of all aisles between cabinets or racks. Refer to *ANSI/TIA/EIA 569-A* for more information.

5.11.3 EMERGENCY INTERIOR LIGHTING

Emergency backup lighting units **shall** be installed to activate immediately upon loss of all AC power.

- Each unit **shall** be equipped with a self-test button or switch.
- Each unit **shall** have a minimum of two lamps. Lamps may be sealed beam or tungsten halogen.
- Batteries **shall** be sealed, maintenance free, and provide a minimum of 90 minutes of emergency power.
- All emergency lights **shall** be UL approved and meet all OSHA, NFPA 101, and any other applicable national, state, jurisdictional, and local life safety code requirements.
- Emergency lights installed in harsh environments **shall** meet all requirements for NEMA 1, 2, 3, 3R, 3S, 4, 4X, and 12 ratings.
- The lights **shall** be located to illuminate any and all doorways and exits.
- Exits **shall** be labeled with illuminated signs reading **EXIT**. Pathways to exits **shall** be marked.
- Emergency lighting within high-rise buildings may require that it be powered from a house power source, and that the emergency lighting be alarmed to the house master alarm system.

5.11.4 EXTERIOR LIGHTING

One exterior light **shall** be installed near the door to provide lighting for personnel entering and exiting the building. The fixture **shall** be type NEMA 3, weather resistant and suitable for general outdoor application.

If floodlights are installed to provide yard/perimeter security lighting, the following requirements shall be met:

- UL approved Quartz and High Pressure Sodium lighting elements **shall** be used.
- Mercury Vapor and Metal Halide lamps **shall not** be used. These lamps can cause serious skin burns and eye inflammation from short-wave ultraviolet radiation if the outer envelope of the lamp is broken or punctured.
- An automatic photo-control switch, with a manual override, can be used to turn the lights on at dusk and off at dawn if desired.
- Fixtures **shall** meet NEMA heavy duty type classification and be UL listed for use in wet locations.

5.12 FIRE PROTECTION/SAFETY

WARNING

The primary intent in suppressing a fire at a communication site is to protect lives. Equipment protection is secondary. If the fire is expected to be entirely suppressed by a manual extinguisher, then the suppression effort can be made, but in no circumstances shall fire suppression be attempted in order to save equipment when personnel safety is at risk. In all cases for occupied shared buildings, the fire department and tenants shall be notified immediately of the fire.

Fire extinguishers can represent an important segment of any overall fire protection program. However, a proper fire suppression program success depends upon the following general conditions:

- The extinguishers are of the proper type and size for a fire that may occur.
- The extinguishers are properly located and identified.
- The extinguishers are in working order and properly maintained.
- Employees have a clear understanding of their functional operation.
- Safety awareness has been made available.

5.12.1 REFERENCE PUBLICATIONS

The following are suggested reference publications regarding fire suppression systems:

- NFPA Fire Code, Volume 1
- NFPA 12 Standard on CO_2 extinguishing systems
- NFPA 13 Standard for installation of sprinkler systems
- NFPA 17 Standard for Dry Chemical Extinguishing system
- NFPA 2001 Standard on Clean Agent Fire Extinguishing Systems
- CAN4-S503-M83 Standard for CO_2 fire extinguishers
- CAN4-S504-77 Standard for Dry Chemical fire extinguishers
- ULC-S504-77 Standard for Dry Chemical fire extinguishers
- ANSI/UL 154 Standard for CO_2 fire extinguishers
- ANSI/UL 299 Standard for Dry Chemical extinguishers

5.12.2 TRAINING AND PROPER USAGE

Site personnel **shall** be familiar with the proper usage of the fire protection equipment provided at the site. Documentation supplied with the equipment **shall** be made available to personnel. Responsible personnel **shall** fully understand the content of such documentation.

More complicated systems, such as an installed automatic system, should be supported with training supplied by the vendor.

5.12.3 FIRE CLASSIFICATIONS

The following fire classifications and information on portable fire extinguishers was acquired from the National Fire Prevention Association literature *NFPA 10*. For additional information on the classification of extinguishers and hazards, refer to *NFPA 10* or applicable jurisdictional/local fire codes.

In general, fires are classified according to the type of combustible material that is consumed. The types are as follows:

TABLE 5-2 FIRE CLASSIFICATIONS

Class	Symbol	Description
Class A Fire		Fires in ordinary combustible materials, such as wood, cloth, paper, rubber, and many plastics.
Class B Fire		Fires in flammable liquids, combustible liquids, petroleum greases, tars, oils, oil-based paints, solvents, lacquers, alcohols, and flammable gases.
Class C Fire		Fires that involve energized electrical equipment where the electrical non-conductivity of the extinguishing media is required.
Class D Fire		Fires in combustible metals, such as magnesium, titanium, zirconium, sodium, lithium, and potassium.

The classification of portable fire extinguishers normally consists of a letter that indicates the class of fire on which the extinguisher has been found to be effective, followed by a rating number (on Class A and Class B only) that indicates the relative extinguishing effectiveness. Fire extinguishers classified for use on Class C or Class D hazards are normally not required to have a rating number.

Modern portable fire extinguishers typically use a picture labeling system to designate the type of fire for which the extinguisher is suitable. See Figure 5-13 for examples.

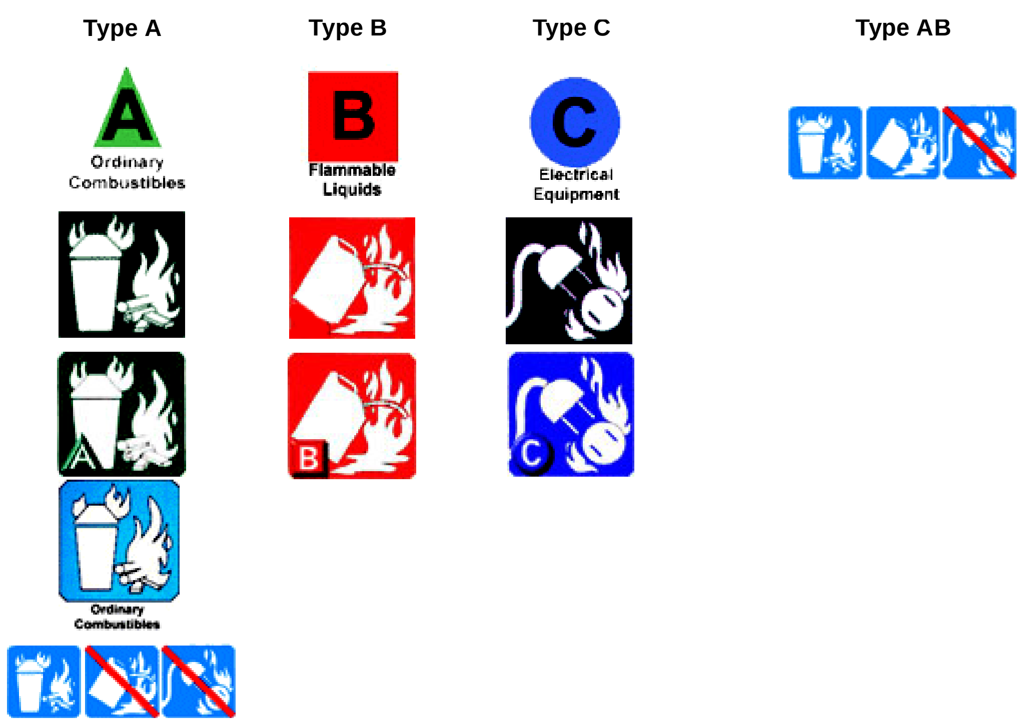


FIGURE 5-13 FIRE CLASSIFICATION LABELING EXAMPLES

Instructions are typically provided on the fire extinguisher label or with permanently installed fire suppression systems. It is important that site personnel be familiar with the location and type of extinguishers available at the site.

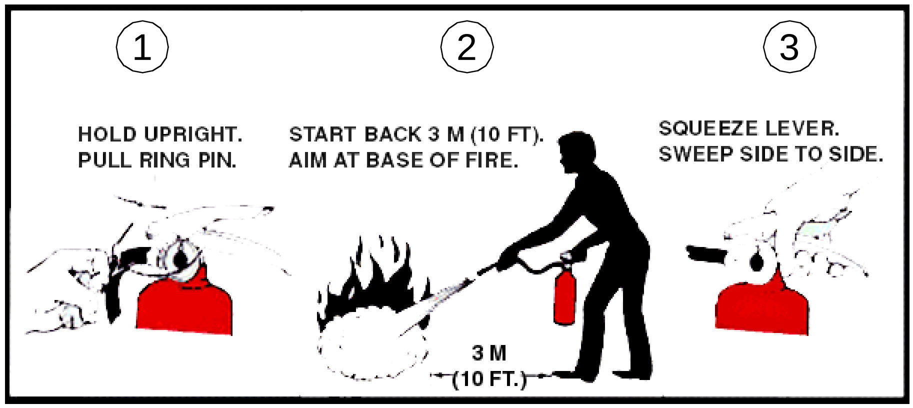


FIGURE 5-14 EXAMPLE OF INSTRUCTIONS PROVIDED ON FIRE EXTINGUISHER LABEL

5.12.4 PORTABLE EXTINGUISHERS

WARNING

The fire department shall be notified as soon as a fire is discovered. Notification shall not be delayed in order to assess the results of fire fighting effort using on-site portable fire extinguishers.

WARNING

Fixed or portable fire suppression systems using water shall not be used in communication sites.

5.12.4.1 MINIMUM REQUIRED COMPLEMENT

All installations **shall** have a minimum of two correctly installed portable fire extinguishers on the premises before equipment is installed. At a minimum, the following size and classification of portable extinguishers are required:

- 9 kg (20 lb.), Class ABC, dry chemical extinguisher (for general fire fighting)
- 3.18 - 4.54 kg (7 - 10 lb.), Class BC, Carbon Dioxide (CO_2) extinguisher (for equipment fire fighting) or FE-36™ 4.54 kg (10 lb.)

NOTE: Review the requirements of *NFPA 10* or applicable jurisdictional/ local regulations to determine the need for additional extinguishers based on site size and special considerations. Depending on the size of the site building, additional extinguishers may be required.

5.12.4.2 REQUIRED STANDARDS FOR PORTABLE FIRE EXTINGUISHERS

Portable fire extinguishers **shall** be listed and labeled, meet or exceed all the requirements of the fire test standards, and meet the appropriate performance standards listed below.

- *Fire Test Standards*: ANSI/UL 711, CAN/ULC-S508-M90
- *Performance Standards*:
  - Carbon Dioxide Types: ANSI/UL 154, CAN/ULC-S503-M90
  - Dry Chemical Types: ANSI/UL 299, CAN/ULC-S504-M86

In an electronic equipment enclosure or room, an FE-36™ (or equivalent) or CO_2-type extinguisher is required. These type extinguishers minimize secondary damage caused by dry chemical agents used in most Class ABC extinguishers. The dry chemical agents contain very fine alkaline-based powders that can cause severe equipment damage due to corrosion. The potential for damage is not just limited to the involved equipment, but may affect all other electronic equipment in the enclosure. The dry chemical extinguishers can also obscure visibility in a closed room, making egress difficult. The dry chemical extinguisher should be considered as the second line of defense if the fire cannot be extinguished with an FE-36 or CO_2-type extinguishers.

5.12.4.3 FIRE EXTINGUISHER COMPARISONS

Some of the more common extinguishers currently used at communication sites are listed in Table 5-3. The advantages and disadvantages of each type are also described.

TABLE 5-3 PORTABLE FIRE EXTINGUISHER COMPARISONS

Type	Advantages	Disadvantages
	Dry Chemical Extinguishers	
Dry Chemical	• Fast flame knockdown characteristics allows the dry chemical to find its way in and around nearly everything in the vicinity of the discharge. • Normally have an ABC rating and are safe for use on structural, fuel, and energized electronic equipment fires. • No adverse environmental impact.	• Dry chemical agents have corrosive characteristics that can be harmful to electronic equipment and other equipment in the general area. • A dry chemical fire extinguisher containing ammonium compounds **shall not** be used on oxidizers that contain chlorine. The reaction between the oxidizer and the ammonium salts can produce an explosive compound. • When discharged in an enclosed or confined space, dry chemical extinguishers limit visibility, cause breathing problems, and clog up air filtration systems. • Clean up can be time consuming and costly.
	Clean Agent Extinguishers	
FE-36™ (HFC-236fa)	• Environmentally friendly replacement of Halon™ 1211 portable extinguishers. • Depending on the size of the extinguishing unit, it can be rated for an ABC classification and discharged from up to 4.9 m (16 ft.) away from fire. • Agent is dispersed as a stream of gas and liquid droplets that physically removes heat and chemically stops combustion. • Electrically nonconductive, residue-free, and will not cause thermal shock damage to electronic equipment. • Zero Ozone Depletion Potential and moderate ratings for the Global Warming Potential and Atmospheric Lifetime.	• May not be readily attainable or easily refilled in certain areas. • Typically much more costly to purchase and maintain than dry chemical extinguishers. • When released under fire conditions hydrofluoric acid (HF) can be produced.
Carbon Dioxide (CO_2)	• Uses a clean gaseous extinguishing agent, with proven reliability. • Normally available in BC classification. Can be used on electronic equipment safely without leaving any residue. • No special environmental impact. • Normally easy to obtain. Inexpensive recharge cost.	• Effective range limited typically between 0.92 to 2.4 m (3 to 8 ft.) and is affected by draft and wind. Initial application needs to start reasonably close to fire. • Usage displaces oxygen, posing a suffocation hazard in confined areas. • Upon coming in contact with moisture, carbon dioxide can form carbonic acid.

5.12.4.4 INSTALLATION OF EXTINGUISHERS

When installing the extinguishers, the following requirements **shall** be observed:

- Portable fire extinguishers **shall** be maintained in a fully charged and operable condition, and kept in their designated places at all times when they are not being used.
- Fire extinguishers **shall** be conspicuously located where they will be readily accessible and immediately available in the event of a fire. Preferably, extinguishers **shall** be located along normal paths of travel, including exits from areas.
- Fire extinguisher locations **shall** be clearly marked. Acceptable means of identifying the fire extinguisher locations include arrows, lights, signs, or coding of the wall or column.
- If more than one fire extinguisher is located in the same location and they are intended for different classes of fires, the intended use of each extinguisher **shall** be marked conspicuously to aid in the choice of the proper extinguisher at the time of a fire.
- Cabinets housing fire extinguishers **shall not** be locked.
- Fire extinguishers **shall not** be obstructed from view.
- Portable fire extinguishers (other than wheeled types) **shall** be securely installed in the hanger or in the bracket supplied or placed in cabinets or wall recesses. The hanger or bracket **shall** be securely and properly anchored to the mounting surface in accordance with the manufacturer’s instructions.
- Fire extinguishers installed under conditions where they are subject to dislodgment **shall** be installed in brackets specifically designed to retain the extinguisher.
- Fire extinguishers having a gross weight not exceeding 18.14 kg (40 lb.) **shall** be installed so the top of the fire extinguisher is not more than 1.53 m (5 ft.) above the floor. Fire extinguishers having a gross weight greater than 18.14 kg (40 lb.) (excluding wheeled types) **shall** be so installed that the top of the fire extinguisher is not more than 1.07 m (3.5 ft.) above the floor. In no case **shall** the clearance between the bottom of the fire extinguisher and the floor be less than 10.2 cm (4 in.).
- Extinguisher operating instructions **shall** be located on the front of the extinguisher and be clearly visible. Hazardous materials identification systems (HMIS) labels, six-year maintenance labels, hydrotest labels, or other labels **shall not** be located or placed on the front of the extinguisher.
- Fire extinguisher mounted in cabinets or wall recesses **shall** be placed so that the fire extinguisher operating instructions face outward. The location of such extinguishers **shall** be conspicuously marked.

5.12.4.5 SAFETY PRECAUTIONS

Health and safety hazards **shall** be considered when using fire extinguishers in confined spaces and on electrical equipment. Adhere to all safety information supplied with the fire extinguishers.

5.12.4.6 INSPECTION

Fire extinguishers **shall** be inspected when initially place in service and thereafter at approximately 30-day intervals (or sooner, as dictated by jurisdictional or local codes). Fire extinguishers **shall** be inspected at more frequent intervals when circumstances require (refer to *NFPA 10* or applicable jurisdictional/local fire code).

In general, the following considerations need to be observed:

- Personnel making inspections **shall** keep records of all fire extinguishers inspected, including those found to require corrective action.
- At least monthly, the date the inspection was performed and the initials of the person performing the inspection **shall** be recorded.
- Records **shall** be kept on a tag or label attached to the fire extinguisher, on an inspection checklist maintained on file, or in an electronic system (e.g., bar coding) that provides a permanent record.
- Fire extinguisher **shall** be subjected to maintenance at intervals of not more than 1 year, at the time of hydrostatic test, or when specifically indicated by an inspection.
- Every 6 years, stored-pressure fire extinguishers that require a 12-year hydrostatic test **shall** be emptied and subjected to the applicable maintenance procedures.
- Each fire extinguisher **shall** have a tag or label securely attached that indicates the month and year the maintenance was performed and that identifies the person performing the service.

5.12.5 FIXED FIRE DETECTION, ALARM, AND SUPPRESSION SYSTEMS

WARNING

Fixed or portable fire suppression systems using water shall not be used in communication sites.

This section specifies minimum requirements for Detection, Alarm, and Suppression systems. For additional requirements, refer to NFPA 12, NFPA 2001, and any other applicable national, state, jurisdictional, and local code requirements that may apply. Specifically, fixed systems comprise the following:

- Detection systems
- Alarm systems
- Automatic suppression systems

Any work involving installation of these systems **shall** be performed only by personnel skilled in this work (typically a contractor specializing in these systems). As such, this section is provided to aid personnel charged with purchasing, inspecting, testing, approving, operating, and maintaining this equipment in their consultations with an appropriate, contracted fire protection engineering firm.

Some communications equipment systems include detectors and alarms that transmit to centralized control centers within the system itself. High-rise buildings often utilize a second dedicated facility alarm and can be included as part of a central alarm system connected to the local fire department.

5.12.5.1 AUTOMATIC DETECTION

Automatic detection **shall** be accomplished by any listed or approved method or device capable of detecting and indicating heat, flame, smoke, combustible vapors, or an abnormal condition in the controlled area that is likely to produce fire. On large installations the fire detection system **shall** consist of a combination ionization smoke detector and a rate compensated fixed temperature thermal detector. This type of two-loop detection system will provide a positive verification of a fire condition and the earliest possible pre-alarm notification. The detector units **shall** conform to UL 268 standards (or equivalent requirements for the site area). If the fire detection system is the type that shuts off the power to the installation, battery operated emergency light sources **shall** be provided in the affected areas.

5.12.5.2 AUTOMATIC ALARMS

Automatic alarms or indicators (or both) indicate the operation of the system, hazards to occupants, or failure of any supervised device. The type (audible or visual), number, and location of these devices **shall** be such that their purpose is satisfactorily accomplished. As a minimum, the fire alarm system **shall** give an initial warning signal for evacuation of occupants and for confirmation of a fire condition. A secondary alarm system **shall** sound, indicating the automatic discharge of a fire-extinguishing agent. The system **shall** have a time delay function between the two warning signals which can be adjusted to provide adequate time for evacuation or abort procedures.

5.12.5.2.1 SITE ALARM SWITCH FORM

Site alarms are defined as any action, reaction, or determinations associated with diagnostics, security, or emergency. All equipment providing alarms will send alarms from the equipment utilizing dry-contact closures. The dry contact closures will conform to Form-C configuration, providing Common, Normally-Open, and Normally-Closed contacts. The outputs will not be referenced to either ground or any voltage potential.

5.12.5.3 AUTOMATIC SUPPRESSION SYSTEMS

Automatic suppression systems automatically discharge fire-extinguishing agents when a fire condition is detected. With use of control panels, directional valves and flow control equipment, these systems can be used to protect against one or more hazards or groups of hazards. Where two or more hazards may be simultaneously involved in the fire by reason of proximity, both hazards **shall** be protected with separate individual systems and the combination arranged to operate simultaneously. The other option is that they could be protected with a single system that **shall** be sized and arranged to simultaneously discharge on all potentially involved hazards that have indicated an alarm condition. A qualified fire protection engineer **shall** be consulted when designing automatic extinguishing systems.

If an overhead sprinkler system is used, the "dry pipe" type **shall** be used. Upon detection of a fire condition, this type of system removes source power to the room and then opens a master valve to fill the overhead sprinklers. These systems sometimes use a primary suppressor such as CO_2, releasing before the sprinkler system is activated. Dry pipe systems can have enough of a delay so that a manual reset can be provided, if allowable. This system is preferable to a "wet" type system, which has the chance of water leakage and resultant equipment damage, and can possibly use rancid water that has been stored in overhead pipes for long periods.

If power connections are made beneath raised floors, waterproof electrical receptacles and connections **shall** be used in all types of installations.

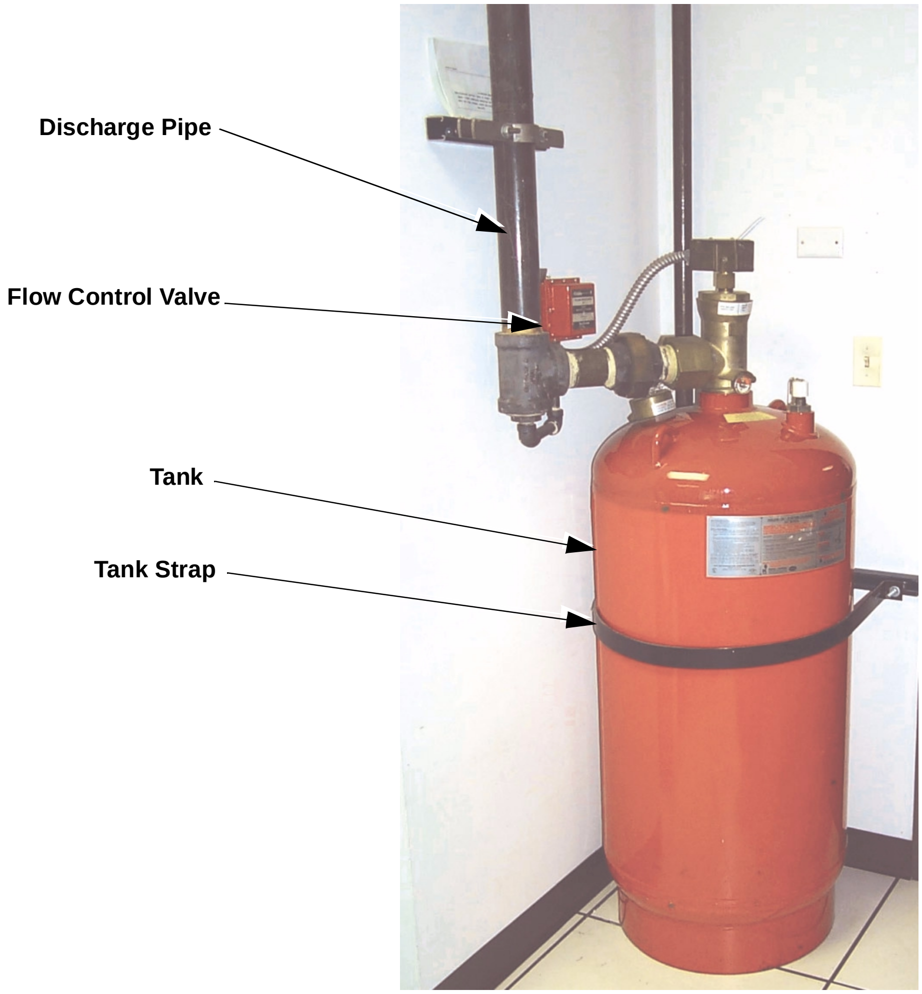


FIGURE 5-15 TYPICAL AUTOMATIC SUPPRESSION SYSTEM

5.12.5.3.1 WARNING SIGNS

Appropriate warning signs **shall** be affixed outside of areas where concentrations of extinguishing gases can accumulate. This should not be limited to just protected spaces but in the adjacent areas where the gases could migrate or leak (such as the storage room for the gas containers, adjacent rooms and hallways). There **shall** be a warning sign posted at the entrance to the protected area and inside the protected space.

5.12.5.3.2 POWER SOURCES

The primary power source for the extinguishing system's operation and control **shall** have the capacity for intended service and **shall** be reliable. When failure of the primary power source occurs which will jeopardize the protection provided, a secondary (standby) power source **shall** supply energy to operate the system for a period of 24 hours and be capable of operating the extinguishing system continuously for the full designed discharged period. The secondary (standby) power **shall** automatically transfer to operate the system within 30 seconds of the loss of primary power.

5.12.5.3.3 FIXED SYSTEMS COMPARISON

If a new system is being installed or an existing fixed fire-extinguishing system is being replaced, always check with local fire prevention authorities and a competent fire protection engineer first. Be ready to supply information about the material composition of the building or housing structure, occupancy of the structure, environment, and equipment that needs to be protected. Ask for their recommendations on the type of extinguishing systems needed, along with any advantages and disadvantages of a particular system.

Some of the more common fixed systems currently used at communication sites are listed in Table 5-4. The advantages and disadvantages of each type are also described.

TABLE 5-4 FIXED-SYSTEM FIRE SUPPRESSION COMPARISONS

Type	Advantages	Disadvantages
	Water Extinguishing System	
Water Extinguishing (Water Sprinkler)	• Upon detection of a fire condition, a "dry pipe" type of system removes source power to the room and then opens a master valve to fill the overhead sprinklers. (The "dry pipe" system is preferable to a "wet pipe" system, which has the chance of water leakage and resultant equipment damage and possible electrical shock.) • No adverse environmental impact.	• If power connections are made beneath raised floors, waterproof electrical receptacles and connections are required. • Either type of water sprinkler system could cause electronic equipment damage and will require an extensive cleanup effort. • Upon discharge, system downtime can be lengthy.
	Clean Agent Extinguishing System	
FE-13™ (HFC-23)	• Environmentally friendly replacement of Halon™ 1301-based systems. • Advantage over CO_2 systems, due to FE-13 lack of oxygen displacement characteristic. • Electrically nonconductive and residue-free. No cleanup is required after discharge and system downtime can be kept to a minimum. • The storage cylinder(s) may be stored away from the protected area. • Storage cylinders can be stored in a wide range of temperatures; containers need not be stored in protected places at room temperature. • System recharge is less expensive than alternative fluorocarbon agents.	• May not be readily attainable or easily refilled in certain areas. • Typically much more costly to purchase and maintain than water systems. • When released under fire conditions hydrofluoric acid (HF) can be produced.
FM-200™ (HFC-227ea)	• Environmentally friendly replacement of Halon™ 1301-based systems. • Less toxic than Halon 1301. • Electrically nonconductive and residue-free; no cleanup is required after discharge. System downtime can be kept to a minimum. • When compared with Halon 1301, FM200 systems require minimal additional floor storage space.	• System recharge can be more expensive than other types of extinguishing agents. • When released under fire conditions hydrofluoric acid (HF) can be produced.
INERGEN™ (IG-541)	• Environmentally friendly replacement of Halon™ 1301-based systems. It has no Ozone Depleting Potential, Global Warming Potential, or Atmospheric Lifetime. • No toxic or corrosive decomposition products. • Electrically nonconductive and residue-free; no cleanup is required after discharge. System downtime can be kept to a minimum. • Since INERGEN is stored as a gas, it can be stored at a substantial distance form the risk area, where more space is available.	• When compared with Halon 1301 and FM200 systems, INERGEN systems require more cylinders and additional floor storage space.

5.12.6 SAFETY EQUIPMENT

The following safety equipment (described in detail in this section) **shall** be permanently located at the site:

- First aid kits
- Battery safety equipment including personal protection equipment
- Construction/installation safety equipment
- Safety markings and barriers

NOTE: It is strongly recommended that all employees obtain formal training and certification in First Aid and CPR.

5.12.6.1 FIRST AID KIT

The need for proper first aid equipment in the workplace is recognized by the Occupational Safety and Health Act (OSHA). This requirement applies to every employer engaged in a business that affects commerce in any way and has employees.

Since many communications facilities are located in remote areas, far from medical help, a first aid kit **shall** be required at each site.

- All First Aid kits, case, and contents **shall** meet or exceed the specifications of ANSI Standard Z308.1.
- All First Aid kits **shall** be mounted in a conspicuous, easily-accessible location.
- The First Aid kit case **shall** be durable, rustproof, and allow for wall mounting.

5.12.6.2 BATTERY SAFETY

NOTE: This section describes conditions associated with wet cell batteries (which typically require the most stringent handling and safety precautions). In all cases, manufacturer's documentation **shall** be read and understood before installing or maintaining battery systems.

Observe the following general battery installation and maintenance considerations:

- Because of the chemical composition, weight, and bulk of many battery configurations, certified transporters and hazardous materials handlers may be required.
- Batteries **shall** have insulated covers and/or insulated terminal protectors.
- Batteries **shall not** be used as a work surface.
- Batteries **shall** be covered when work is in progress overhead.
- Seismic racks are for required for seismically active locations (Moment Magnitude 3 or greater), and **shall** be bolted to floors and grounded.

- The US Federal Clean Water Act, with jurisdictional or local option by location, does not allow battery acid spills, which are neutralized, to be flushed down the drain or spilled on soil. Some locations have no such restrictions.

Depending on the type of batteries used, a safety kit may be required within the battery area. Figure 5-16 shows a typical battery safety kit.

FIGURE 5-16 TYPICAL BATTERY SAFETY KIT

Where required by OSHA or applicable jurisdictional or local codes, the following equipment **shall** be supplied:

- A lightweight, acid resistant bib type apron **shall** be permanently stored on site near the battery plant. The fabric **shall** be acid, caustic, puncture resistant, and meet Federal Standard 5903.2-191 for flame resistance.
- An acid resistant, full face shield, **shall** be permanently stored on site near the battery plant. The shield **shall** meet all requirements of ANSI Z87.1. Protective eye wear that does not provide full face protection is not allowed.
- One pair of acid resistant gloves **shall** be permanently stored on site near the battery plant. These gloves **shall** be of sufficient length to cover the hand, wrist, and forearm for protection from chemical splash.
- One 0.5 kg (1 lb.) box of baking soda or equivalent acid neutralizing compound **shall** be permanently stored on site near the battery plant. Water is required to mix with the baking soda.
- An emergency eyewash station **shall** be permanently mounted near the battery plant. The eyewash station **shall** use an isotonic saline wash capable of neutralizing acids or caustics and **shall** be able to flush the eye for 15 minutes. A plumbed eyewash station and a shower should be provided in battery areas if possible.

NOTE: In most cases, sealed batteries do not require venting. Check jurisdictional or local codes for applicability. Also check the labels on the batteries for the proper protection based on that particular type of battery.

When specified by OSHA and/or applicable jurisdictional or local codes, the following requirements **shall** be observed at all sites where batteries are part of the installation:

- Provisions **shall** be made to exhaust gases produced by batteries. For wet cell batteries the manufacturer-specified stationary battery flame-arresting vent **shall** be installed on each cell. This vent **shall** be secure, clean, and in good repair to help ensure maximum protection against potential explosion. Sealed batteries do not have an opening for adding electrolyte; however, there is generally a small vent hole that opens as required to vent internal gasses. There are two methods which may be used to vent battery gases. One method is to use an exhaust fan on a timer, changing the total room air four times per hour. The other method is to use a manifold system that consists of tubing connected to each cell and vented to the outside.
- "NO SMOKING" signs **shall** be prominently displayed in the battery room and on the exterior of the battery room entry door. Smoking, or the source of any spark producing materials, **shall** be strictly prohibited in this area.
- Wet cell batteries should always be maintained in the upright position. Care **shall** be taken to help ensure batteries are not tilted during installation.
- Insulated tools **shall** be used when working around batteries to minimize the potential for an accidental short circuit.
- Sealed batteries may crack or develop a leak. It is desirable that a plastic tray be placed on the floor under the batteries to contain any acid that may leak.
- Batteries **shall** be kept clean to reduce short circuit hazards, rack corrosion and the possibility of electrical shock.

CAUTION

Batteries should be cleaned with clear water. Do not use abrasive cleaners, detergents or petroleum-based cleaning products on battery container.

- Battery banks consisting of multiple cells with circuit protection greater than 20 amperes **shall** have 1 cm (1/2 in.) or greater thickness Lexan or hard rubber protective shield installed on a support frame and securely mounted in front of the battery rack to protect personnel should there be a violent structural failure of any cell(s). This protective shield **shall** extend from 7.6 cm (3 in.) above to 7.6 cm (3 in.) below the height of the cells being protected.
- When batteries are located in an area that is accessible to persons other than qualified system maintenance personnel, an additional protective shield as described above **shall** be installed to cover the top of all cells and battery circuit conductors to prevent conductive materials from contacting battery posts or circuit conductors on top of the cells.

- At sites where batteries constructed with bolt-on terminal connections are used, the following items are required:
  - Connector bolt wrench (nonconductive)
  - Lifting sling and spreader block if applicable
- At all sites using wet cell batteries, the following items are required:
  - OSHA-approved emergency eyewash kit (A plumbed eyewash station and a shower should be provided in battery areas if possible.)
  - Rubber gloves, apron, and face shield
  - Container of baking soda to neutralize spilled acid
  - Container of water to mix with baking soda
  - Container of non-oxidation material for coating electrical connections
- At sites with flooded lead-acid batteries, the following items are required:
  - Hydrometer with markings every 10 points
  - Acid-resistant container for storing the hydrometer
  - Thermometer, Battery

5.12.7 PERSONAL SAFETY EQUIPMENT

5.12.7.1 HARD HATS

Hard hats **shall** be worn when overhead work is being performed at the site.

Approved hard hats **shall** be manufactured from a non-conductive material such as high density polyethylene. Hard hats **shall** meet or exceed ANSI Z89.1 requirements, OSHA requirements, or other jurisdictional/local regulations.

5.12.7.2 FULL BODY HARNESS AND LANYARDS

Full body harness with a retractable or shock absorbing lanyard that limits a free fall to 1.82 m (6 ft.) **shall** be used. In addition, positioning lanyards **shall** also be used if a fall of less than 1.82 m (6 ft.) would result in contact with other equipment such as antennas, dishes, or star or side mounts. Lanyards **shall** have a minimum breaking strength of 22250 N (5000 lb-force). **Body belts shall not to be used**. Only locking snaphooks **shall** be used on the lanyards and **shall** be sized for the anchorage being used. All D-rings and snaphooks **shall** have a minimum tensile strength of 22250 N (5000 lb-force).

FIGURE 5-17 EXAMPLE OF FULL BODY HARNESS

5.12.7.3 SAFETY MARKINGS AND BARRIERS

- Approved warning fence **shall** be at least 1.2 m (4 ft.) high. Approved warning fence **shall** be chain link fabric with appropriate warning signs attached, or high density polyethylene material molded in high visibility red/orange color.
- Barrier tape **shall** be at least 7.6 cm (3 in.) wide, made with a high visibility color, and utilize repeated wording such as “CAUTION” in black lettering.
- Approved vehicle barriers **shall** be at least 1 m (37 in.) high and 0.6 m (24 in.) wide. Barriers **shall** utilize high visibility striping and coloration. Barriers used after sundown **shall** be equipped with flashing lights that meet Federal ITE specifications for type “A” flashing lights.
- Approved traffic cones **shall** be at least 0.7 m (28 in.) high and meet all DOT requirements for high visibility coloring.
- Other signage, such as EME hazard, NFPA diamonds, and important phone number lists, may also be required.

5.12.8 ON SITE COMMUNICATIONS

It is recommended that some form of two-way communications be available at each facility, for safety reasons as well as for performing maintenance and troubleshooting. Most outages occur after hours and normally only one technician is dispatched to perform repairs.

- Important numbers **shall** be posted on or near the communications devices.
- For maintenance and troubleshooting, a telephone or microwave orderwire is invaluable, if monitored. In most cases the technician must contact a central support group and/or a computer in order to obtain help. Many new systems require a communications link to download the operational information in order for the equipment to function.
- Note that neither a mobile radio in a maintenance vehicle nor a personal portable radio should routinely be used for onsite communications requirements.
- On-site communication between personnel on the ground and any personnel working on a tower **shall** be maintained at all times.
- For maintenance and troubleshooting, a mobile telephone is acceptable.

5.13 SIGNAGE

A site building, shelter, or enclosure **shall** be posted with signs identifying the site and providing notices and warnings. The types of site signage **shall** be in accordance with national, state, and jurisdictional/local regulations.

Signs containing general required notices, along with spaces for custom information, are commercially available and should be used. Warning signs containing the appropriate information and symbols are also commercially available and should be used.

5.13.1 MINIMUM REQUIRED SIGNAGE

At a minimum, sites which are not continuously supervised **shall** post the following:

- **Authorized Personnel Only - No Trespassing**

  Mandatory legal requirement exists in which the site is to be conspicuously posted to limit access to the site. Signage **shall** be posted during all phases of site planning, construction, and operation. See Figure 5-18 for an example.

FIGURE 5-18 TYPICAL "NO TRESPASSING" SIGN

- **Entity Responsible for Site**

  The site **shall** have conspicuous signage that identifies the site operating entity and provides appropriate contact information.

  Permit or licensing information (as assigned by the Federal Communications Commission or other equivalent) **shall** also be included. See Figure 5-19 for an example.

FIGURE 5-19 TYPICAL ENTITY IDENTIFICATION SIGN

- **Battery Area Signage**

  NFPA signs advising the fire department of battery electrolyte reactivity with water **shall** be posted.

  Appropriate signage **shall** be present on doors leading to battery rooms and within the room itself, notifying personnel of explosion, chemical, and electrical hazards within the area.

  "NO SMOKING" signs **shall** be prominently displayed in the battery room and on the exterior of the battery room entry door.

5.13.2 ADDITIONAL SIGNAGE

Depending on the site's function, additional signage may be required. These signs typically notify of potential hazards associated with authorized or unauthorized site entry.

Engineering personnel designing the site **shall** be aware of conditions that may be present at the site that could warrant warning signage. Such conditions are, but are not limited to, high voltage and RF energy emissions hazards. See Figure 5-20 for an example of an RF notice.

NOTE: See Appendix E for more information regarding EME signage.

FIGURE 5-20 TYPICAL RF WARNING SIGN

CHAPTER
6

EXTERNAL GROUNDING

This chapter provides requirements and guidelines for designing, installing, and testing the external grounding electrode system at a communications site.

NOTE: Refer to Appendix C for grounding cellular installations.

This chapter contains information on the following topics:

6.1 INTRODUCTION

The requirements and guidelines in this chapter are derived from NFPA 70, NFPA 780, ANSI T1.313-1997, and ANSI/EIA/TIA-222-F. Other industry specifications and standards from which these requirements are derived are listed throughout the chapter. The requirements and guidelines in this chapter are provided to enhance personnel safety and equipment reliability.

> **NOTE:** NFPA 70 is the National Electrical Code® (NEC®) and NFPA 780 is the Standard for the Installation of Lightning Protection Systems.

All site development and equipment installation work **shall** comply with all applicable codes in use by the authority having jurisdiction. Where conflicting, Government and local codes **shall** take precedence over the requirements of this document.

Safety of personnel and protection of electronic equipment from ground faults, lightning, electrical surges, and impulses is of utmost importance at any communications site. Though unexpected electrical events like lightning strikes and power surges cannot be prevented, this chapter provides installation information on external grounding electrode systems that may help minimize damage caused by these events.

Unusual site conditions may require additional effort to achieve an effectively bonded and grounded site. Consultation with an engineering firm specializing in grounding electrode system design is recommended in these instances.

Some of the benefits of a properly designed and installed low-impedance external site grounding electrode system are described below. (Refer to *NFPA 70, Article 250-2* for more information).

- To help limit the voltage caused by accidental contact of the site AC supply conductors with conductors of higher voltage.
- To help dissipate electrical surges and faults to minimize the chances of injury from grounding system potential differences.
- To help limit the voltages caused by lightning.
- To stabilize the AC voltage under normal conditions relative to the earth.
- To aid the operation of some types of surge suppressor units.
- To provide a common signal reference ground.

6.2 DESIGN REQUIREMENTS FOR GROUNDING ELECTRODE SYSTEMS

At a communications site, there shall be only one grounding electrode system. For example, the telephone system ground, AC power system ground, underground metallic piping, and any other existing grounding system **shall** be bonded together to form a single grounding electrode system (per NFPA 70, Articles 250-90, 800-40, 810-21, and 820-40; and NFPA 780, Section 3-14.1).

A grounding electrode system **shall** have low electrical impedance, with conductors large enough to withstand high fault currents. The lower the grounding electrode system impedance, the more effectively the grounding electrode system can dissipate high energy impulses into the earth.

All grounding media in or on a structure **shall** be interconnected to provide a common ground potential. This **shall** include lighting protection, electric service, telephone and antenna system grounds, as well as underground metallic piping systems. Underground metallic piping systems typically include water service, well castings located within 7.6 m (25 ft.) of the structure, gas piping, underground conduits, underground liquefied petroleum gas piping systems, and so on. Interconnection to a gas line **shall** be made on the customer's side of the meter (per NFPA 780, Section 3-14).

The impedance requirement for a communications site's grounding electrode system is determined based on the classification of the site. Communications sites can be classified into two categories, described below (per IEEE Standard 142-1991 and NFPA 70, Article 250).

6.2.1 TYPE A - LIGHT DUTY

Requirement: Type A sites **shall** achieve a resistance to earth of **25 Ω or less**. Type A sites have the following characteristics:

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

6.2.2 TYPE B - LIGHT INDUSTRIAL/COMMERCIAL

NOTE: A site meeting Type A criteria but that is considered critical to system operation by the customer, or is located in an area particularly susceptible to lightning strikes, should be classified as Type B.

Requirement: Type B sites **shall** achieve a resistance to earth of **5 Ω or less**. Type B sites have the following characteristics:

- Telecommunication repeater equipment is installed, such as a cellular, PCS, or wide-area repeater site.
- Communication system dispatch console equipment is installed.
- Equipment with specific manufacturer requirements for a 5 Ω grounding electrode system is installed (telephony).
- Power for the site is supplied only by a generator.
- Large installations or multiple systems, such as telephone or electronic switches, LANs/WANs, and Mobile Switching Offices (MSO) are installed.

6.2.3 SOIL PH

The pH (Hydrogen ion concentration) of the soil where a grounding electrode system is to be installed should be tested before the system is installed. Acidic soils (pH below 7) can have a destructive affect on copper and other metals.

Test soil pH using a commercially available soil pH meter or a swimming pool acid/base tester. If using a swimming pool acid/base tester, mix and test a solution containing one part site soil and one part distilled water.

In strongly acidic soils (pH of 5 or below), it is recommended that precautionary measures be taken to help maintain the life expectancy of the grounding electrode system. Some options may be as follows:

- Consult an engineering firm.
- Encase all grounding electrode system components in a ground enhancing material (see “Ground Enhancing Materials” on page 6-13).
- Use electrolytic ground rods encased in a ground enhancing material and installed in accordance with the manufacturer’s instructions. See paragraph 6.3.1.2 on page 6-8 and paragraph 6.3.1.6 on page 6-13.
- Use solid copper ground rods instead of copper-clad rods.
- Use larger connecting conductors, such as 67.43 mm^2 csa (#2/0 AWG) instead of 35 mm^2 (#2 AWG).
- Test the grounding electrode system at least once a year, (see “Ground System Testing/Verification” on page 6-63”).

6.3 GROUNDING ELECTRODE SYSTEM COMPONENT REQUIREMENTS

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

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

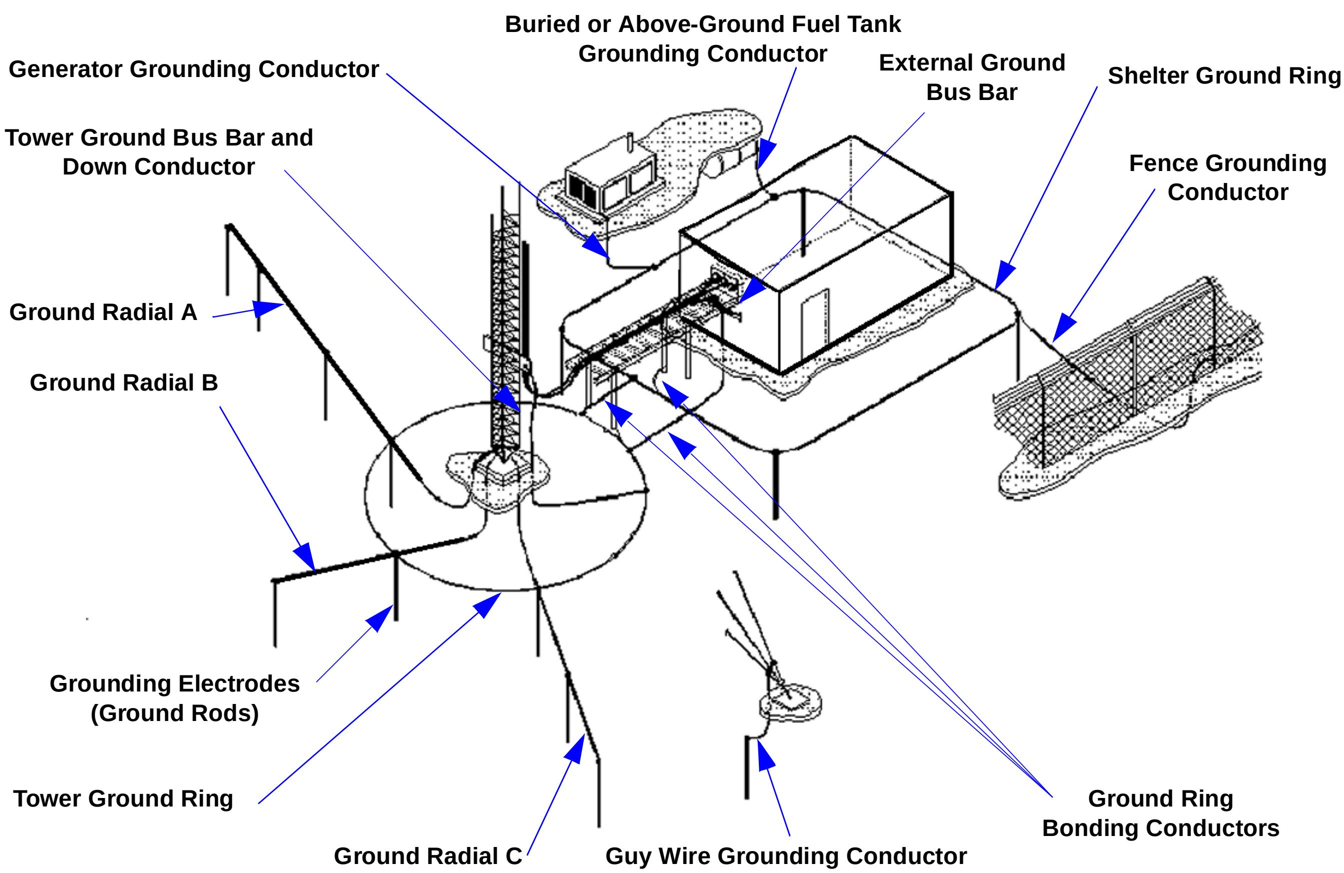


FIGURE 6-1 TYPICAL TYPE B EXTERNAL GROUNDING ELECTRODE SYSTEM

6.3.1 GROUNDING ELECTRODES

Grounding electrodes are the conducting elements used to connect electrical systems and/or equipment to the earth. The grounding electrodes are placed into the earth to maintain electrical equipment at the potential of the earth and to dissipate over-voltages into the earth. Grounding electrodes may be ground rods, metal plates, concrete encased conductors, ground rings, electrolytic ground rods, the metal frame of building or structure and metal underground water pipes (per NFPA 70, Article 250 (c) and NFPA 780, Section 3.)

NOTE: Metallic underground gas piping **shall not** be used as a grounding electrode (per NFPA 70, Article 250-52(a)), but **shall** be bonded upstream from the equipment shutoff valve to the grounding electrode system as required by NFPA 70, Article 250-104(b) and NFPA 780, Section 3-14.1.

WARNING

Before excavating or digging at a site, have the local utility company or utility locator service locate the underground utilities.

6.3.1.1 GROUND RODS

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

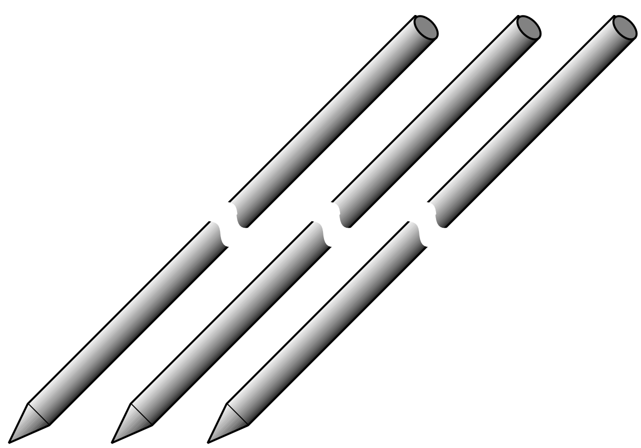


FIGURE 6-2 TYPICAL GROUND RODS

- Ground rods **shall** be copper-clad steel, solid copper, hot-dipped galvanized steel, or stainless steel. The rods **shall** have a minimum length of 2.44 m (8 ft.) and minimum diameter of 15.9 cm (0.625 in.), or as otherwise required by NFPA 70, Article 250-52. The actual diameter, length, and number of rods required may vary with site dimensions and/or as determined by an engineering study based on the soil resistivity profile of the site. Refer to "Soil Resistivity Measurements" on page 4-13, *NFPA 70, Article 250-52,* and *NFPA 780, Section 3-13* for more information.
- The method of bonding grounding conductors to ground rods **shall** be compatible with the types of metals being bonded.
- Ground rods **shall** be free of paint or other nonconductive coatings (NFPA 70, Article 250-52 and NFPA 780, Section 3-13.1).
- Where practical, ground rods **shall** be buried below permanent moisture level (NFPA 70, Article 250-52).
- Ground rods **shall not** be installed more than 4.9 m (16 ft.) apart (or twice the length of the rod) and not less than 1.8 m (6 ft.) apart (per NFPA 70, Article 250-56).
- Ground rods **shall** be buried to a minimum depth of 0.76 m (30 in.) below finished grade, where possible, or buried below the freeze line, whichever depth is greater.
- Ground rods that cannot be driven straight down, due to contact with rock formations, may be driven at an oblique angle of not greater than 45 degrees from the vertical, or may be buried horizontally and perpendicular to the building, in a trench at least 0.76 m (30 in.) deep, as shown in Figure 6-3. (See *NFPA 70, Article 250-52* and *NFPA 780, Section 3-13.1.5* for more information.)

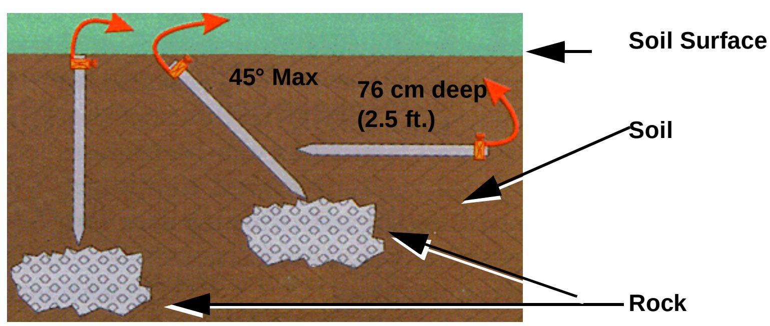


FIGURE 6-3 ANGLED GROUND ROD INSTALLATION

WARNING

When operating any kind of power tool, always wear appropriate safety glasses and other protective gear to prevent injury.

- Hammer drills or electric jackhammers may be used to drive in the ground rods. Do not deform the head of the ground rod.

- If rock formations prevent ground rods from being driven to the specified depth, an alternate method of achieving an acceptable grounding electrode system **shall** be engineered and implemented.
- Ground rods used to ground galvanized tower guy wires **shall** be installed in accordance with "Self-supporting Towers and Guyed Lattice Towers" on page 6-29.
- When the grounding system design requires a deeper grounding electrode, two or three ground rods **shall** be exothermically welded end-to-end as shown in Figure 6-4. Other methods of connecting the rods together **shall not** be used.

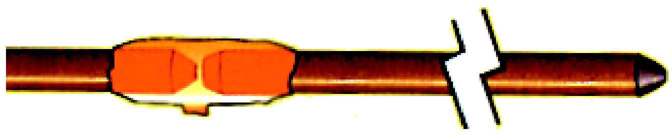


FIGURE 6-4 SPLICING TWO GROUND RODS

6.3.1.2 ELECTROLYTIC GROUND RODS

At sites where, due to poor soil conductivity (high resistivity) and/or limited space, an acceptable grounding electrode system resistance cannot be achieved using copper-clad steel rods and other methods described in this chapter, commercially available electrolytic ground rods may be used. Electrolytic ground rods (Figure 6-5) are available in straight or L-shaped versions and in various lengths from 3.05 m (10 ft.) to 6.1 m (20 ft.), or longer as a special order. Electrolytic ground rods are generally constructed of 5.4 cm (2.125 in.) diameter hollow copper pipe. This copper pipe is filled with a mixture of non-hazardous natural earth salts. Holes at various locations on the pipe allow moisture to be hygroscopically extracted from the air into the salt within the pipe, therefore forming conductive electrolytes. These electrolytes then leach out of the pipe into the soil, improving soil conductivity. Electrolytic ground rods are often inserted into a pre-drilled hole, or in the case of L-shaped rods, placed into a trench at least 76 cm (30 in.) deep, and encased in a ground enhancing material (Refer to "Ground Enhancing Materials" on page 6-13).

Electrolytic ground rods should be considered for use in grounding electrode systems covered by concrete or pavement, such as parking lots. By allowing moisture to enter, the design of the electrolytic ground rod improves the resistance of the grounding electrode system.

NOTE: Unless prohibited by local environmental authorities, condensation from the site's HVAC system may be routed to the ground rod area to keep the soil moist, improving conductivity.

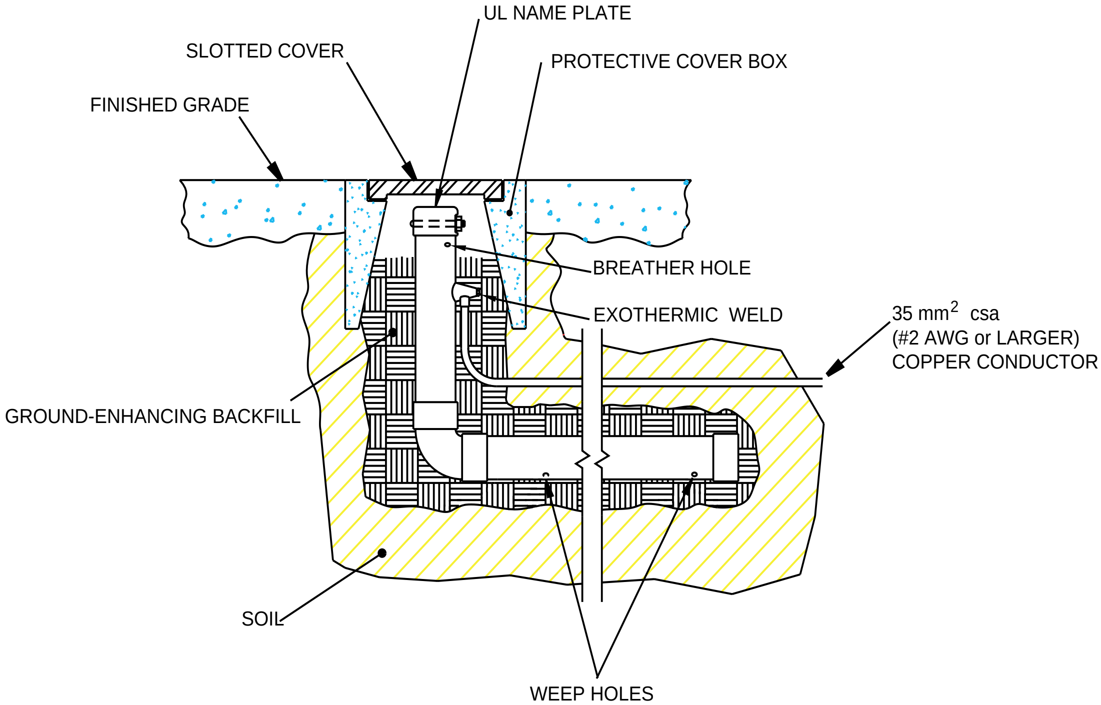
Some electrolytic ground rods provide significant improvement over copper-clad steel rods of the same length and may last several years longer than the copper-clad steel rods.

The resistance to earth of some electrolytic ground rods is more stable in environments with variations in temperature and moisture.

Requirements for the use of electrolytic ground rods are listed below.

- Electrolytic rods **shall** be UL listed.
- Electrolytic rods **shall** be installed per manufacturers' recommendation.
- Electrolytic rods **shall** be maintenance free.
- Electrolytes within the rod **shall** be environmentally safe and approved by the environmental jurisdiction having authority.
- Ground enhancing backfill materials **shall** be environmentally safe and approved by the environmental jurisdiction having authority.

L-Shaped



Straight

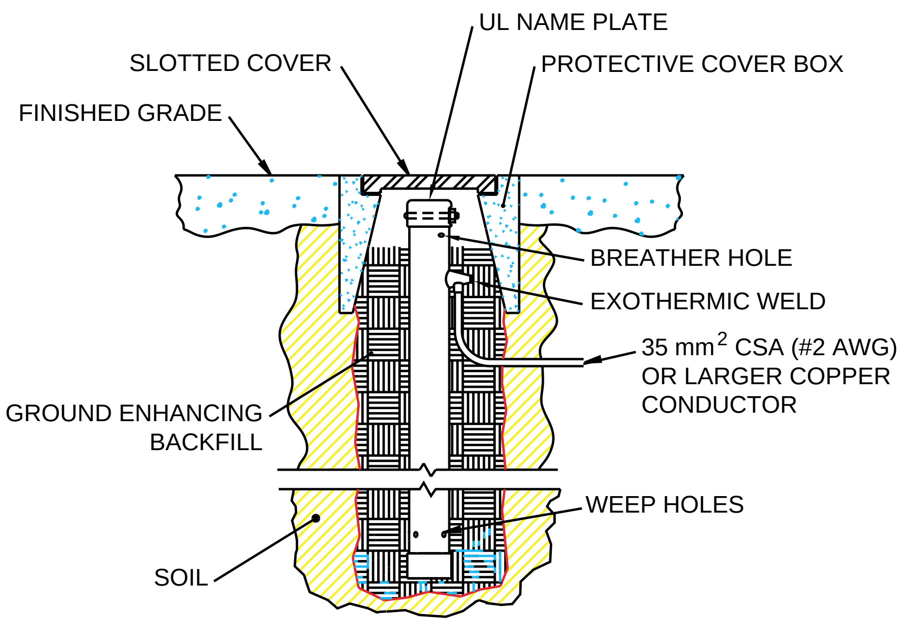


FIGURE 6-5 ELECTROLYTIC GROUND RODS

6.3.1.3 GROUND PLATES

Ground plates (Figure 6-6) may be used in special cases if specifically engineered into the design of the grounding electrode system or otherwise required due to soil conditions. A ground plate electrode **shall** expose not less than 0.186 m^2 (2 sq. ft.) of surface to exterior soil and **shall** be buried not less than 76.2 cm (2.5 ft.) below the surface of the earth. If soil conditions do not allow the ground plate to be buried at this depth, see *NFPA 780, Section 3-13.1.5* for more information. Refer to "Sand, Coral, or Limestone Environments" on page 6-53 for a recommended example of the use of ground plates in unfavorable environments.

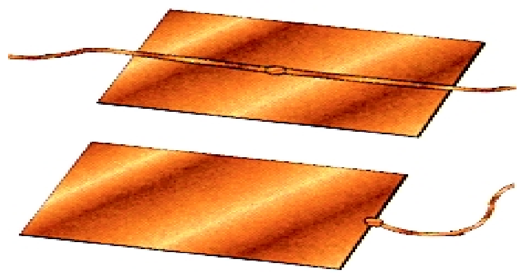


FIGURE 6-6 TYPICAL GROUND PLATES

6.3.1.4 CONCRETE-ENCASED ELECTRODES

Though concrete-encased electrodes (also known as Ufer electrodes) are not required by this standard, they should be used in new construction as a method of supplementing the grounding electrode system. Concrete-encased electrodes (Figure 6-7) enhance the effectivity of the grounding electrode system in two ways: the concrete absorbs and retains moisture from the surrounding soil; and the concrete provides a much larger surface area in direct contact with the surrounding soil. This may be especially helpful at sites with high soil resistivity and/or limited area for installing a grounding electrode system. Requirements for a concrete-encased electrode, if used, are listed below (per NFPA 70, Article 250-50 and NFPA 780, Section 3-13.2).

- Concrete-encased electrode **shall** be encased by at least 5 cm (2 in.) of concrete, located within and near the bottom of a concrete foundation or footing that is in direct contact with the earth.
- Concrete-encased electrode **shall** be at least 6.1 m (20 ft.) of bare copper conductor not smaller than 25 mm^2 csa (#4 AWG) or at least 6.1 m (20 ft.) of one or more bare or zinc galvanized or other conductive coated steel reinforcing bars or rods at least 12.7 mm (0.5 in.) in diameter.
- Concrete-encased electrode **shall** be bonded to any other grounding electrode system at the site.

FIGURE 6-7 TYPICAL CONCRETE-ENCASED ELECTRODE

6.3.1.5 GROUND TEST WELLS

Ground test wells are not required, but may be desired for troubleshooting and/or inspecting the grounding electrode system components. Ground test wells are typically constructed of PVC tubing 20.3 cm (8 in.) or more in diameter and have a detachable cover to keep debris out. A typical PVC ground test well is shown in Figure 6-8.

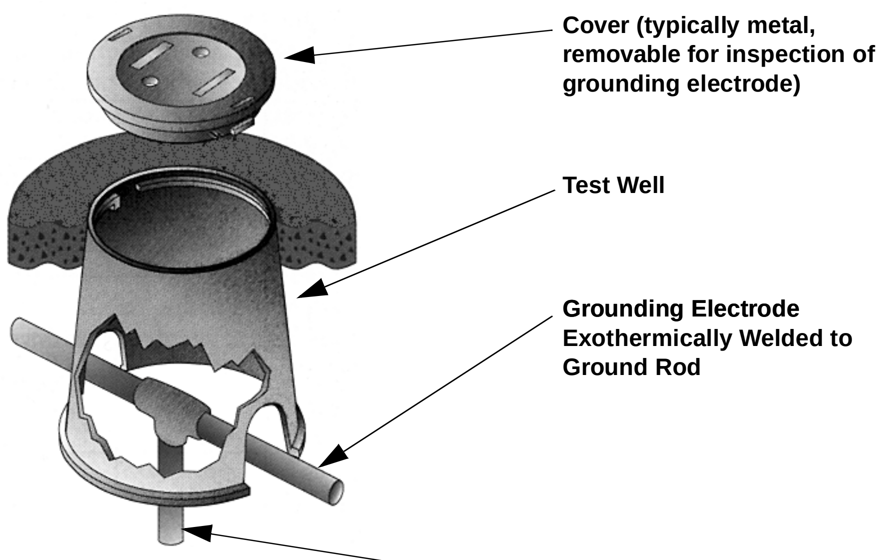


FIGURE 6-8 TYPICAL GROUND TEST WELL

6.3.1.6 GROUND ENHANCING MATERIALS

Ground enhancing material may be used as needed to improve the grounding electrode system resistance or to protect the grounding electrode system components from very acidic soil. Ground enhancing material is generally used with electrolytic ground rods, but may also be used on grounding conductors, ground rods and ground plates as a way to improve the resistance to ground of a grounding electrode system. Requirements for the use of ground enhancing material are as follows:

- Ground enhancing material **shall** be packaged specifically for the purpose of ground enhancement.
- Ground enhancing material **shall** be environmentally safe and approved by the environmental jurisdiction having authority.
- Ground enhancing material **shall** be used in accordance with manufacturers' instructions.
- Ground enhancing material **shall not** have a corrosive effect on the grounding electrode system components.

6.3.2 GROUNDING CONDUCTORS

Grounding conductors are the conductors used to connect equipment or the grounded circuit of a wiring system to a grounding electrode or grounding electrode system. These conductors may be the wires that connect grounding electrodes together, form buried ground rings, and connect objects to the grounding electrode system. (See *NFPA 70, Article 100* for more information.)

6.3.2.1 GENERAL SPECIFICATIONS

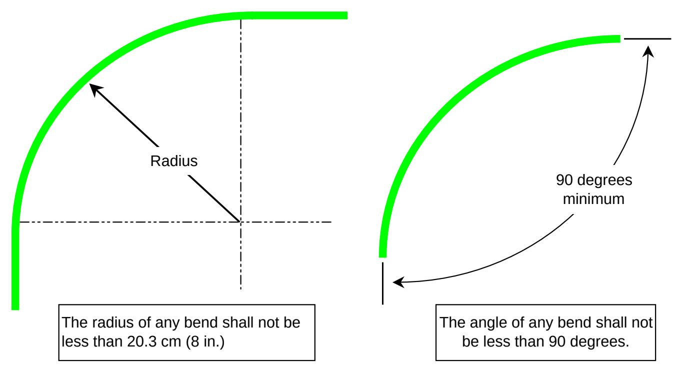
All external grounding conductors **shall** be bare tinned solid or stranded 35 mm^2 csa (#2 AWG) or larger copper wire and **shall** meet the size requirements of NFPA 70, Article 250-66. Solid wire is recommended below grade to prolong longevity. For areas highly prone to lightning and/or areas with highly acidic soil, larger conductors should be considered.

Solid straps or bars may be used as long as the cross-sectional area equals or exceeds that of the specified grounding conductor.

6.3.2.2 BENDING GROUNDING CONDUCTORS

The following requirements apply when installing grounding conductors:

- Sharp bends **shall** be avoided because the sharp bend increases the impedance and may produce flash points. See Figure 6-9.
- Grounding conductors **shall** be run as short, straight, and smoothly as possible, with the fewest possible number of bends and curves. (See *NFPA 70, Articles 800-40, 810-21*, and *820-40*.
- A minimum bending radius of 20 cm (8 in.) **shall** be maintained, applicable to grounding conductors of all sizes (per NFPA 780, Section 3-9.5 and ANSI T1.313-1997). A diagonal run is preferable to a bend even though it does not follow the contour or run parallel to the supporting structure.
- All bends, curves, and connections **shall** be toward the ground location, rod or ground bar (grounded end) of the conductor.



NOTE: Applicable to all grounding conductor sizes.

FIGURE 6-9 MINIMUM BENDING RADIUS FOR GROUNDING CONDUCTORS

6.3.2.3 SECURING GROUNDING CONDUCTORS

External grounding conductors, especially copper straps, are exposed to movement by wind and other physical forces that can lead to damage or breakage over time. The following requirements **shall** apply when installing grounding conductors:

- The grounding conductor or its enclosure **shall** be securely fastened to the surface on which it is carried.
- Grounding conductors **shall** be attached using nails, screws, bolts, or adhesives as necessary.
- The fasteners **shall not** be subject to breakage and **shall** be of the same material as the conductor or of a material equally resistant to corrosion as that of the conductor.
- Approved bonding techniques **shall** be observed for the connection of dissimilar metals.
- Grounding conductors **shall** be securely fastened at intervals not exceeding 91 cm (3 ft.). (See *NFPA 70, Articles 250-64(b), 810-21(c)*, and *NFPA 780, Section 3-10*.)

6.3.2.4 EXTERNAL GROUND RING

The buried external ground ring should encircle the site structures and provides a means of bonding ground rods together and bonding other grounding electrode system components together, improving the overall grounding electrode system.

Requirement for external ground rings are listed below. (See Figure 6-10; refer to *NFPA 70, Article 250-50* and *NFPA 780, Section 3-13.3* for more information.)

- Building ground ring **shall** encircle the building or shelter.
- Tower ground ring **shall** encircle the tower structure whenever possible.
- Building ground ring and tower ground ring **shall** be bonded together in at least two points using a 35 mm^2 csa (#2 AWG) minimum bare tinned copper conductor.
- Ground rings **shall** be installed in direct contact with the earth at a depth of 76 cm (30 in.) below the earth's surface whenever possible, or below the frost line, whichever is deeper.
- Ground rings **shall** be installed at least 0.9 m (3 ft.) from the building foundation and should be installed beyond the drip line of the roof. It is recommended that the building ground ring and ground rods be positioned 0.6 to 1.8 m (2 to 6 ft.) outside the drip line of the building or structure to ensure that precipitation wets the earth around the ground ring and rods (MIL-HDBK-419A)
- Tower ground rings **shall** be installed at least 0.9 m (3 ft.) from the tower foundation.
- Ground rings **shall** consist of bare solid or stranded tinned copper conductor not smaller than 35 mm^2 csa (#2 AWG). For highly lightning prone areas, larger conductors should be considered.

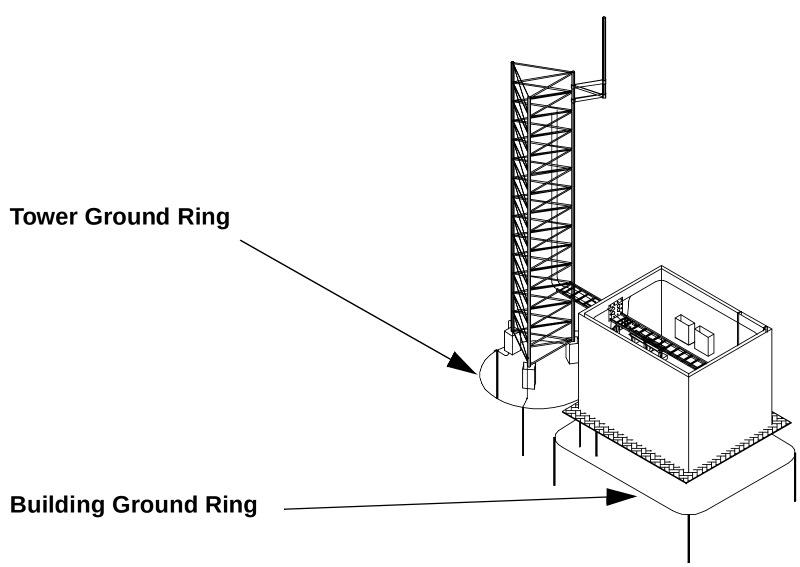


FIGURE 6-10 SITE GROUND RING SYSTEM

6.3.3 EXTERNAL GROUND BUS BAR

The purpose of the external ground bus bar is to provide a convenient termination point for multiple grounding conductors. When required, the external ground bus (EGB) **shall** be constructed and minimally sized in accordance with Table 6-1, ensuring that the ground bus bar is large enough to accommodate all coaxial connections and connection to the grounding electrode system. The external ground bus bar **shall** be installed at the point where the antenna transmission lines enter the building, and **shall** be connected to the external ground ring using the straightest possible downward run of 35 mm^2 csa (#2 AWG) or larger bare solid or stranded tinned copper conductor. See Figure 6-11.

For reduced impedance to the grounding electrode system, the EGB can be connected to the external ground ring using solid copper strap. Relatively small copper strap has significantly less inductance (impedance to lightning) than large wire conductors. For example, 3.8 cm (1.5 in.) copper strap has less inductance than 67.43 mm^2 csa (#2/0 AWG) wire. To further reduce the inductance to ground, several copper straps can be installed across the entire length of the external ground bus bar and routed down to the external grounding ring. See Figure 6-12.

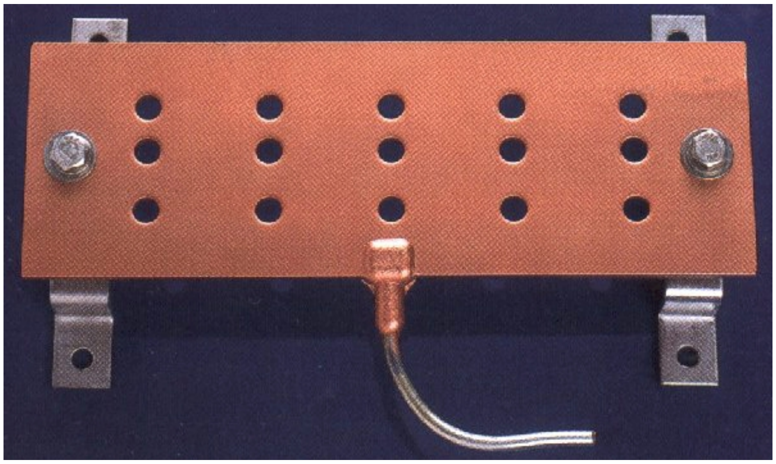


FIGURE 6-11 EXTERNAL GROUND BUS BAR

FIGURE 6-12 INTEGRATED CABLE ENTRY PORT WITH GROUND STRAPS

TABLE 6-1 EXTERNAL GROUND BUS BAR SPECIFICATIONS (WHEN REQUIRED)

Item	Specification
Material	Bare, solid Alloy 110 (99.9%) copper bus bar or plate of one piece construction May be electrotin-plated.
Minimum Dimensions	Width: 5 cm (2 in.) Length: 30.5 cm (12 in.) Thickness: 0.635 cm (1/4 in.)
Mounting brackets	Stainless steel
Insulators	polyester fiberglass 15 kV minimum dielectric strength flame resistant per UL 94 VO classification
Conductor mounting holes	Number dependent on number of conductors to be attached Holes to be 1 cm (7/16 in.) minimum on 1.9 cm (3/4 in.) centers to permit the convenient use of two-hole lugs.
Method of attachment of grounding electrode conductor.	Exothermic welding Irreversible crimp connection Other suitable irreversible crimp connection process

6.3.4 TOWER GROUND BUS BAR

The purpose of the Tower Ground Bus Bar (TGB) is to provide a convenient termination point for multiple transmission line grounding conductors. The tower ground bus bar should be an integral part of the tower construction or vertical transmission line cable ladder assembly. If the tower ground bus bar is not part of the tower construction, it **shall** be constructed and minimally sized in accordance with Table 6-2, ensuring the ground bus bar is large enough to accommodate all coaxial cable connections and connection to the grounding electrode system. The tower ground bus bar **shall** be physically and electrically connected to the tower.

The tower ground bus bar **shall** be installed below the transmission line ground kits, near the area of the tower at the point where the antenna transmission lines transition from the tower to the shelter. The tower ground bar **shall** be directly bonded to the tower, using hardware of materials suitable for preventing dissimilar metal reactions, if possible and allowed by the tower manufacturer. The tower ground bus bar **shall** also be connected to the tower ground ring with a 35 mm^2 csa (#2 AWG) or larger bare tinned solid copper conductor. Avoid bending this conductor. This conductor may be sleeved in PVC for protection if desired. (See *ANSI T1.313-1997*)

For reduced impedance to the grounding electrode system, the TGB can be connected to the external ground ring using solid copper strap. Relatively small copper strap has significantly less inductance (impedance to lightning) than large wire conductors. For example, 3.8 cm (1.5 in.) copper strap has less inductance than 67.4 mm^2 csa (#2/0 AWG) wire. To further reduce the inductance to ground, several copper straps can be installed across the entire length of the tower ground bus bar and routed down to the external grounding ring.

Additional ground bus bars may be installed at different heights along the vertical length of the tower for bonding multiple transmission line ground kits, if not already included as part of the tower structure. The additional ground bus bars **shall** be bonded directly to the tower using tower manufacturer approved methods.

Vertical Mount **Horizontal Mount**

FIGURE 6-13 TYPICAL TOWER GROUND BUS BARS

TABLE 6-2 TOWER GROUND BUS BAR SPECIFICATIONS

Item	Specification
Material	Bare, solid Alloy 110 (99.9%) copper bus bar or plate of one piece construction May be electrotin-plated.
Minimum Dimensions	Width: 5 cm (2 in.) Length: 30.5 cm (12 in.) Thickness: 0.635 cm (1/4 in.)
Mounting brackets	Stainless steel
Conductor mounting holes	Number dependent on number of conductors to be attached Holes to be 1 cm (7/16 in.) minimum on 1.9 cm (3/4 in.) centers to permit the convenient use of two-hole lugs.
Method of attachment of grounding electrode conductor.	Exothermic welding Irreversible crimp connection Other suitable irreversible crimp connection process

6.4 Minimum Site Grounding Requirements

This section provides the minimum grounding requirements for installing a grounding electrode system at a communications site and for bonding site equipment to the grounding electrode system. Develop a grounding electrode system engineering design, using either a consulting firm or Motorola engineering. The grounding electrode system **shall** achieve the ground resistance specified in “Design Requirements for Grounding Electrode Systems” on page 6-3.

The requirements for installing a grounding electrode system are as follows:

- Perform a soil resistivity test at the site as described in “Soil Resistivity Measurements” on page 4-13.
- Calculate the resistance of a single ground rod as described in “Interpreting Test Results” on page 4-20.
- Calculate the number of equally spaced ground rods that are needed to meet the resistance requirements of the site using “Interpreting Test Results” on page 4-20. If the required resistance cannot be met, recalculate using longer and/or larger diameter ground rods. If the resistance still cannot be met, refer to “Special Grounding Situations” on page 6-49 and/or consult an engineering firm.
- Using a site drawing, determine where to install the needed rods, while maintaining **equal** separation between rods.
- Develop a detailed site grounding electrode system drawing based on the previous steps.
- Install the grounding electrode system using components and techniques as specified throughout this chapter.
- Bond all external metal objects to the grounding electrode system as required throughout this chapter.
- Test the grounding electrode system as described in “Ground System Testing/ Verification” on page 6-63.

6.4.1 Metallic Objects Requiring Bonding

All metal objects, as allowed by their manufacturer, that are located within 3.05 m (10 ft.) of the external grounding electrode system, or are associated with the communications site equipment, **shall** be bonded to the external grounding system using 35 mm^2 csa #2 AWG conductors as described in “Grounding Conductors” on page 6-13 (ANSI T1.313-1997). This includes but is not limited to:

- Internal Master Ground Bar (MGB)
- Metallic entry points
- Ice bridge
- Building ice shields

- Antenna tower
- Tower guy wires
- Transmission lines
- Piping
- Air conditioner
- Solid metal siding on buildings
- Vent covers
- Generator and support skids
- Storage tanks (above and below grade) if allowed
- Anchors and/or skids on prefabricated buildings
- Satellite masts and mounts
- GPS masts
- CCTV masts
- Conduits or raceways
- External light fixtures or support masts
- Fences
- Main electrical service grounding electrode system
- Main telephone company ground (if external)
- Metal roofing and truss systems
- Metallic structures on the building roof or rain gutter systems
- Any other grounding electrode systems at the site

Series or daisy chain[1] connection arrangements **shall not** be used. (See Figure 7-21 on page 7-39 for an example of a “daisy-chained” ground connection.)

1. The series or daisy chain method, which refers to any method of connection whereby the conductors are connected from one peripheral device to a second and possibly on to a third device in a series arrangement whereby the removal of the second connection point interrupts the ground path from the first device, **shall not** be used.

6.4.2 FENCES AND GATES

All site fencing within 3.05 m (10 ft.) of the grounding electrode system, or any object grounded to the grounding electrode system, **shall** be bonded to the external grounding electrode system as shown in Figure 6-14 to prevent shock hazard to personal from lightning or other electrical anomalies (ANSI T1.313-1997). Figure 6-15 shows an example of one method of bonding a fence gate to the adjacent fence post.

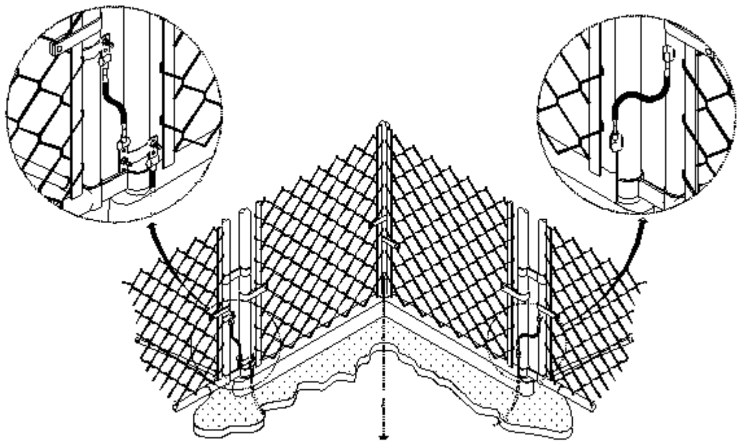


FIGURE 6-14 FENCE GROUNDING METHOD

A minimum of four bare tinned 35 mm^2 csa (#2 AWG) solid or stranded tinned copper conductors **shall** be brought from the external building ground ring. Each lead **shall** be bonded to its respective corner fence post. (See *IEEE STD-80* and *ANSI T1.313-1997* for more information).

Grounding electrode system connections to a commercial-grade fencing and gates **shall** be made using the exothermic welding process where possible. Coat all welded connections with zinc-enriched paint to prevent rusting. If exothermic welding is not possible, use the methods described below for residential fencing.

FIGURE 6-15 EXAMPLE OF GATE BONDING

If the site has residential quality fencing and/or preexisting fencing, it **shall** be grounded using heavy duty, tinned listed pipe clamps designed for grounding and stainless steel hardware. Residential-grade and/or preexisting fencing will not typically withstand exothermic welding.

All gates **shall** be bonded to the gate supporting fence post with 35 mm^2 csa (#2 AWG) minimum stranded copper wire using methods described above. This jumper wire should be constructed with a highly flexible conductor. The gate supporting fence post **shall** also be bonded to the opposite gate post. See Figure 6-16.

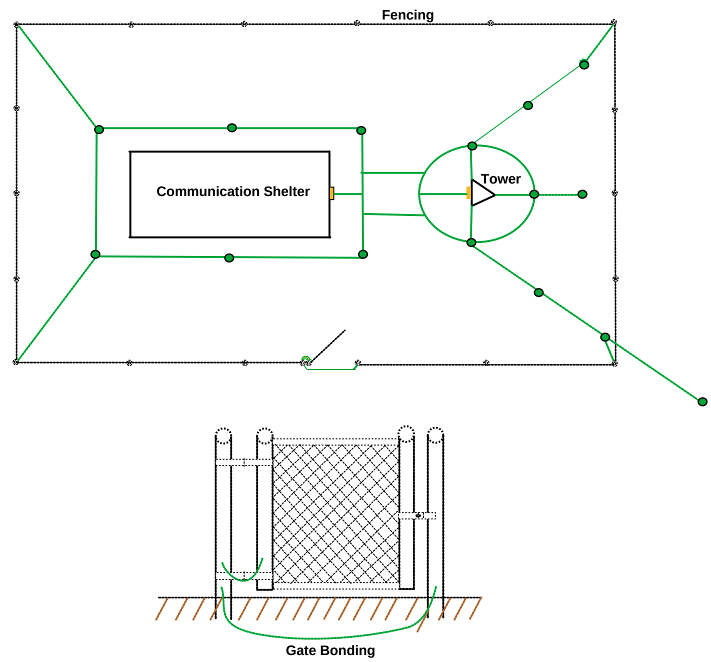


FIGURE 6-16 FENCE AND GATE GROUNDING METHOD

Fences around tower guy anchor points **shall** be bonded to the guy anchor ground rod 2.4 m (8 ft.), connected with a 35 mm^2 csa (#2 AWG) bare tinned solid copper conductor and bonded as outlined above. Guy anchor fence gates **shall** be bonded as described above.

WARNING

Braided straps shall not be used because they corrode too quickly and can be a point for RF interference.

If the site has non-electrified entry deterrent fence headers of barbed wire, razor wire, or other metallic wiring, the headers **shall** be bonded back to each corner fence post. The corner fence posts shall be bonded back to the grounding electrode system as described above (see Figure 6-17 for an example). The following method **shall** be used for bonding the deterrent wiring:

- The deterrent wiring **shall** be bonded to the corner fence post using a bare tinned 35mm^2 csa (#2 AWG) solid or stranded copper conductor.
- The copper conductor **shall** be attached by an approved bonding method to the corner fence post just below the wire support apparatus.
- Each individual run of the deterrent wiring **shall** be bonded to the copper conductor using a listed bimetallic transition connector.
- Each connection **shall** be liberally coated with a conductive antioxidant compound at the point of insertion into the connector.
- The tinned copper conductor **shall** be routed so as not come into direct contact with the deterrent wiring, fence post, fence fabric or support apparatus for the wire.
- The grounding conductor **shall** follow the proper routing methods described in this section.

FIGURE 6-17 PROPER BONDING OF ENTRY DETERRENT WIRE FENCE HEADERS

6.4.3 CABLE RUNWAYS/ICE BRIDGES

Tower cable runway/ice bridges **shall** be bonded to the external ground bus bar and grounded at all support posts using exothermic welding or other suitable method. This connection **shall** be of 35 mm^2 csa (#2 AWG) minimum bare tinned solid or stranded copper wire attached to each post and connected to the external grounding electrode system.

The tower cable runway/ice bridge **shall not** be bonded to the tower ground bus bar. Unsupported ice bridges **shall** be kept isolated from the tower using electrical isolation hardware as required, as shown in Figure 6-18. This increases the impedance from the tower to the building, reducing the amount of energy reaching the communications shelter in the event of a lightning strike. This does not lessen the cable runway/ice bridge grounding requirements.

If more than one span of cable runway is used between the tower and building, it is recommended that bonding jumpers be installed between the sections. The bonding jumpers should use two hole lugs and stainless steel hardware, or other suitable methods should be installed between each section to prevent loss of ground continuity with weathering.

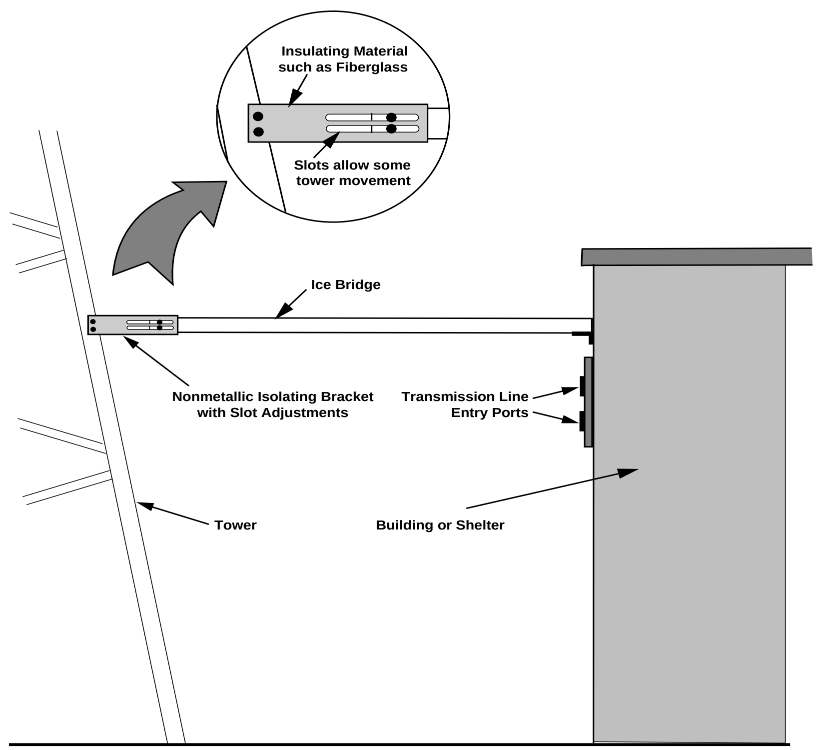


FIGURE 6-18 ELECTRICALLY ISOLATING THE ICE BRIDGE FROM THE TOWER

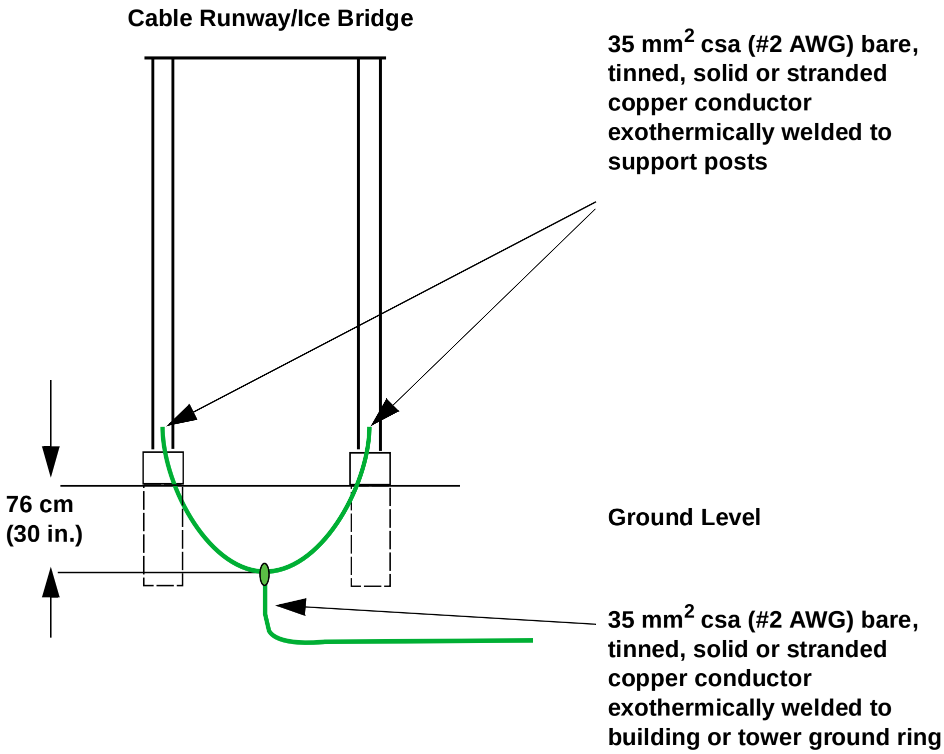


FIGURE 6-19 PROPER GROUNDING OF SELF-SUPPORTING ICE BRIDGE

FIGURE 6-20 EXAMPLE OF ICE BRIDGE ISOLATED FROM THE TOWER

6.4.4 ROOF-MOUNTED ANTENNA MASTS AND METAL SUPPORT STRUCTURES

All roof-mounted antenna masts and metal antenna support structures **shall** be bonded to the building grounding electrode system. If a separate antenna and/or tower grounding electrode system is installed, it **shall** be bonded to the building electrical grounding electrode system. Consult the building engineer or manager to determine information about existing building grounding electrode systems. The building engineer should also be informed before attempting to weld or drill on the building rooftop (See *NFPA 70, Article 250-52* and *Article 810-21* for more details).

NOTE: Rooftop mounted towers are not covered in this section. Refer to "Rooftop Mounted Tower Structures" on page 6-34 for information about rooftop tower grounding requirements.

Grounding **shall** comply with the following:

- NFPA 70, Article 810-21.
- Roof-mounted antenna masts and metal support structures **shall** be bonded to any existing lightning protection system as required by NFPA 780, Section 3-17.
- Grounding conductor **shall not** be required to be insulated (per NFPA 70, Article 810-21(b)). Green-jacketed conductor or equivalent is recommended for runs inside.
- Grounding conductor **shall** be protected from physical damage (per NFPA 70, Article 810-21(d) and NFPA 780, Section 3-9.11).
- Grounding conductor **shall** be run in as straight a line as is practical (per NFPA 70, Article 810-21(e) and ANSI T1.313-1997).
- Grounding conductor **shall** be securely fastened at intervals not exceeding 91 cm (3 ft.). (See *NFPA 70, Article 250-64(b), 810-21(c)* and *NFPA 780, Section 3-10* for more information.)
- Minimum bend radius of grounding conductors **shall** be 20.3 cm (8 in.), and the included angle **shall not** exceed 90 degrees as shown in Figure 6-9 (per NFPA 780, Section 3-9.5 and ANSI T1.313-1997).
- Grounding conductors **shall** be permitted to be run either outside or inside the building or structure (per NFPA 70, Article 810-21(g)).
- Grounding conductors run outside from the roof top to ground **shall** be protected for a minimum distance of 1.8 m (6 ft.) above grade level when located in areas susceptible to damage (per NFPA 780, Section 3-9.11).
- The roof-mounted antenna mast and support structure **shall** be grounded using grounding conductors sized as follows:
    - Using 35 mm^2 (#2 AWG) or larger tinned solid or stranded copper conductor for overall building heights or conductor runs of 23 m (75 ft.) or less. (See *NFPA 780, Section 3-1.1* for more information.) Untinned green-jacketed[1] conductor may also be used.

- Using 67.43 mm^2 csa (#2/0 AWG) or larger tinned solid or stranded copper conductor for overall building heights or conductor runs more than 23 m (75 ft.). (See *NFPA 780, Section 3-1.1* for more information.) Untinned green jacketed[1] conductor may also be used.

- The grounding conductor **shall** be connected to the nearest accessible location on at least one of the following and more than one if practical and available. (See *NFPA 70, Article 810-21(f), NFPA 780, Sections 3-9* and *3-9.10* for more information.)
  - The building or structure grounding electrode system as covered in NFPA 70, Article 250-50, using down conductors from the roof-top directly to the building's grounding electrode system. Down conductors should not be used as the only means of grounding the roof mounted antenna mast and metal support structures, unless no other secondary means are available.
  - Connection to the grounding electrode system may include items listed below. (See *NFPA 70, Article 810-21(f)* for more information).
    - Underground connection directly to the grounding electrode system, or directly to a supplemental grounding electrode system and bonding the grounding electrode systems together (see Figure 6-41). Connection to the grounding electrode system **shall** comply with "Bonding to the External Grounding Electrode System" on page 6-56.
    - The metallic power service raceway.
    - The service equipment enclosure.
    - The electrical service grounding electrode conductor.
    - The power service accessible means external to enclosures as covered in NFPA 70, Article 250-92(b), using grounding conductors as described above.
    - The power service accessible means external to enclosures as covered in NFPA 70, Article 250-92(b).
- Effectively grounded interior metal water piping system as covered in NFPA 70, Article 250-104(a).
- Effectively grounded metal structure, including exposed structural building steel. See also *NFPA 780, Section 3-16* for more information.

See Figure 6-39 for examples of rooftop grounding.

NOTE: Before metal piping systems are relied upon for use in a grounding electrode system, electrical continuity **shall** be verified. See *NFPA 70, Article 250-68* for more details.

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1. Ground conductors may be green, green with a yellow stripe or black with green tape on a black conductor at points designated by NFPA 70, Article 250-119 or jurisdictional codes.

If the building grounding electrode system resistance cannot be verified or cannot provide a low-impedance path to ground (see “Ground System Testing/Verification” on page 6-63), a supplemental grounding electrode system should be installed to ensure the resistance requirements of this chapter are met. The supplemental grounding electrode system **shall** be bonded to the existing grounding electrode system (per NFPA 70, Article 810-21(j) and NFPA 780, Section 3-14.1). See Figure 6-41 for an example of a supplemental grounding electrode system.

WARNING

Do not attempt to install a separate grounding electrode system without bonding it to the existing grounding electrode system. A difference in potentials could result.

6.4.5 TOWERS

Antenna masts and metal support structures **shall** be grounded (See *NFPA 70, Articles 810-15* and *810-21, ANSI T1.313-1997*, and *ANSI/EIA/TIA 222-f* for more information). Antenna towers **shall** be bonded to the tower ground ring, as described in this section. The tower ground ring **shall** be bonded to the building ground ring with at least two conductors of 35 mm^2 csa (#2 AWG) bare solid or stranded tinned copper conductor. Conductors bonded to the tower structures **shall** be exothermically welded or as required to comply with the tower manufacturer’s requirements. It is recommended that ground radials be used on all tower ground rings when the necessary land area is available. (See “Enhancing Tower Grounding Systems” on page 6-49.)

Some antenna structures, such as water storage tanks, require special grounding and bonding techniques and should be specifically engineered.

6.4.5.1 SELF-SUPPORTING TOWERS AND GUYED LATTICE TOWERS

Self-supporting and guyed lattice towers **shall** be grounded as follows:

- The tower **shall** be encircled by a ground ring containing at least 3 equally spaced ground rods. For optimum ground rod spacing of 4.88 m (16 ft.) for 2.44 m (8 ft.) ground rods, the tower ground ring should have a minimum diameter of 5.49 m (18 ft.).
- Self-supporting towers exceeding 1.5 m (5 ft.) in base width **shall** have 4 ground rods (ANSI T1.313-1997 and ANSI/EIA/TIA-222f). For a optimum ground rod spacing of 4.88 m (16 ft.) for 2.44 m (8 ft.) ground rods, the tower ground ring should have a minimum diameter of 7 m (23 ft.).
- The tower ground ring **shall** be installed in accordance with “External Ground Ring” on page 6-15.

- Ground rods **shall** meet the specification and be installed in accordance with "Ground Rods" on page 6-6. Ground rods used for grounding steel antenna towers, or installed in close proximity of the tower should be galvanized to prevent galvanic corrosion of the tower (See *ANSI/TIA/EIA-222-F*). This is especially important when the resistivity of the soil is at or below 2,000 ohm-cm (See *ANSI/TIA/EIA-222-F, Annex J*).
- Each leg of a self-supporting tower **shall** be bonded to the tower ground ring using grounding conductors of 35 mm^2 csa (#2 AWG) minimum, bare tinned solid or stranded copper conductor. See Figure 6-21.

FIGURE 6-21 SELF-SUPPORTING TOWER LEG GROUNDING

The bottom plate of a guyed tower **shall** be bonded to the tower ground ring using three equally spaced grounding conductors; or each leg **shall** be bonded to the tower ground ring. Bonding **shall** be done using 35 mm^2 csa (#2 AWG) minimum, bare solid or stranded tinned copper conductor. See Figure 6-22.

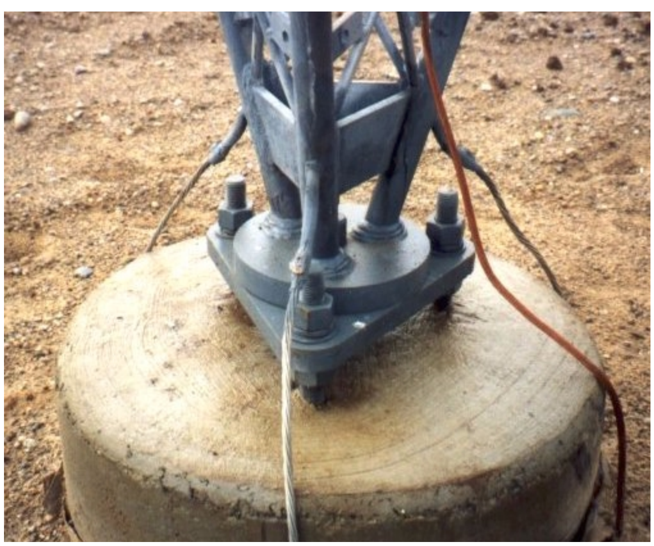


FIGURE 6-22 GUYED TOWER GROUNDING

The tower grounding conductors **shall** be exothermically bonded to the tower unless specifically directed otherwise by the tower manufacturer.

The tower grounding conductors **shall** each be bonded to the tower ground ring at the location of the respective closest ground rod. Bonding **shall** meet the requirements of "Bonding to the External Grounding Electrode System" on page 6-56.

Guy wires **shall** be grounded as follows (see Figure 6-23 and Figure 6-24):

- A ground rod **shall** be installed at each guy anchor point, with the following exception: if the guy anchor is not encased in concrete, the tower anchor itself will serve as the ground point.
- If the guy wire anchor is encased in concrete, keep copper rods a minimum of 61 cm (2 ft.) away. A galvanized rod can be used if desired without any minimum spacing requirements. Ground rods used for grounding guy wires should be galvanized to prevent galvanic corrosion of the guy anchor (See *ANSI/TIA/EIA-222-F*). This is especially important when the resistivity of the soil is at or below 2,000 ohm-cm (See *ANSI/TIA/EIA-222-F, Annex J* for more information).
- The ground rod **shall** be installed in accordance with "Ground Rods" on page 6-6.
- A grounding conductor of 35 mm^2 csa (#2 AWG) solid or stranded bare tinned copper **shall** be bonded to the ground rod in accordance with"Bonding to the External Grounding Electrode System" on page 6-56. Do not use untinned wire.
- The grounding conductor **shall** be connected to each guy wire using stainless steel clamps. Each connection **shall** be coated in an anti-oxidant compound.

WARNING

Do not attempt to exothermically weld to tower guy wires.

- The grounding conductor **shall** be connected to the guy wires above the turnbuckles.
- A continuous vertical drop **shall** be maintained.

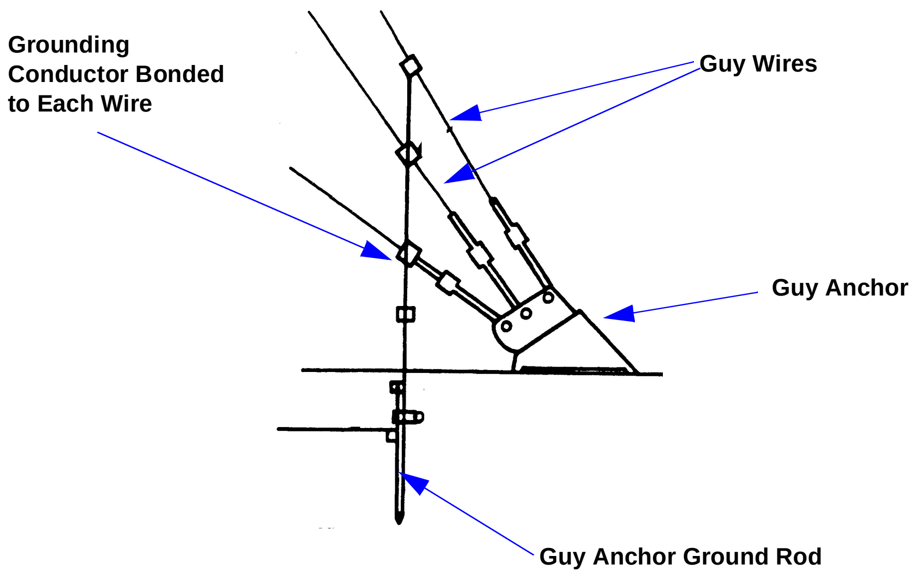


FIGURE 6-23 TOWER GUY WIRE GROUNDING

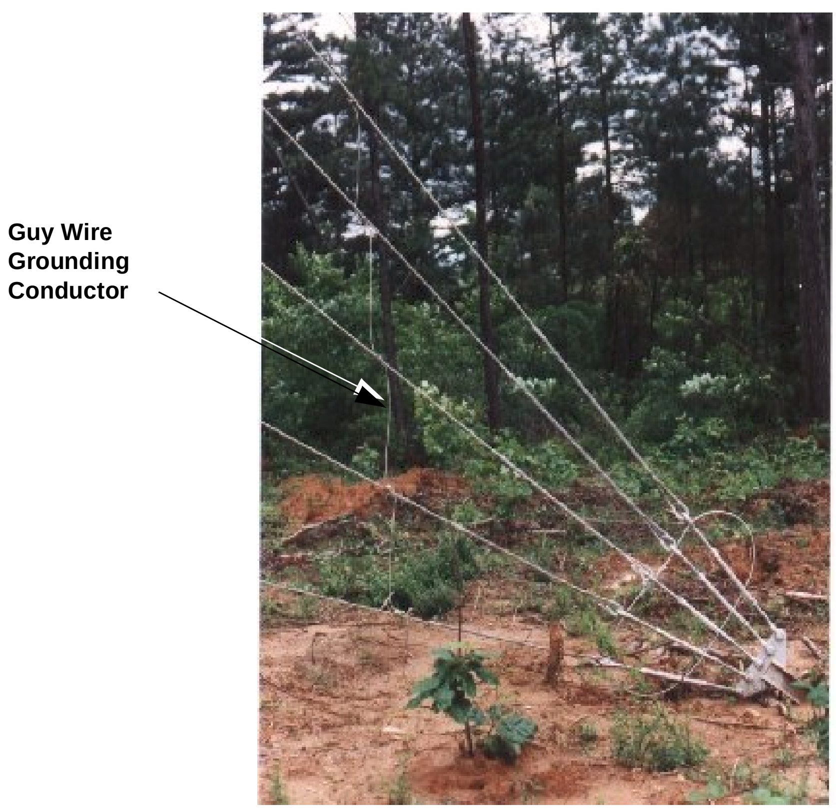


FIGURE 6-24 EXAMPLE OF TOWER GUY WIRE GROUNDING

6.4.5.2 MONOPOLE TOWERS

WARNING

No welding, heating, or drilling of tower structural members shall be performed without written approvals from the tower manufacturer.

Monopole towers **shall** be grounded as follows (see Figure 6-25 and Figure 6-26):

- The tower **shall** be encircled by a ground ring containing at least four equally spaced ground rods. For a optimum ground rod spacing of 4.88 m (16 ft.) for 2.44 m (8 ft.) ground rods, the tower ground ring should have a minimum diameter of 7 m (23 ft.).
- The tower ground ring **shall** be installed in accordance with "External Ground Ring" on page 6-15.
- Ground rods **shall** meet the specification and be installed in accordance with "Ground Rods" on page 6-6.
- The tower **shall** be bonded to the tower ground ring using at least four equally spaced grounding conductors of 35 mm^2 csa (#2 AWG) minimum, bare tinned solid copper conductor. For high lightning prone geographical areas, larger conductors and/or more conductors should be used.
- The tower grounding conductors **shall** be exothermically bonded to the tower unless specifically directed otherwise by the tower manufacturer.
- The tower grounding conductors **shall** be bonded to the tower ground ring using exothermic welding or high compression fittings compressed to a minimum of 12 tons (13.3 tonnes) of pressure.

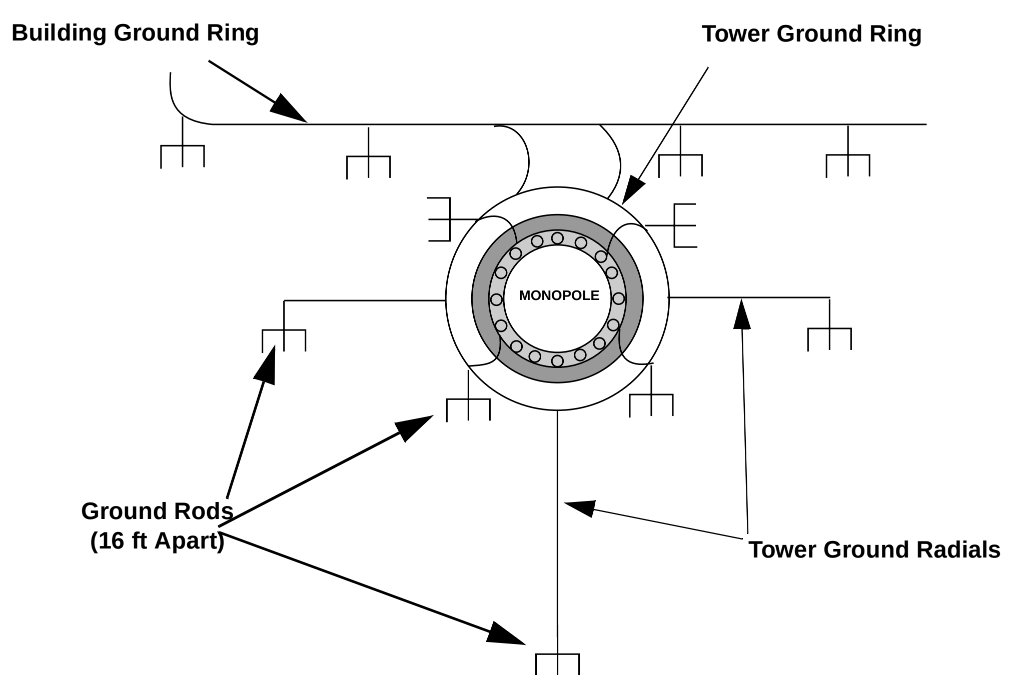


FIGURE 6-25 MONOPOLE TOWER GROUNDING

FIGURE 6-26 EXAMPLE OF MONOPOLE TOWER GROUND CONDUCTOR

6.4.5.3 ROOFTOP MOUNTED TOWER STRUCTURES

Rooftop mounted towers may increase the lightning risk index for the buildings they are installed upon. Due to their increased height and lightning risk probability, all exposed buildings with rooftop towers **shall** be equipped with a lightning protection system as outlined in NFPA 780 (See *ANSI T1.313-1997* for more information).

An engineering firm specializing in the design and installation of lightning protection systems should be consulted for proper design and installation of the building lightning protection system. Rooftop mounted tower structures **shall** be grounded in accordance with the following requirements:

- ANSI T1.313-1997
- The lightning protection system **shall** meet the requirements of NFPA 780.
- The rooftop mounted tower support legs **shall** be interconnected with a conductor to form a roof tower ground ring. A guyed tower base plate can be used in place of the roof tower ground ring.
    - The conductors **shall** meet the requirements of“Grounding Conductors” on page 6-13.
    - Bonding to the tower **shall** meet the requirements of the tower manufacturer and “Bonding Methods” on page 6-60.
- The roof tower ground ring or guyed tower base plate **shall** bond to the main roof perimeter lightning protection ring by a minimum of two opposing conductors at or within 61 cm (24 in.) of a grounding down conductor, or other main grounding conductor as defined by NFPA 780, such as effectively grounded structural steel.
    - The conductors **shall** meet the requirements of “Grounding Conductors” on page 6-13.
    - Bonding of the conductors **shall** meet the requirements of“Bonding Methods” on page 6-60.

- All tower guy/anchors that are attached directly to the roof **shall** be bonded to the lightning protection system ring.
    - The bonding conductors **shall** meet the requirements of "Grounding Conductors" on page 6-13.
    - Bonding of the tower guy/anchors to the lightning protection system ring **shall** meet the requirements of "Bonding Methods" on page 6-60.
- Other metallic objects on the roof **shall** be bonded to the roof perimeter lightning protection system ring as required by NFPA 780 and ANSI T1.313-1997.
- All grounding electrodes at the building **shall** be bonded together to form a grounding electrode system. See *NFPA 70, Articles 250-90, 800-40, 810-21*, and *820-40*; and *NFPA 780, Section 3-14*.

See Figure 6-27 for an example of a typical rooftop tower grounding system.

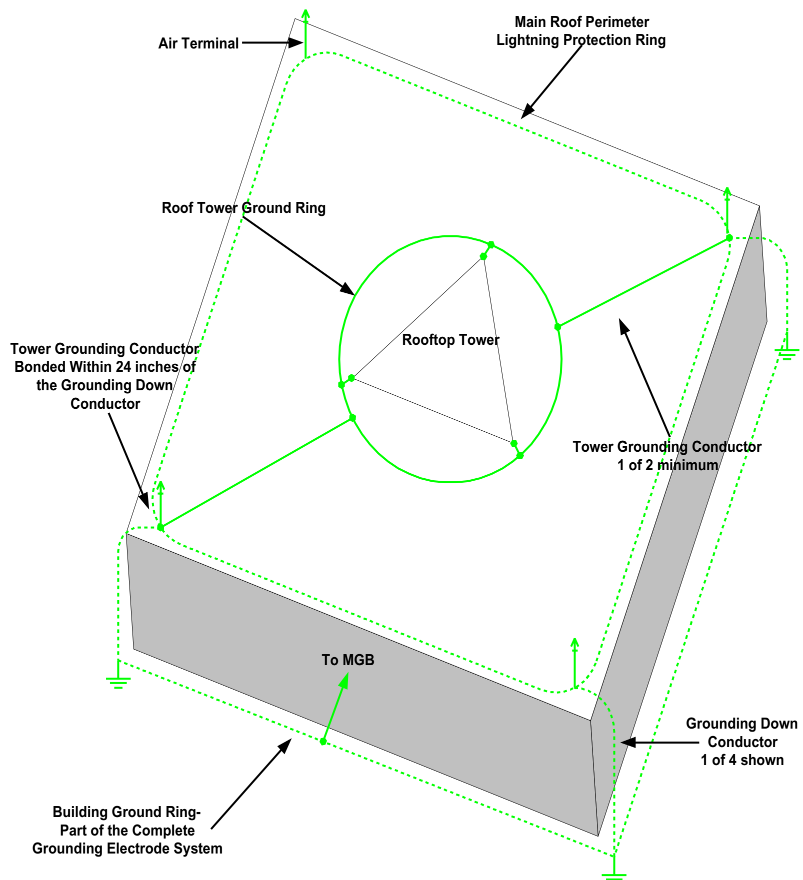


FIGURE 6-27 TYPICAL ROOFTOP TOWER GROUNDING RING

6.4.6 RF TRANSMISSION LINES AND PREAMPLIFIERS

Tower mounted antenna preamplifiers **shall** be grounded to the tower using 35 mm^2 csa (#2 AWG) solid or stranded tinned copper conductor. Connection to the amplifier **shall** be made in accordance with the amplifier manufacturer requirements. Connection to the tower **shall** be made using exothermic welding unless another method, such as mechanical clamps, is specified by the tower manufacturer. See Figures 6-29 through 6-32 for examples of transmission line grounding conductor attachment methods.

Transmission lines **shall** be grounded to prevent lightning from creating a difference of potential between the tower and the transmission lines. Such a potential difference could cause arcing between the tower and the coaxial transmission line cable, resulting in damage to the transmission lines. All transmission lines **shall** be grounded using ground kits as follows (See *ANSI T1.313-1997* for more information):

- Transmission line ground kits **shall** be installed per manufacturer specifications.
- Transmission line ground kits **shall** be sealed from the weather to prevent water and corrosion damage to the transmission line.
- Transmission line ground kits attached to the tower **shall** be attached to a tower manufacturer-approved ground bus bar or other tower manufacturer approved locations on the tower structure. Cable ladders **shall not** be used as a grounding point for transmission lines unless effectively grounded using low impedance methods and specifically designed by the tower manufacturer as a transmission line grounding point.
- Transmission line ground kits **shall** be attached to the tower using tower manufacturer approved methods, such as clamps or exothermic welding. See Figure 6-28 through Figure 6-33 for examples of methods used to attach to the tower.
- Transmission line ground kit grounding conductors **shall** be installed without drip loops, parallel to the transmission line, and pointed down towards the ground to provide a direct discharge path for lightning.
- Transmission lines **shall** be grounded at the top of the vertical run, near the antenna.
- Transmission lines **shall** be grounded at the bottom of the vertical run, no more than 1.8 m (6 ft.) above the horizontal transition to the building, shelter, equipment housing, or cabinet.
- Additional transmission line ground kits **shall** be installed as needed to limit the distance between ground kits to 22.8 m (75 ft.). High lightning prone geographical areas should consider ground kits at intervals no more than 15.24 m (50 ft.).
- Transmission lines at the bottom of the vertical run **shall** be bonded to the tower ground bus bar, when provided. If no tower ground bus bar is provided, then the transmission line **shall** bond directly to the tower using methods described above.
- Transmission lines **shall** be grounded to the external ground bus bar within 61 cm (2 ft.) of the building, shelter, equipment housing, or cabinet entry (See *NFPA 70, Article 820-33*).

CAUTION

Braided ground conductors shall not be used under any circumstances. Braided conductors corrode easily and become a point for RF interference.

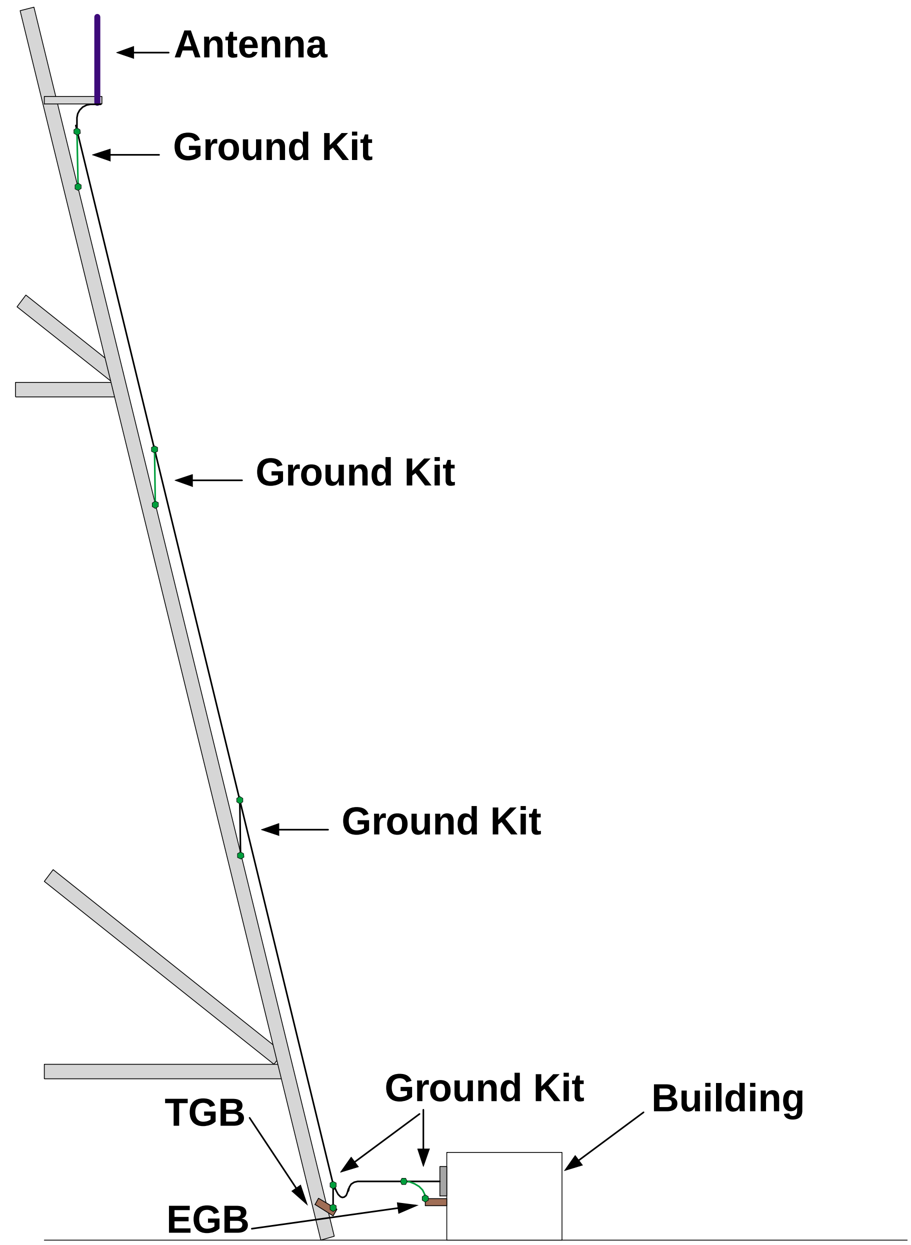
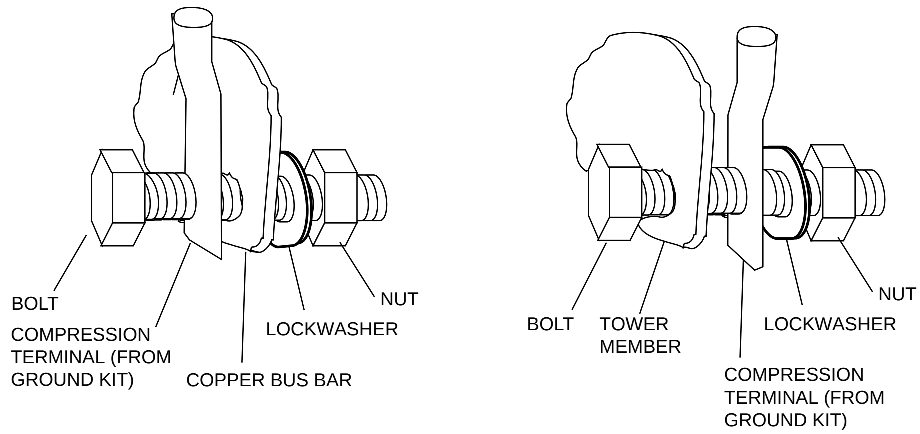


FIGURE 6-28 LOCATION OF TRANSMISSION LINE GROUNDING KITS



Compression Terminal and Ground Kit to Bus Bar Configuration

Ground Kit to Existing Tower Structure Bolt (Bolt with Vertical Drop Only)

NOTE:
Except for Tower Member and Bus Bar, all materials shall be stainless steel or equivalent.

FIGURE 6-29 TOWER GROUND KITS

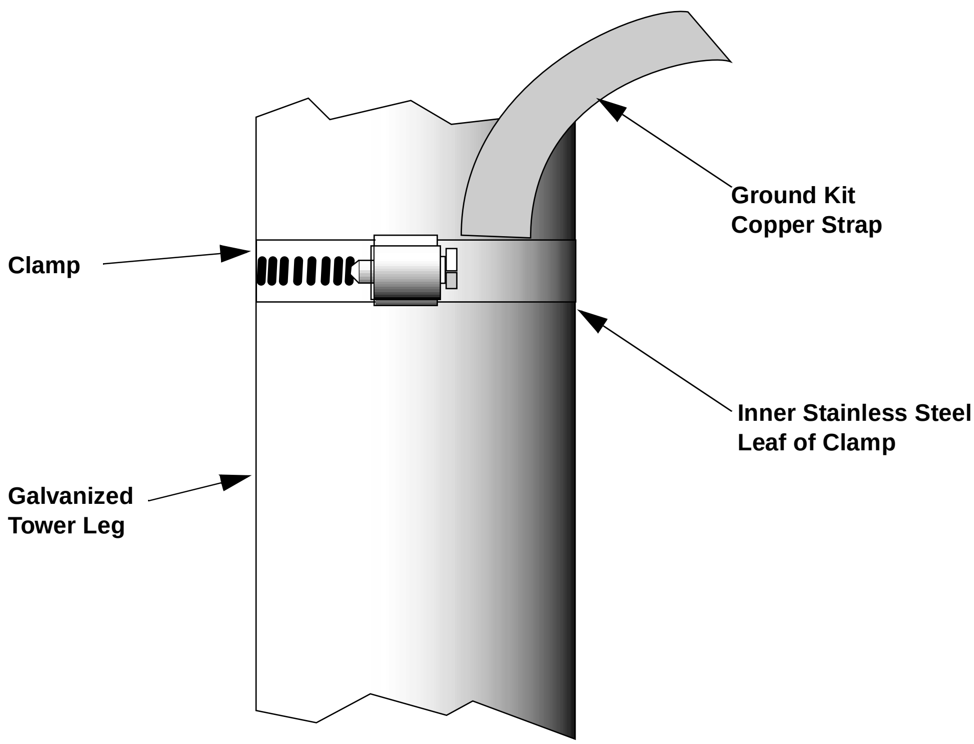


FIGURE 6-30 GROUNDING TRANSMISSION LINE TOP AND MIDDLE (TUBULAR TOWER)

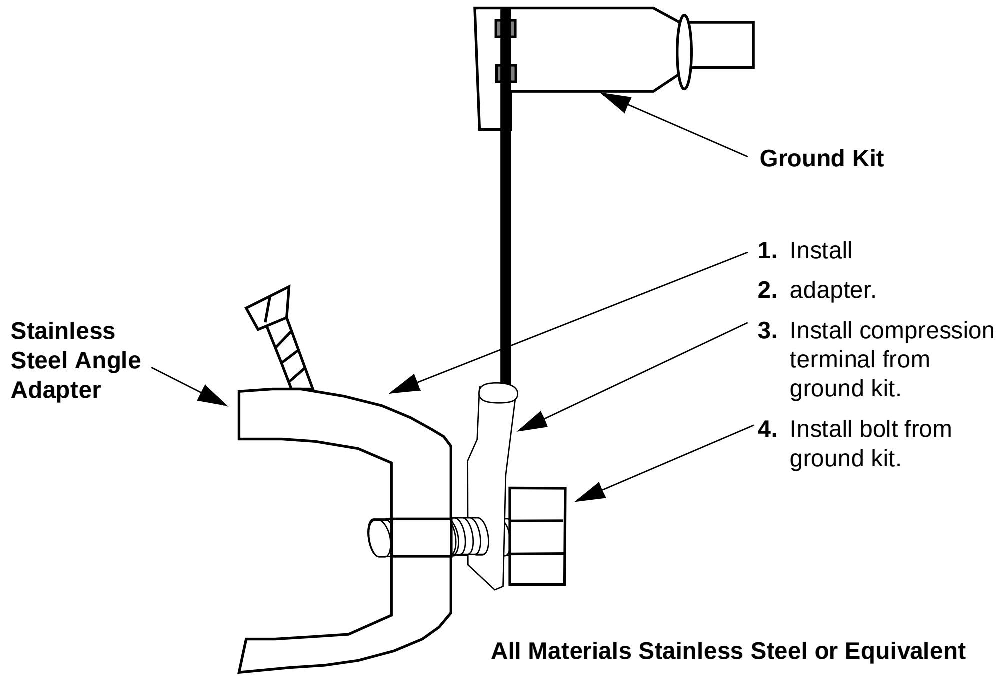


FIGURE 6-31 GROUNDING TRANSMISSION LINE TOP AND MIDDLE (ANGULAR TOWER)

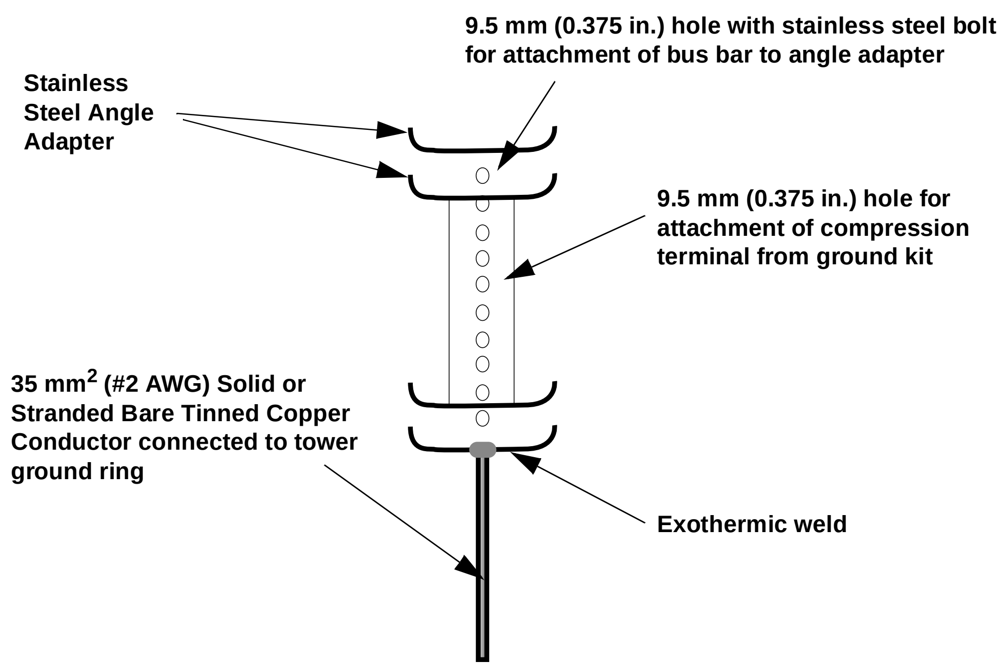


FIGURE 6-32 BUS BAR CONFIGURATION, BOTTOM GROUND KIT (ANGULAR TOWER)

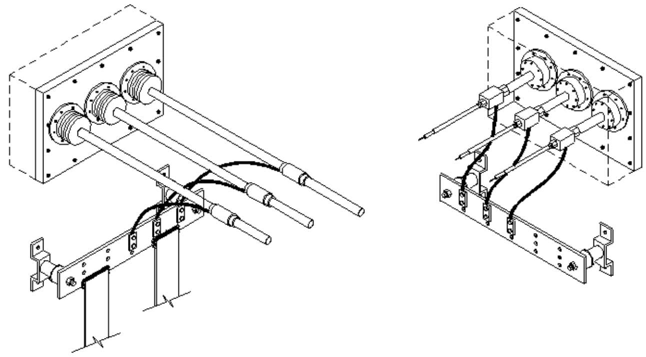


FIGURE 6-33 TRANSMISSION LINE GROUNDING AT BUILDING ENTRY POINT

6.4.7 METALLIC BUILDING SIDING

Metal siding through which electrical service or utility conductors penetrate (per NFPA 70, Article 250-116 FPN) and prefabricated shelter frames and anchors **shall** be bonded to the site grounding electrode system. When solid metal siding panels are insulated from one another (by weatherstripping), each panel **shall** be bonded to the external grounding electrode system.

6.4.8 DEDICATED COMMUNICATIONS SITE BUILDING

All dedicated communications site buildings **shall** have an external grounding electrode system installed. The grounding electrode system resistance **shall** meet the requirements of “Design Requirements for Grounding Electrode Systems” on page 6-3. (See *ANSI T1.313-1997* for more information.)

A typical site grounding electrode system layout is shown in Figure 6-34. The building grounding electrode system requirements are as follows and **shall** also include any additional grounding electrode system components needed to achieve the resistance requirements of the site (see “Minimum Site Grounding Requirements” on page 6-20):

- The building **shall** be encircled by a ground ring installed in accordance with paragraph 6.3.2.4 on page 6-15.
- The building ground ring **shall** have a ground rod, as specified in paragraph 6.3.1.1 on page 6-6, at each corner of the shelter and rods as necessary to reduce the distance between rods to a maximum of 4.9 m (16 ft.), or twice the rod’s length.
- The ground rods **shall** be installed in accordance with paragraph 6.3.1.1 on page 6-6.

- The ground rods **shall** be exothermically bonded to the ground ring or as otherwise allowed in "Bonding to the External Grounding Electrode System" on page 6-56.
- The building ground ring **shall** be bonded to the tower ground ring using a minimum of two 35 mm^2 csa (#2 AWG) bare tinned copper conductors.
- Tower **shall** be grounded in accordance with "Towers" on page 6-29.

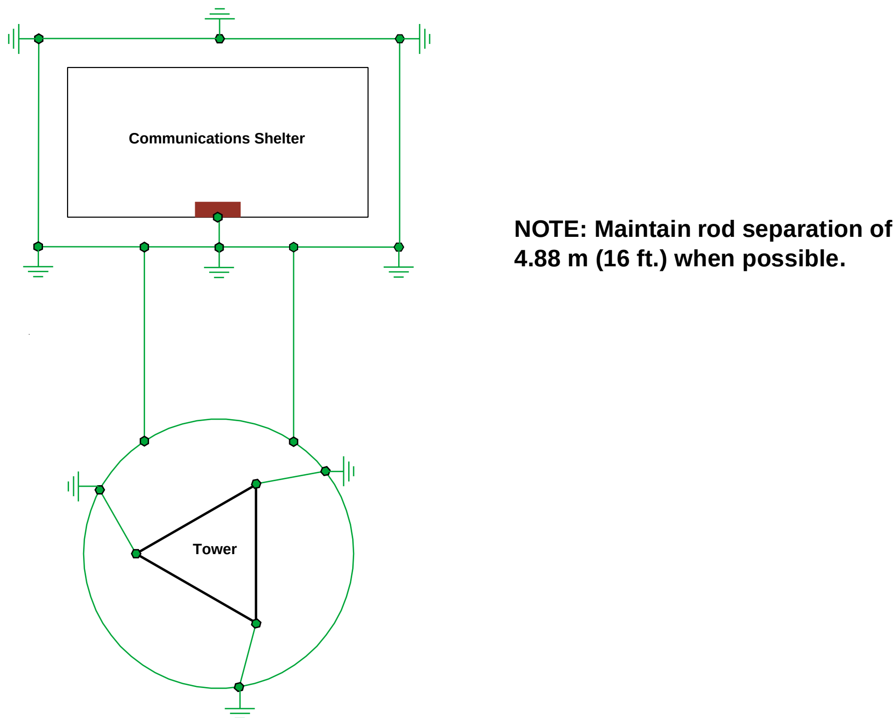


FIGURE 6-34 SITE GROUNDING ELECTRODE SYSTEM

6.4.8.1 GENERATORS EXTERNAL TO THE BUILDING

Generators installed outside of the building, within 1.8 m (6 ft.) of the building, **shall** be bonded to the nearest practical location on the grounding electrode system as shown in Figure 6-35. External generator grounding **shall** comply with the following:

- Bonding to the generator chassis **shall** be done in accordance with the manufacturer's requirements.
- Grounding conductors **shall** meet the requirements of "Grounding Conductors" on page 6-13.
- Bonding to the grounding electrode system **shall** be done in accordance with "Bonding to the External Grounding Electrode System" on page 6-56.

- Generators installed more than 1.8 m (6 ft.) away from the building, shelter, equipment housing, or cabinet grounding electrode system **shall** have an additional ground rod installed near the generator and bonded to the generator (ANSI T1.313-1997). See Figure 6-35.
  - The additional ground rod **shall** meet the requirements of "Ground Rods" on page 6-6.
  - The additional ground rod **shall** be installed using methods described in "Ground Rods" on page 6-6.

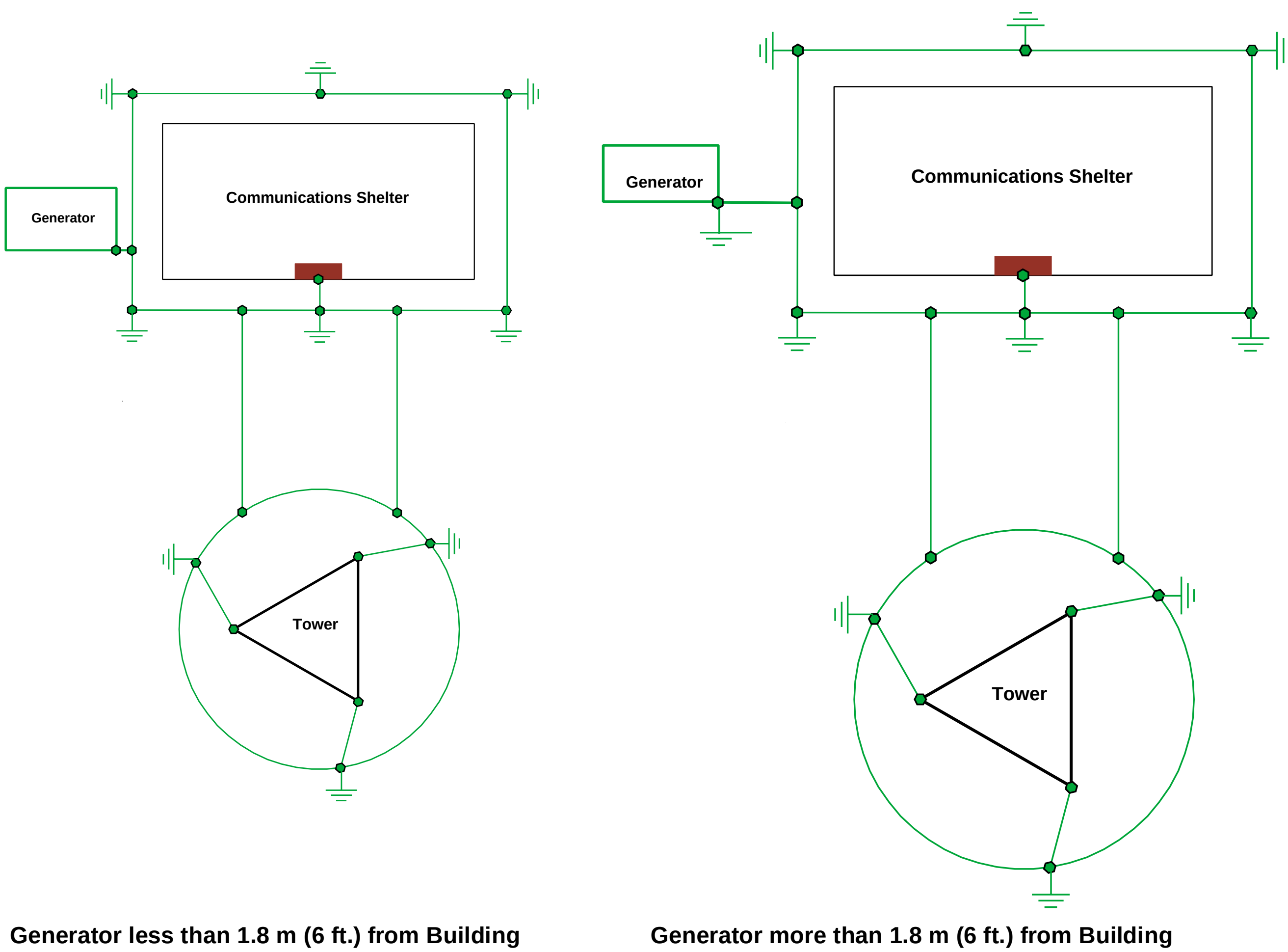


FIGURE 6-35 GENERATOR GROUNDING

6.4.9 INTEGRATED COMMUNICATIONS SITES

For communications sites located on the rooftop or within a building whose primary purpose is something other than a communications site, connection of the communications internal grounding system as described in Chapter 7, "Internal Grounding," **shall** be made to the building grounding electrode system (See ANSI/TIA/EIA-607). Connection of the communications site master ground bus bar (MGB) to the building grounding electrode system **shall** be as made using the following techniques:

NOTE: Gas piping systems **shall not** be used as part of a grounding electrode system (per NFPA 70, Article 250-52).

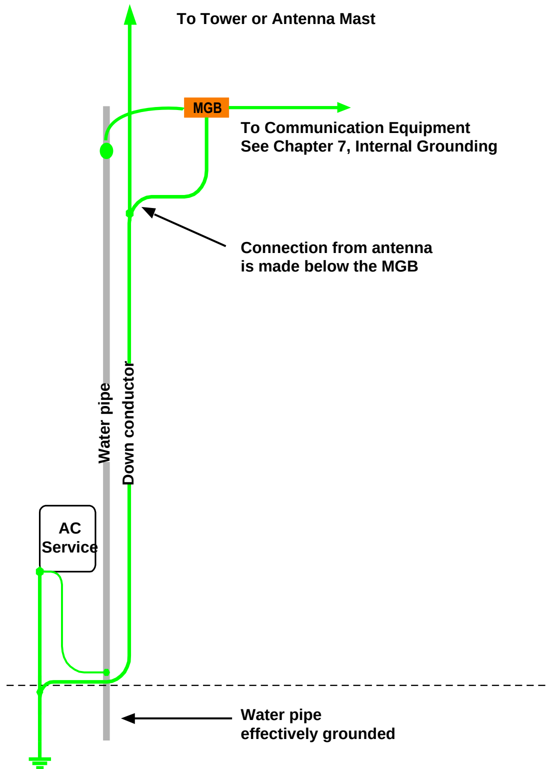
NOTE: Before metal piping systems are relied upon for use in a grounding electrode system, electrical continuity **shall** be verified. (See *NFPA 70, Article 250-68* for more details.)

- For integrated communications sites with roof mounted antennas or antenna structures, the requirements of "Roof-Mounted Antenna Masts and Metal Support Structures" on page 6-27 **shall** be followed.
- Grounding conductor **shall** be protected from physical damage (per NFPA 70, Article 810-21(d) and NFPA 780, Section 3-9.11).
- Grounding conductor **shall** be run in as straight a line as is practical (per NFPA 70, Article 810-21(e) and ANSI T1.313-1997).
- Grounding conductor **shall** be securely fastened at intervals not exceeding 91 cm (3 ft.). (See *NFPA 70, Articles 250-64(b), 810-21(c)* and *NFPA 780, Section 3-10* for more information.)
- Minimum bend radius of grounding conductors **shall** be 20.3 cm (8 in.), and the included angle **shall not** exceed 90 degrees as shown in Figure 6-9 per NFPA 780, Section 3-9.5 and ANSI T1.313-1997.
- Grounding conductors **shall** be permitted to be run either outside or inside the building or structure (per NFPA 70, Article 810-21(g)).
- Grounding conductors run outside from the roof top to ground **shall** be protected for a minimum distance of 1.8 m (6 ft.) above grade level when located in areas susceptible to damage (per NFPA 780, Section 3-9.11).
- The integrated communications site **shall** be grounded using grounding conductors sized as follows:
  - Using 35 mm^2 csa (#2 AWG) or larger tinned copper conductor for conductor runs of 23 m (75 ft.) or less. (See *NFPA 780, Section 3-1.1* for more information.) Untinned green jacketed[1] conductor or equivalent may also be used.
  - Using 67.43 mm^2 csa (#2/0 AWG) or larger tinned copper conductor for conductor runs more than 23 m (75 ft.). (See *NFPA 780, Section 3-1.1* for more information.) Untinned green jacketed[1] conductor may also be used.

- The grounding conductor **shall** be connected to the nearest accessible location on at least one of the following and more than one if practical and available (See *NFPA 70, Article 810-21(f)*, *NFPA 780, Sections 3-9* and *3-9.10* for more information):
    - The building or structure grounding electrode system as covered in NFPA 70, Article 250-50, using down conductors from the integrated communications site directly to the building's grounding electrode system. Down conductors should not be used as the only means of grounding the integrated communications site, unless no other secondary means are available. Connection to the grounding electrode system may include items listed below. (See *NFPA 70, Article 810-21(f)* for more information.)
        - Underground connection directly to the grounding electrode system, or directly to a supplemental grounding electrode system and bonding the grounding electrode systems together (See Figure 6-39). Connection to the grounding electrode system **shall** comply with "Bonding to the External Grounding Electrode System" on page 6-56.
        - The metallic power service raceway.
        - The service equipment enclosure.
        - The electrical service grounding electrode conductor.
        - The power service accessible means external to enclosures as covered in NFPA 70, Article 250-92(b), using grounding conductors as described above.
    - Effectively grounded interior metal water piping system as covered in NFPA 70, Article 250-104(a), using grounding conductors as described above.
    - Effectively grounded metal structure, including exposed structural building steel, using grounding conductors as described above. (See *NFPA 780, Section 3-16* for more information.)

Figure 6-37 and Figure 6-38 show grounding options for integrated sites, based on ANSI/TIA/EIA-607.

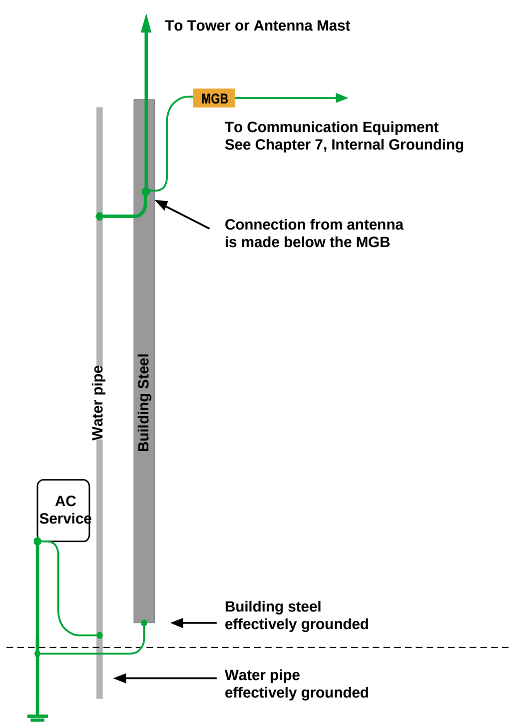
1. Ground conductors may be green, green with a yellow stripe or black with green tape on a black conductor at points designated by NFPA 70, Article 250-119 or jurisdictional codes.



NOTES:

1. 35 mm^2 csa (#2 AWG) conductor for runs of 22.9 m (75 ft.) or less
2. 67.43 mm^2 csa (#2/0 AWG) conductor for runs longer than 22.9 m (75 ft.)

FIGURE 6-36 SITE ON DIFFERENT FLOOR THAN AC SERVICE FEED, BUILDING STEEL NOT AVAILABLE



NOTES:

1. 35 mm^2 csa (#2 AWG) conductor for runs of 22.9 m (75 ft.) or less
2. 67.43 mm^2 csa (#2/0 AWG) conductor for runs longer than 22.9 m (75 ft.)

FIGURE 6-37 SITE ON DIFFERENT FLOOR THAN AC SERVICE FEED, BUILDING STEEL AVAILABLE

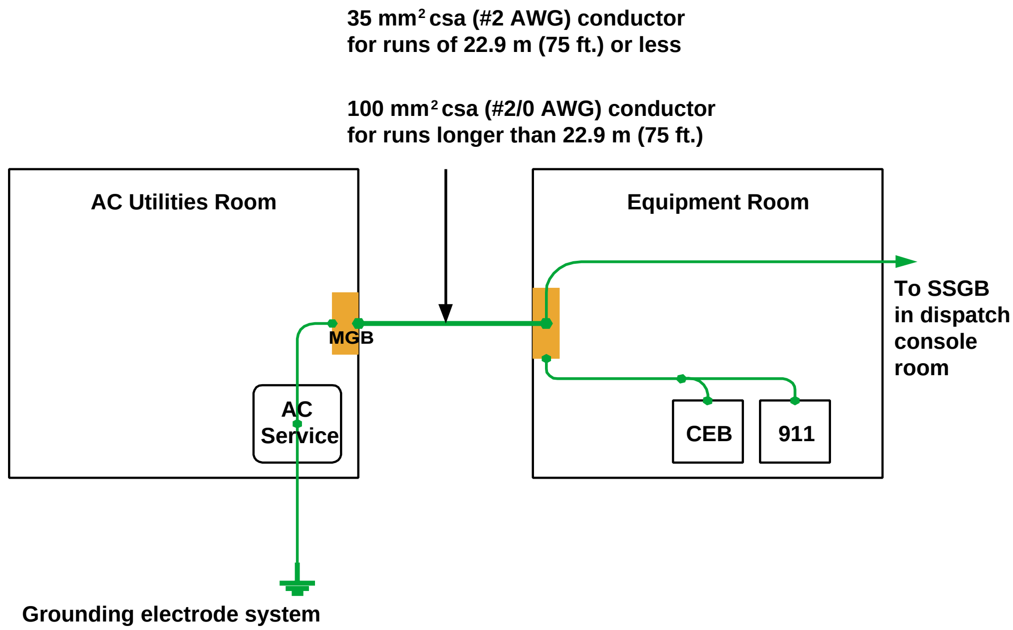


FIGURE 6-38 SITE ON SAME FLOOR BUT DIFFERENT ROOM THAN AC SERVICE FEED

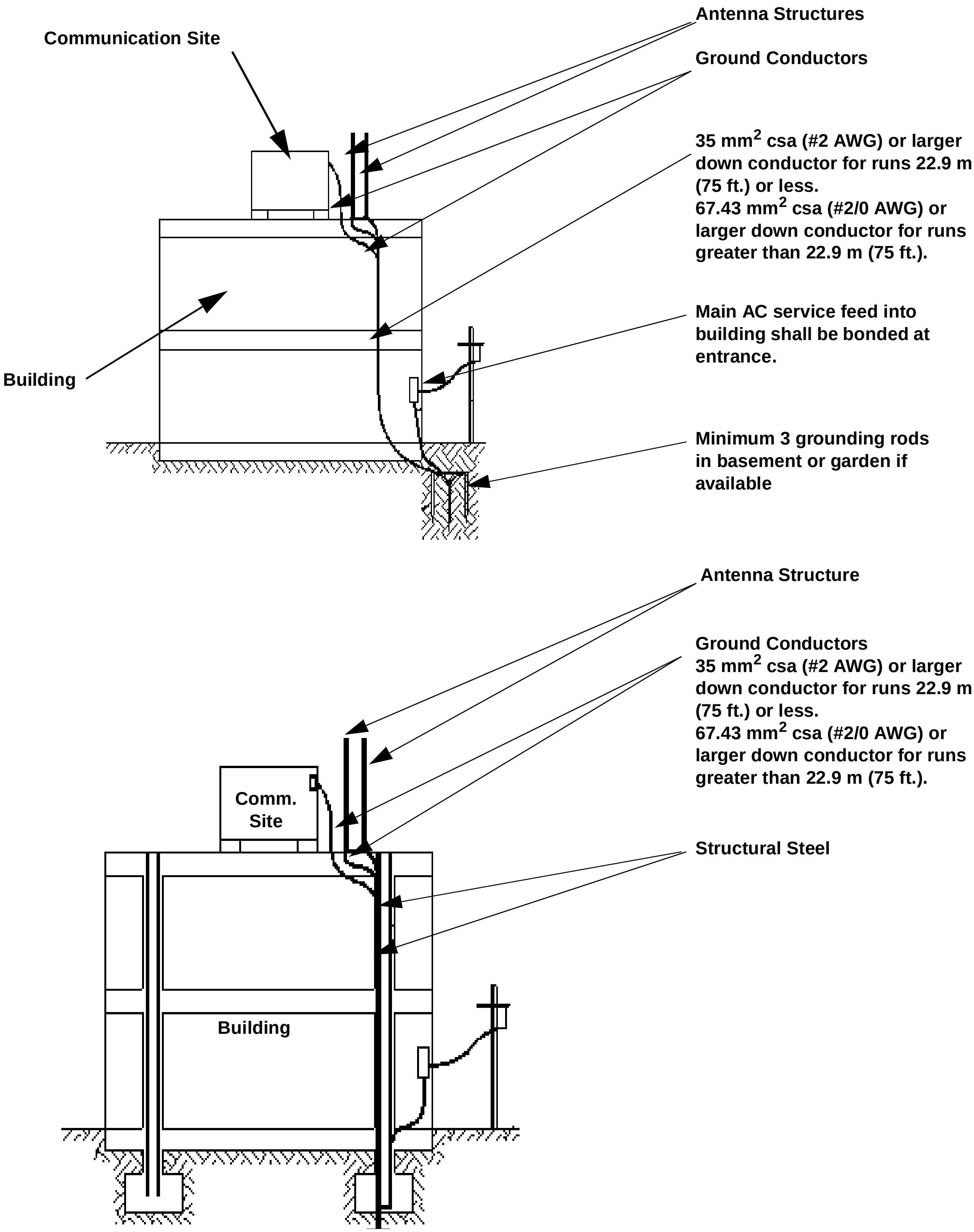


FIGURE 6-39 GROUNDING ROOFTOP INSTALLATIONS

6.4.10 CLASS A SITES

In sites defined as Class A, a single ground rod may be sufficient if it can achieve 25 Ω or less. Refer to “Soil Resistivity Measurements” on page 4-13 to determine the necessary requirements of a single ground rod achieving 25 Ω or less. If a single ground rod cannot achieve 25 Ω or less, alternate methods **shall** be used. Such methods may be small ground ring (see Figure 6-41), multiple ground rods installed in a straight line (see Figure 6-42), electrolytic ground rods, other methods described in this chapter, or specific design by a engineering firm specializing in grounding electrode system design. See “Interpreting Test Results” on page 4-20 to calculate the resistance of a ground ring, ground grid, or parallel ground rods. Requirements for burying grounding electrode system components in soil with good resistivity are shown in Figure 6-40.

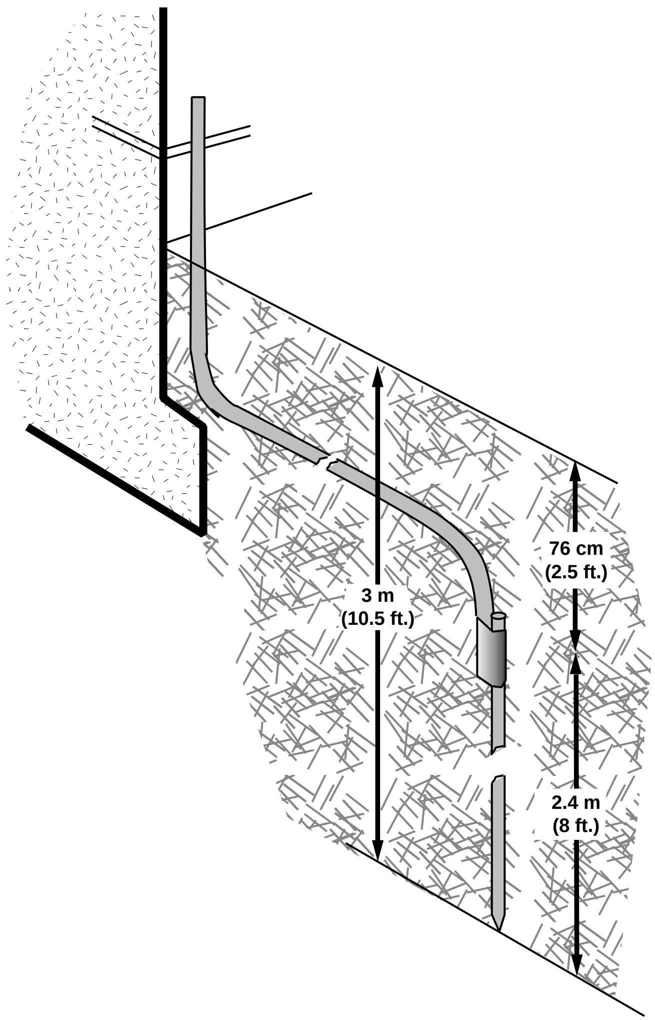


FIGURE 6-40 GROUNDING IN MOIST CLAY SOIL

6.4.11 SPECIAL GROUNDING SITUATIONS

Site conditions such as limited area and high (poor) soil resistivity can sometimes require additional enhancements to the external grounding system. Some techniques for enhancing the grounding system are described below.

6.4.11.1 ENHANCING TOWER GROUNDING SYSTEMS

For high lightning prone geographical areas and/or sites with high soil resistivity, additional tower grounding should be considered. Additional tower grounding should include ground radials, which are conductors installed horizontally into the ground away from the tower and building. (See *ANSI T1.313-1997* for more information.)

- The ground radials **shall** be bonded to the tower ground ring near each leg.
- The ground radials **shall** be 35 mm^2 csa (#2 AWG) minimum bare tinned copper conductor.
- The ground radials should be installed a minimum of 76 cm (30 in.) below the surface of the earth when possible.
- The ground radials should include a ground rod every 4.87 m (16 ft.) (or twice the length or the ground rods) installed as described in "Ground Rods" on page 6-6.
- Ground radials may be up to 14.6 m (48 ft.) long or more if the property allows (more parallel radial extensions may be more effective than extending radial length).
- Tower ground radials at a site should be of different lengths to prevent resonance during a lightning strike.
- See Figure 6-1 on page 6-5 for an example of ground radials.

6.4.11.2 ROOF-TOP AND INTEGRATED COMMUNICATIONS SITES

Roof-top and integrated communications sites may require special techniques for achieving a suitable grounding electrode system when encircling the building would not be feasible, such as in a downtown metropolitan location. Some options may be:

- Consulting an engineering firm specializing in grounding electrode system design.
- Installing a small ground ring in an available location. See Figure 6-41.
- Installing multiple parallel rods in a straight line. See Figure 6-42.
- Installing electrolytic ground rods.
- Supplemental grounding electrode systems **shall** be bonded to the existing building grounding electrode system.

LEGEND:

1. Conductor
2. Exterior wall
3. PVC Conduit guard 3.175 cm (1.25 in.) x 2.13 m (7 ft.)
4. PVC extended 30.5 cm (1 ft.) below finished grade
5. Cable fasteners installed every 91 cm (3 ft.)
6. Exothermically welded or high-compression conductor bond
7. Ground rod bond
8. Ground rod Minimum rod separation is 4.88 m (16 ft.)
9. Bond between small ground ring and existing grounding electrode system
10. Ground ring, minimum diameter 5.47 m (18 ft.)

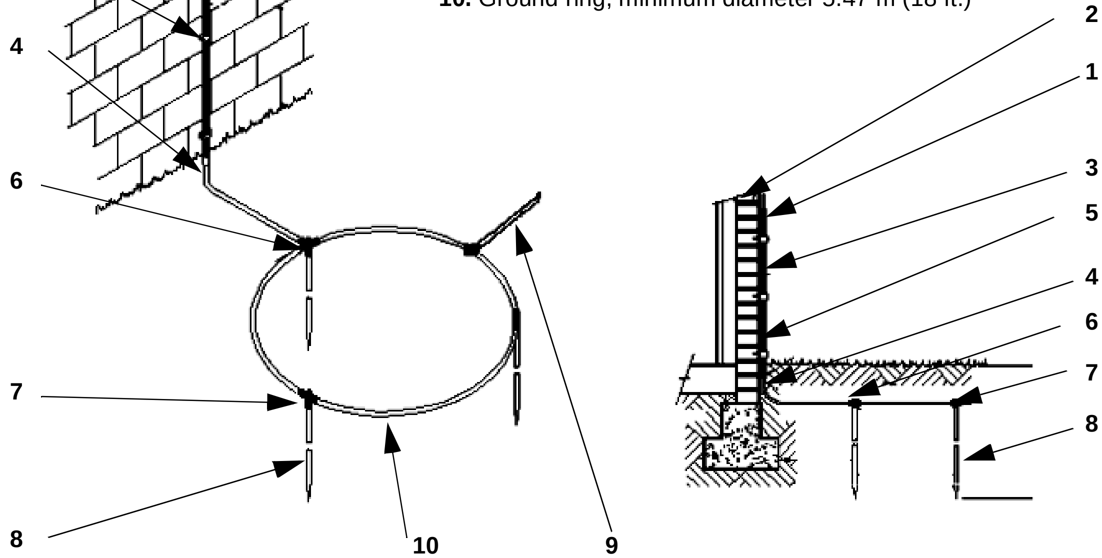


FIGURE 6-41 SMALL GROUND RING INSTALLATION

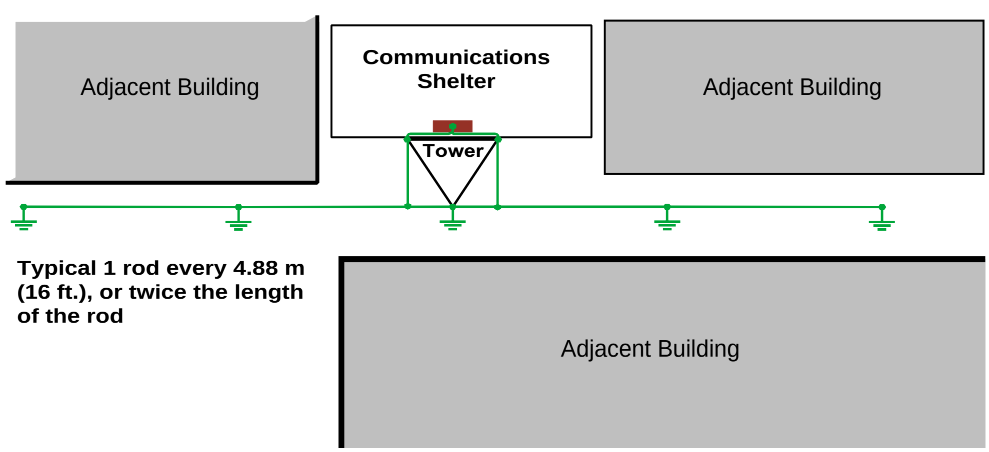


FIGURE 6-42 TYPICAL LINEAR GROUNDING ELECTRODE SYSTEM

6.4.11.3 METAL SHIPPING CONTAINERS USED AS COMMUNICATIONS BUILDINGS

Grounding electrode systems for metal shipping containers used as communications buildings **shall** conform to the standards specified in this chapter. All equipment inside the shipping container **shall** conform to the grounding requirements of Chapter 7, Internal Grounding.

The outside of the shipping container **shall** be bonded to the external grounding electrode system at all four corners as a minimum. Requirements for grounding a metal shipping container are as follows:

- Grounding conductors **shall** meet the requirements of "Grounding Conductors" on page 6-13.
- Connection to the grounding electrode system **shall** meet the requirements of "Bonding to the External Grounding Electrode System" on page 6-56.
- Connection to the metal shipping container **shall** be exothermically welded. See "Exothermic Welding" on page 6-60.

6.4.11.4 SITES WITH LIMITED SPACE FOR THE GROUNDING ELECTRODE SYSTEM

Some sites, such as locations in metropolitan areas or areas close to adjacent buildings or property lines, have very little space available for installing a grounding electrode system. One solution for achieving the required impedance to ground may be to install a grounding electrode grid system using all available space on the property.

A grounding electrode grid system consists of grounding electrodes, typically rods, installed in a grid pattern. The grounding electrodes are all equally spaced and connected together underground with a grounding conductor. The grounding electrodes **shall** meet the specifications and installation requirements of "Grounding Electrodes" on page 6-6. Grounding conductors used to connect the grounding electrode **shall** meet the specifications of "Grounding Conductors" on page 6-13 and **shall** be buried at least 76 cm (30 in.) deep or below the frost line, whichever is deeper. Bonding of all components **shall** meet the requirements of paragraph 6.5. See Figure 6-42 for an example of a grounding electrode grid system for an available area of 9.14 m x 9.14 m (30 ft. x 30 ft.), with all ground rods separated by 3 m (10 ft.).

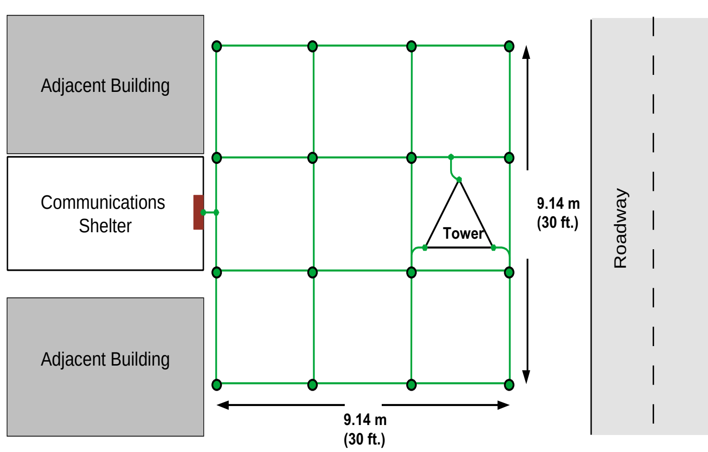


FIGURE 6-43 TYPICAL GROUNDING GRID

Refer to “Interpreting Test Results” on page 4-20 to determine if the desired resistance to ground can be achieved using different rod lengths or thickness and/or separation. If the resistance to ground cannot be achieved using standard rods, electrolytic rods should be considered. Burying the grounding conductor in at least 15.2 cm (6 in.) of ground enhancing material should also be considered (see “Ground Enhancing Materials” on page 6-13) as a method of improving the resistance to ground.

6.4.11.5 TOWERS WITH LIMITED SPACE FOR A GROUND RING

Towers installed close to a building may not have adequate space for a complete tower ground ring or for ground rods spaced properly to achieve the resistance requirements of the site. Depending on the available space, the tower can be grounded using multiple parallel rods and/or ground radials (See paragraph 6.4.11.1 and Figure 6-42).

Refer to “Interpreting Test Results” on page 4-20 to determine the number of rods and rod spacing required to achieve the resistance requirements of the site.

6.4.11.6 GROUNDING ELECTRODE SYSTEMS COVERED BY CONCRETE OR ASPHALT

When installing a grounding electrode system, every attempt should be made to ensure that the surface area above the grounding electrode system is not covered with concrete or asphalt. Areas covered with concrete or asphalt will dry out over time, therefore increasing the resistance to ground of the grounding electrode system. Some alternatives to covering the are with concrete and asphalt are listed below. See *MIL-HDBK-419A* for more information.

- Cover the area with gravel.
- Landscape the area.
- Use electrolytic ground rods when the area must be covered with concrete or asphalt.

6.4.11.7 STONE MOUNTAIN TOPS

Some sites are located on mountaintops because of their RF propagation characteristics. In the instances where there is no soil or very little soil at the site, special designs will be needed. Some options may be:

- Consulting an engineering firm specializing in grounding electrode system design.
- Using down conductors to a lower area where there is usable soil. See Figure 6-44.
- Installing the standard design system as required for a dedicated communications site (see paragraph 6.4.8 on page 6-40) with components buried as deep as the soil will allow and encasing all components with a ground enhancing material.
- Installing ground plates instead of ground rods and encasing the plates with ground enhancing material.
- Installing tower radial extensions and/or radial extensions from the building throughout the property. Install radials and rods as specified in this document or to a depth allowed by the soil.
- Installing horizontal electrolytic rods.

- Using concrete encased electrodes as part of the building construction wherever possible.
- Installing copper strap radials on the surface of the rocks in all directions from the tower. The copper straps may be covered with top soil and/or ground enhancing material. Each copper strap radial should be a different length to prevent ringing of the tower during a lightning strike.

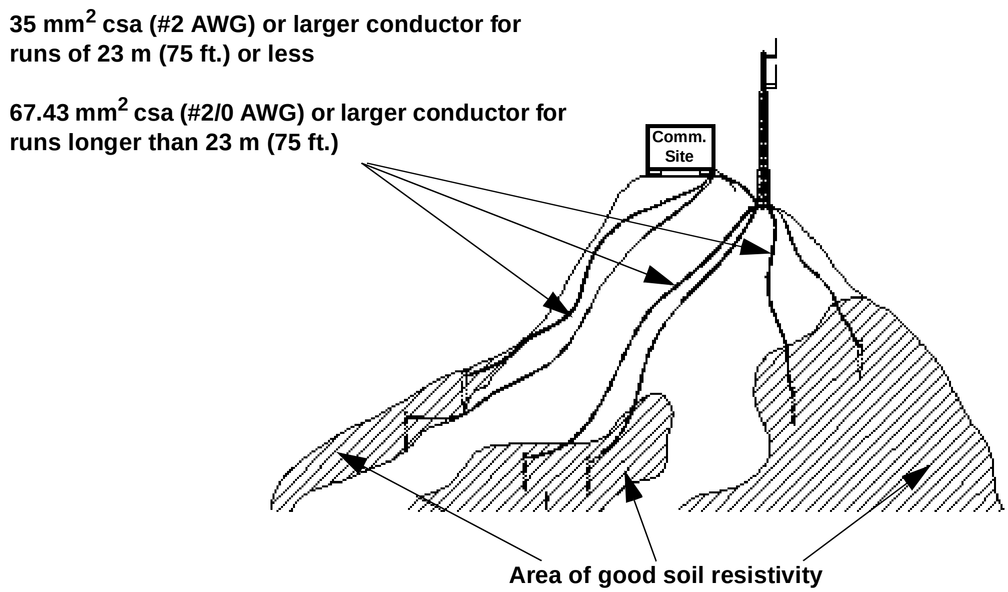


FIGURE 6-44 EXAMPLE OF SOILLESS GROUND SYSTEM

6.4.11.8 SAND, CORAL, OR LIMESTONE ENVIRONMENTS

Sites with very high soil resistivity, such as sites with sand, coral and limestone, require special grounding techniques. Some options are:

- Consulting an engineering firm specializing in grounding electrode system design.
- Electrolytic ground rod systems.
- Installing tower ground radials from the building throughout the property. Install radials and rods as specified in this chapter and encase all components with a ground enhancing material.
- Installing radials and rods throughout the site to form a grid system and using a ground enhancing material if needed. See "Sites With Limited Space for the Grounding Electrode System" on page 6-51.
- Using concrete encased electrodes as part of the building construction wherever possible.

- Using multiple large copper plates (9.29 to 18.6 m^2 (10 to 20 sq. ft.) buried to an optimal depth of 1.52 m to 2.44 m (5 to 8 ft.). The plates are placed on edge and bonded to the grounding electrode system using exothermically welded 35 mm^2 csa (#2 AWG) solid copper wire. Placing the plates on edge allows the plates to be buried with a minimum of excavation and may make it possible to obtain more surface area contact with ground-enhancing backfill material. Laying the plates flat does not significantly lower the resistance. The use of a number of well-placed ground plates in parallel is preferred to placing longer rows of ground plates. (IEEE Std. 142-1991, p. 183).

6.4.11.9 SHALLOW TOPSOIL ENVIRONMENTS

Some sites are located in areas where bedrock is near the surface or where the top soil is less than 30.5 cm (1 ft.) deep. These areas require installation of specialized grounding electrode systems and may require the support of a consulting or engineering firm specializing in grounding electrode system design.

Requirements and recommendations for grounding electrode systems in areas with shallow topsoil are provided below. (See *NFPA 780, Section 3-13* for more information.)

- Encircle the building with a ground ring as described in “External Ground Ring” on page 6-15, burying the ground ring as allowed by the soil conditions. Bond a ground plate to the ground ring at each corner of the building, and install additional ground plates as required to keep the maximum distance between ground plates 4.9 m (16 ft.). The ground plates **shall** be buried no less than the depth of the ground ring and **shall** meet the requirements of “Ground Plates” on page 6-11. Bonding **shall** meet the requirements “Bonding to the External Grounding Electrode System” on page 6-56. See Figure 6-45.

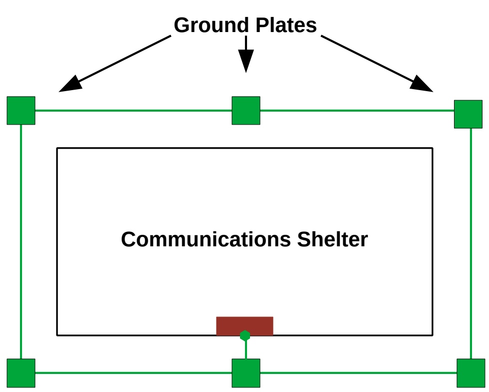


FIGURE 6-45 GROUNDING ELECTRODE SYSTEM WITH GROUND PLATES

- Encircle the building with a ground ring and ground plates as describe above. Install a ground radial conductor in a trench extending away from the building at each corner of the building and bond the ground radials to the ground ring in accordance with “Bonding to the External Grounding Electrode System” on page 6-56. Each ground radial may have ground plates installed every 4.9 m (16 ft.) or less along its length. See Figure 6-46.

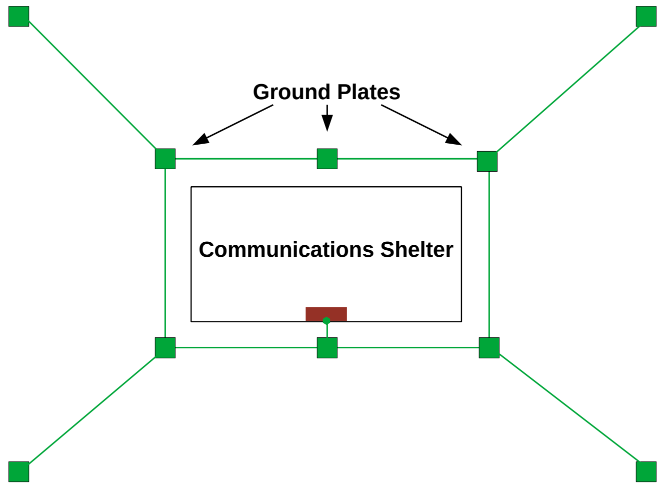


FIGURE 6-46 GROUNDING ELECTRODE SYSTEM WITH GROUND PLATES AND RADIALS

- Additional ground radials extending away from the building may be used as needed to meet the resistance requirements of the grounding electrode system.
- In clay soils, trenches **shall** be at least 3.7 m (12 ft.) long and from 0.3 to 0.6 m (1 to 2 ft.) deep.
- In sandy or gravelly soil, trenches **shall** be at least 7.5 m (24 ft.) long and from 0.6 m (2 ft.) deep.

- In sandy, gravelly, or other soils of poor conductivity, ground enhancing materials should be used to improve the grounding electrode system resistance to ground. Ground enhancing material **shall** meet the requirements of "Ground Enhancing Materials" on page 6-13.
- All soil and backfill materials **shall** be tamped around buried grounding conductors and grounding plates.
- If the required grounding electrode system resistance cannot be achieved using the above recommendations, consider supplementing the system with horizontal electrolytic ground rods.
- The tower can be grounded in the same manner.

6.5 BONDING TO THE EXTERNAL GROUNDING ELECTRODE SYSTEM

6.5.1 REQUIREMENTS

Single point grounding systems installed within equipment shelters, as described in Chapter 7, "Internal Grounding," and the ANSI/TIA/EIA-607 standard, **shall** be bonded to the external grounding electrode system. Any grounding electrode system installed as part of a communications equipment installation **shall** be bonded to the existing electrical service grounding electrode system. (See *NFPA 70, Articles 250-90 FPN*, *800-40, 810-21*, and *820-40* for more information.)

All below-grade grounding connections **shall** be joined using exothermic welding or high-compression fittings compressed to a minimum of 12 tons (13.3 tonnes) of pressure, or as otherwise required by the specific component manufacturer. Manufacturer requirements **shall** be followed for all connections. Connectors and fitting used **shall** be listed for the purpose, for the type of conductor, and for the size and number of conductors used.

All above grade grounding connections **shall** be joined using exothermic welding, listed[1] lugs, listed pressure connectors, listed clamps, or other listed means required by the specific component manufacturer. Connecting hardware **shall** be listed for the purpose, for the type of conductor, and for the size and number of conductors used. All mechanical connections **shall** be coated with an anti-oxidant compound. (See *NFPA 70, Article 250-70* for more information.)

All exothermic and irreversible compression connections for use on external grounding applications **shall** be UL 467 listed, IEEE 837 approved. Copper connectors **shall** maintain minimum 88% conductivity rating. Compression systems **shall** include crimped die index and company logo for purposes of inspection. Aluminum **shall not** be used for connection purposes.

Bonding **shall** be performed so that a suitable and reliable connection exists. The following requirements **shall** be observed when bonding ground connections:

- Paint, enamel, lacquer and other nonconductive coatings **shall** be removed from threads and surface areas where connections are made to ensure good electrical continuity (per NFPA 70, Article 250-12). Use of a star washer does not alleviate the requirement to remove nonconductive coatings from attachment surfaces.
- After bonding to a painted or galvanized structure, the area **shall** be primed and painted.
- Two-hole lugs secured with fasteners in both holes should be used to prevent movement of the lug.

1. Listed means that the item or device is listed by UL or an approved testing laboratory or complies with the definition as specified in NFPA 70, Article 100.

- Exothermic welding is the preferred method for bonding connections to the external grounding electrode system.
- If exothermic welding is not used, irreversible compression fittings compressed with a compression tool with a minimum of 12 tons (13.3 tonnes) of pressure **shall** be used.
- When connecting ground lugs or compression terminals to ancillary equipment such as air conditioners and vent hoods, a lock washer **shall** be placed on the nut side. See Figure 6-47. Sheet metal screws and/or self-tapping screws **shall not** be used.

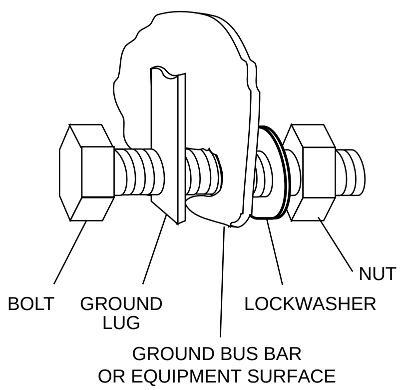


FIGURE 6-47 PROPER LOCATION OF WASHER WHEN CONNECTING GROUND LUG

6.5.2 DISSIMILAR METALS

The bonding of two dissimilar metals may result in Galvanic corrosion, a reaction that occurs at the junction of dissimilar metals when they are exposed to moisture. The degree and rate of corrosion depends on the relative position of the metals in the electrochemical series. The metals at the top of Table 6-3 corrode more easily than those at the bottom. To determine the likelihood of two metals reacting, determine the difference between their listed EMFs. If it is greater than 0.6 Volts, Galvanic corrosion resulting in an undesirable high-resistance connection will result if the two metals are bonded together. If the difference is **0.6 Volts or less**, the metals may be safely bonded, but **shall** be coated with anti-oxidant compound or joined with an exothermic weld designed specifically for bonding the two different metals.

Some methods for preventing galvanic corrosion are listed below.

- Use the same metal throughout the system when possible.
- Exothermically weld connections of different metals when weld material is available for the metals being bonded. See “Exothermic Welding” on page 6-60.
- Copper conductors **shall not** be installed on aluminum roofing or siding.
- Aluminum and copper **shall not** be directly connected to each other unless using exothermic welding materials specifically intended for these two metals to make the connection. Aluminum and copper may be joined with the use of a listed bimetallic transition connector of stainless steel. These connectors **shall** be listed for the size and number of conductors and marked with **AL/CU.** These connections **shall** be liberally coated with a conductive antioxidant at the point of insertion into the connector.
- Copper **shall not** come in contact with galvanized steel.
- Tinned copper **shall** be used when connecting to a galvanized steel structure.

TABLE 6-3 GALVANIC ACTION OF DISSIMILAR METALS

METAL	EMF (Volts)
Magnesium	+2.37
Magnesium Alloys	+0.95
Beryllium	+1.85
Aluminum	+1.66
Zinc	+0.76
Chromium	+0.74
Iron or Steel	+0.44
Cast Iron	Reliable Values N/A
Cadmium	+0.40
Nickel	+0.25
Tin	+0.14
Stainless Steel	Reliable Values N/A
Lead	+0.13
Brass	Reliable Values N/A
Copper	-0.34
Bronze	Reliable Values N/A
Copper-Nickel Alloys	-0.35
Monel	Reliable Values N/A
Silver Solder	-0.45
Silver	-0.80
Graphite	-0.50
Platinum	-1.20
Gold	-1.50
Lead	+0.13

6.5.3 BONDING METHODS

The following paragraphs describe acceptable methods for bonding to the external grounding electrode system. Exothermic welding and the use of high-compression fittings are the only acceptable methods for below-grade bonding. Split bolts and other mechanical connection methods **shall not** be used.

6.5.3.1 EXOTHERMIC WELDING

Exothermic welding is a method of welding electrical connections without an external heat source such as electricity or gas. The process is based on the reaction of granular metals which when combined, produce a molten metal. This reaction, which is completed in seconds, takes place in a crucible. The liquid metal flows from the crucible into a mold where it meets the ends of the conductors to be welded. The temperature of the molten metal is sufficient to fuse the metal of the conductors, resulting in a welded molecular bond. Exothermic welding alloys are available for aluminum, copper, and copper to steel connections.

WARNING

Follow manufacturer's warnings and safety requirements.

Heavy clothing, work shoes or boots, gloves, and safety glasses shall be worn when performing exothermic welding,

Exothermic welding shall not be performed unless another person capable of rendering first aid is present. A suitable fire extinguisher shall be close by with an attendant during the process.

Observe the following prerequisites for exothermic welding:

- Follow manufacturer's safety warnings and requirements.
- Follow the manufacturer's recommendations.
- Use the proper molds for the conductors being welded.
- Use the proper weld material for the metals being welded.
- Properly clean all metal parts prior to welding.
- Properly dry all metal parts and molds prior to welding.

The exothermic welding process is shown in Figures 6-48 and 6-49.

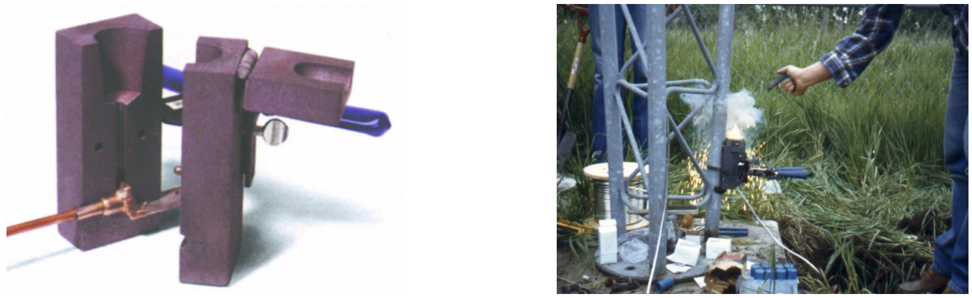


FIGURE 6-48 EXOTHERMIC WELDING MOLD (LEFT) AND PROCESS (RIGHT)

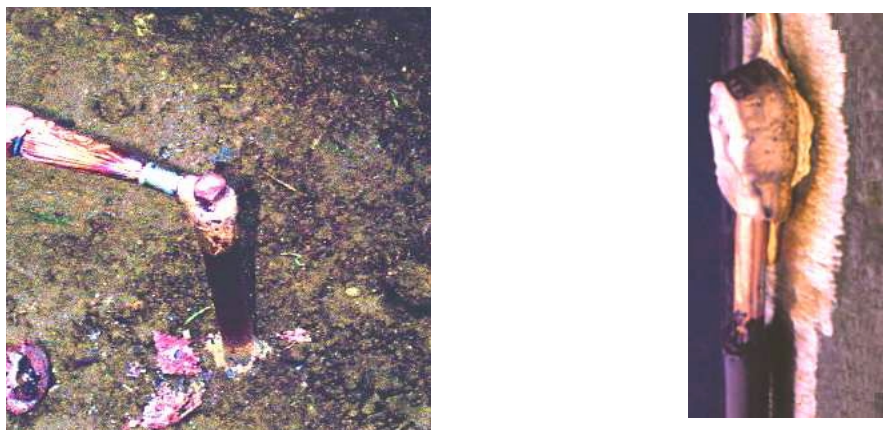


FIGURE 6-49 COMPLETED EXOTHERMIC WELDS IN TRENCH AND ON TOWER

6.5.3.2 HIGH COMPRESSION FITTINGS

WARNING

Wear safety glasses, hard hat, and steel-toes shoes when working with high-compression fittings.

When using high-compression fittings, always use the compression tool recommended by the manufacturer in accordance with the instructions provided by the manufacturer. Use fittings made of the same material as the materials being bonded to avoid dissimilar metal reactions. See Figure 6-50 for examples of high-compression fittings.

- Use fittings properly sized for the conductors being bonded.
- Use fittings and compression tools rated at 12 tons (13.3 tonnes) of force.
- Use only UL-listed tap connectors.
- To ensure good contact, clean conductors using a wire brush before crimping.
- Coat all crimped connections with antioxidant compound before crimping.

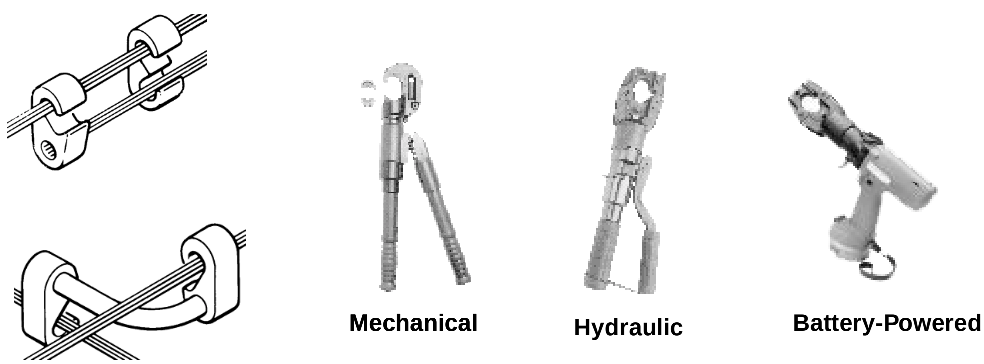


FIGURE 6-50 HIGH-COMPRESSION CONNECTORS AND TYPICAL CRIMPING TOOLS

6.6 GROUND SYSTEM TESTING/VERIFICATION

WARNING

Procedures in this section shall not be performed by untrained or unqualified personnel, nor are any procedures herein intended to replace proper training. It is required that personnel attempting to measure the resistance of a grounding electrode system receive prior formal training on the subject and on its associated safety hazards. All applicable laws, rules and codes regulating the work on electrical systems shall be complied with at all times.

This section provides procedures for performing resistance testing of the site grounding electrode system. The resistance of a grounding electrode system **shall** be measured after its installation and before it is bonded to the power company neutral wire or any other utility, such as the telephone ground or metallic pipes.

Periodic testing **shall** be performed on the site annually when the site ground system can be safely disconnected from the power company neutral wire. Suggested best practice is to perform the test at least once every year, with tests being performed in alternate seasons to verify results under diverse soil moisture/temperature conditions.

NOTE: Grounding electrode system testing **shall** be performed anytime the site is suspected to have taken a direct lightning strike.

6.6.1 OVERVIEW

Testing **shall** be performed using one of the three methods which are described in this chapter. The methods are:

- **Three-Point/Fall-of-Potential Testing**

  This method is the most widely accepted. However, performing the test may require access to areas that may be beyond the site property lines. When testing a grounding electrode system consisting of a multi-bonded/multi-grounding electrode system, the distance required for testing is directly related to the effective diagonal distance of the buried grounding electrode system.

- **Clamp-on Ohmmeter**

  This method **shall** be used when access to necessary space needed for the Three-Point/Fall-of-Potential test is not available. However, the clamp-on ohmmeter test can only be performed after AC utilities have been connected to the site and various feed conductors are accessible.

- **Combined Soil Resistivity Testing with Clamp-on Ohmmeter Testing**

  This method **shall** only be used in special cases where three-point/fall-of-potential testing or clamp-on ohmmeter testing cannot directly provide a suitable evaluation. The data obtained from soil resistivity testing and clamp-on ohmmeter testing is then used by an engineering firm specializing in grounding electrode system design to make determinations regarding the grounding electrode system.

6.6.2 LIMITATIONS TO PERFORMING TESTING

The following conditions must be met in order to perform grounding electrode system testing:

- Three-Point/Fall-of-Potential testing is possible only if the following conditions can be met:
  - Sufficient land area must be available to perform a three point/fall-of-potential test. The reference probe may likely need to be inserted into soil that is beyond the site fence or property line. Testing using a clamp-on ohmmeter may be an option in these cases.
  - The grounding electrode system must be able to be isolated from the power company grounded conductor (may be a neutral wire).
- Clamp-on Ohmmeter testing is possible only if the following conditions can be met:
  - Site must be supplied with commercial power company-provided power. Sites supplied only by a generator or other non-commercial power may not be suitable for clamp-on ohmmeter testing.
  - Neutral wire must be present as part of the power company service.
  - Neutral wire must be part of an extensive power company grounding system. In systems such as 3-phase delta service, the neutral wire may not be part of the extensive power company grounding system.
  - The grounding electrode system must be connected to the power company grounded conductor (may be a neutral wire).
  - For sites using a multi-bonded/multi-grounding electrode system (such as commonly used at communications sites), a point on neutral wire for meter to clamp onto must be available before its first bond to the site.
  - For a single grounding electrode system, the grounding electrode conductor must be accessible for the meter to clamp onto at a point between the grounding electrode and any other connection (such as the telephone company ground or a metallic pipe).
- Combined Soil Resistivity/Clamp-on Ohmmeter testing is possible only if the following conditions can be met:
- System must be such that gathering of individual grounding electrode system component values with a clamp-on-ohmmeter can be available for use by an engineering firm.

- A soil resistivity profile for the site has been performed and is available for use by an engineering firm.

If these conditions cannot be met, an added supplemental grounding electrode system can be installed. This supplemental grounding electrode system could be installed and tested prior to its connection to the existing system. This supplemental system should be installed in such a manner as to allow an easy disconnect point for future testing.

6.6.3 THREE-POINT/FALL-OF-POTENTIAL METHOD TESTING PROCEDURE

6.6.3.1 TEST DESCRIPTION

The Three-Point/Fall-of-Potential test is the most widely accepted and recommended test method. This procedure is documented in *ANSI/IEEE STD 81* and should be referred to for more details.

In the Three-Point/Fall-of-Potential test, two test rods are driven into the soil. These rods are placed in a straight line from an electrode in the grounding electrode system to be tested (referred to here as connection 'X'). One of the test rods, referred to here as rod 'Z', is placed at a known distance from the X connection. The other test rod (referred to here as rod 'Y') is placed at various distances between the X connection and rod Z. If a known current is applied between the X connecting point and rod Z, a potential difference (voltage drop) will exist between the X connection and rod Y. The fall-of-potential tester measures the voltage drop between the X connection and rod Y, and converts the measurement to a resistance reading using Ohm's Law (R= E/I). In this manner, the resistance at any point between the X connection and rod Z can be measured. The multiple readings obtained during this test are entered and plotted as data points on a graph. From the graph, the resistance of the grounding electrode system can be determined.

6.6.3.2 REQUIRED TEST EQUIPMENT AND SUPPLIES

- Three-Point/Fall-of-Potential Ground Resistance Tester (with supplied test leads, test clips, and probes)
- Small sledgehammer
- Tape measure
- Safety glasses
- Gloves
- Several photocopies of Table 6-6, "Three-Point Test Worksheet" on page 6-85. This will be needed to record and keep track of several measurements across the site.
- Several photocopies of Figure 6-57, "Three-Point Test Graph Form" on page 6-87. This will be needed to plot a graph of the resistance profile across the measurement area.

6.6.3.3 PREPARATIONS FOR TESTING

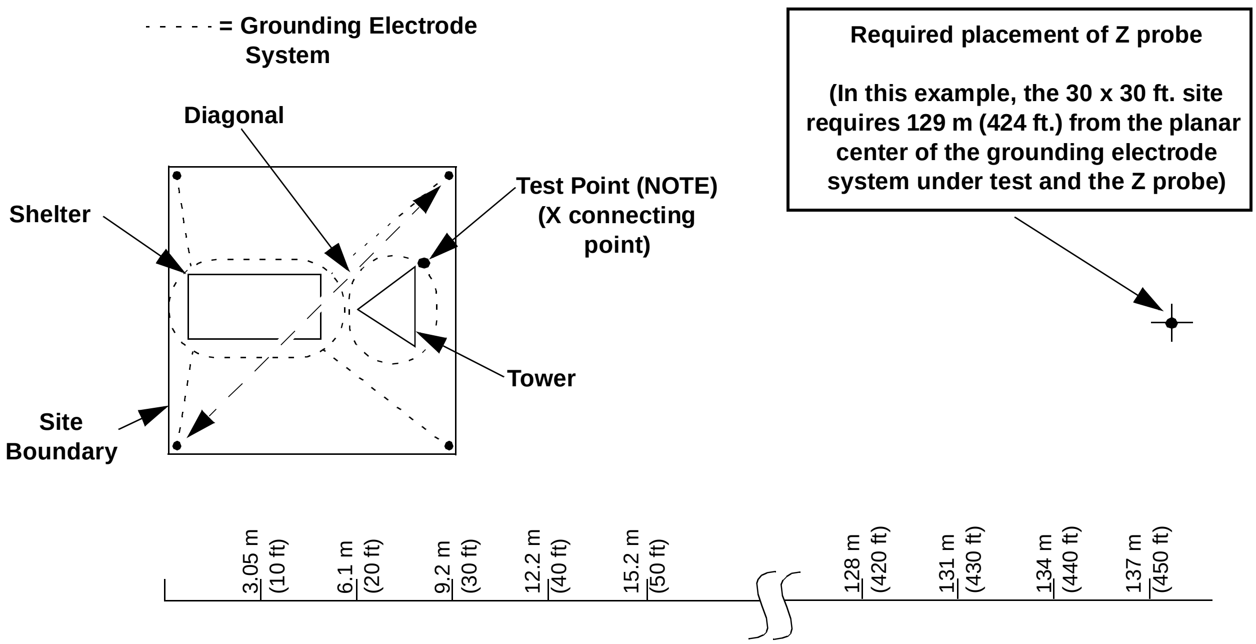
6.6.3.3.1 TESTING AREA REQUIREMENTS

This test requires a reference test rod (outer reference test probe Z) which **shall** be placed outside the field of influence of the grounding electrode system. In many cases, this required location will be outside of the site property line. Figure 6-51 shows a typical site layout and its required spacing distance between the site and the reference test rod. As such, the following stipulations apply:

- For a **single grounding electrode system**, the distance of the reference probe **shall** be minimally 5 times, to preferably 10 times, the depth of the grounding electrode from the surface of the soil to the bottom of the buried electrode. For three-point testing distance measurements, the planar center of a single grounding electrode system is the electrode connecting point above ground.
- **For a multi-bonded/multi-grounding electrode system**, the distance of the reference probe **shall** be minimally 5 times, to preferably, 10 times the diagonal distance of the grounding electrode system. For three-point testing distance measurements, the planar center of a multi-bonded/multi-grounding electrode system is the extreme edge of the system in the direction of where the test probes are inserted.

Use Table 6-4 or Table 6-5 to obtain the value for 10-times spacing distance between the site and the outer reference test probe (Z). (Table 6-4 provides values in Feet; Table 6-5 provides values in Meters.) For the minimum 5 times distance; divide the resulting numbers by 2.

NOTE: Any required permissions **shall** be obtained for accessing and placing a test probe on adjacent property before testing is attempted.



NOTE: Connection point of meter X clip is typically to external master ground bus.

FIGURE 6-51 OUTER REFERENCE ELECTRODE (Z-PROBE) PLACEMENT FOR A TYPICAL SITE

TABLE 6-4 REQUIRED Z-PROBE SPACING FOR SITE LENGTHS AND WIDTHS (IN FEET)

	Site Length (ft)									
Site Width (ft)	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100**
10	141	224	316	412	510	608	707	806	906	1005
20	224	283	361	447	539	632	728	825	922	1020
30	316	361	424	500	583	671	762	854	949	1044
40	412	447	500	566	640	721	806	894	985	1077
50	510	539	583	640	707	781	860	943	1030	1118
60	608	632	671	721	781	849	922	1000	1082	1166
70	707	728	762	806	860	922	990	1063	1140	1221
80	806	825	854	894	943	1000	1063	1131	1204	1281
90	906	922	949	985	1030	1082	1140	1204	1273	1345
100	1005	1020	1044	1077	1118	1166	1221	1281	1345	1414
110	1105	1118	1140	1170	1208	1253	1304	1360	1421	1487
120	1204	1217	1237	1265	1300	1342	1389	1442	1500	1562
130	1304	1315	1334	1360	1393	1432	1476	1526	1581	1640
140	1404	1414	1432	1456	1487	1523	1565	1612	1664	1720
150	1503	1513	1530	1552	1581	1616	1655	1700	1749	1803
160	1603	1612	1628	1649	1676	1709	1746	1789	1836	1887
170	1703	1712	1726	1746	1772	1803	1838	1879	1924	1972
180	1803	1811	1825	1844	1868	1897	1931	1970	2012	2059
190	1903	1910	1924	1942	1965	1992	2025	2062	2102	2147
200	2002	2010	2022	2040	2062	2088	2119	2154	2193	2236

TABLE 6-5 REQUIRED Z-PROBE SPACING FOR SITE LENGTHS AND WIDTHS (IN METERS)

	Site Length (m)									
Site Width (m)	3.05	6.1	9.2	12.2	15.2	18.3	21.3	24.4	27.4	30.5
3.05	43	68.3	96.3	125.6	155.4	185.3	215.5	245.7	276.1	306.3
6.1	68.3	86.3	110	136.2	164.3	192.6	221.9	251.5	281	310.9
9.2	96.3	110	129.2	152.4	177.7	204.5	232.3	260.3	289.3	318.2
12.2	125.6	136.2	152.4	172.5	195	219.8	245.7	272.5	300.2	328.3
15.2	155.4	164.3	177.7	195	215.5	238	262.1	287.4	313.9	340.8
18.3	185.3	192.6	204.5	219.8	238	258.8	281	304.8	329.8	355.4
21.3	215.5	221.9	232.3	245.7	262.1	281	301.8	324	347.5	372.2
24.4	245.7	251.5	260.3	272.5	287.4	304.8	324	344.8	367	390.4
27.4	276.2	281	289.3	300.2	313.9	329.8	347.5	367	388	410
30.5	306.3	310.9	318.2	328.3	340.8	355.4	372.2	390.4	410	431
33.5	336.8	340.8	347.5	356.6	368.2	381.9	397.5	414.5	433.1	453.2
36.6	367	371	377	385.6	396.2	409	423.4	439.5	457.2	476
39.6	397.5	400.8	406.6	414.5	424.6	436.5	449.9	465.1	482	499.9
42.7	428	431	436.5	443.8	453.2	464.2	447	491.3	507.2	524.3
45.8	458.1	461.2	466.3	473	482	493	504.4	518.2	533.1	549.6
48.8	488.6	491.3	496.2	502.6	510.8	520.9	532.2	545.3	559.6	575.2
51.8	519	521.8	526	532.2	540.1	549.6	560.2	572.7	586.4	601
54.9	549.6	552	556.3	562	569.4	578.2	588.6	600.5	613.3	627.6
57.9	580	582.2	586.4	591.9	598.9	607.2	617.2	628.5	640.7	654.4
60.1	610.2	612.6	616.3	621.8	628.5	636.4	645.9	656.5	668.4	681.5

6.6.3.3.2 SITE AC POWER DISCONNECT REQUIREMENTS

This test requires disconnection of the site grounding electrode system from the power company grounded conductor (may be a neutral wire). This is required in order to allow testing that is limited **only** to the site grounding electrode system. Attempting to perform measurements while the site remains connected to the extensive ground/neutral system of the power company artificially enhances the grounding electrode system reading, resulting in measurement error. Therefore, for an existing site supplied by commercial AC power that contains a neutral wire which is part of an extensive power company grounding system, the following steps must be taken first:

1. Coordinate the test with the customer and/or site owner and all other affected parties.
2. Arrange for the site to have the power company AC power turned off. If the site must remain operational while testing is being done, the site will have to be switched to a back-up power source if it is available.

WARNING

Check for current on the grounding electrode conductor before disconnecting. Never disconnect the ground of a live circuit. Disconnecting the ground of a live circuit could cause death or severe injury.

3. Have the site grounding electrode system isolated from the power company grounded conductor (may be a neutral wire) by a qualified electrician, ensuring that it has no secondary path to the site via a conduit or other connection (this can be verified with the use of a multimeter). The only way to achieve this (especially at a communications site with a multi-bonded/multi-grounding electrode system) may be having the power company grounded conductor (may be a neutral wire) disconnected from the site.
4. Remove any other grounding electrode connection that may influence the measurement of the on-site grounding electrode system, such as the telephone company ground connection and metallic water/gas pipes.

6.6.3.4 THREE-POINT TEST PROCEDURE

Perform three-point test as described in the following procedure. Figure 6-52 shows typical Ground Resistance Tester connections and test probe orientations.

WARNING

Follow Ground Resistance Tester manufacturer’s warning and caution information when using tester. Follow furnished instructions when inserting and removing test rods into soil.

Make certain this procedure is fully understood before proceeding with test.

PROCEDURE 6-1 THREE-POINT TEST PROCEDURE

1	On Ground Resistance Tester, connect test leads to the **X**, **Y**, and **Z** terminals.
2	Short the **X** and **Xv** connections on the Ground Resistance Tester.
3	Connect the **X** lead to the grounding electrode system under test. (This is typically via a test clip connection to the external master ground bus.)
4	Connect the **Y** lead to the measurement (Y) probe.
5	Determine the required placement of outer reference probe (Z) in accordance with paragraph 6.6.3.3.1, “Testing Area Requirements”.
6	Place the outer reference probe (Z) into the soil at the determined location. Connect the outer reference probe (Z) to meter terminal **Z**.
7	Note the distance of the outer reference probe (Z) from the grounding electrode system (this distance will be used in determining subsequent measurements). On the photocopy of the Three-Point Test Worksheet, write down this distance in the “100%” space.
8	Place the measurement probe (Y) it the soil starting close to the area of the grounding electrode system under test. Take a measurement.
9	On the photocopy of the Three-Point Test Worksheet, write down the reading in the “0%” row of the worksheet.
10	Place the measurement probe (Y) at 10% of the distance between the grounding electrode system ‘X’ connection and the outer reference probe (Z). Take a measurement. **Example:** Assuming a “100%” distance of 430 ft., Y probe would be placed at 43 ft. for “10%” measurement location. **NOTE:** Placement of the measurement probe (Y) must be along a straight path between the grounding electrode system ‘X’ connection and the outer reference probe (Z).
11	On the photocopy of the Three-Point Test Worksheet, write down the reading in the appropriate row of the worksheet.

PROCEDURE 6-1 THREE-POINT TEST PROCEDURE (CONTINUED)

12	At every 10% point, repeat steps 10 and 11 for the remaining spaces on the worksheet.
13	On the photocopy of Three-Point Test Graph Form, plot a graph of the measured resistances for all points listed on the worksheet.
14	Using Figure 6-53, assess the test results as follows: • **Valid Test:** At approximately 62% of the total distance (“100%” distance), a plateau or “flat spot” should be noticeable in the plot, as shown in “VALID TEST GRAPH” in Figure 6-53. The resistance at this plateau is the validated resistance of the system under test. • **Invalid Test Graph (insufficient distance of Z-probe):** If there is no plateau on the plot, shown in “INVALID TEST GRAPH (Z-Probe Spacing)” in Figure 6-53, the test is considered invalid since the Z probe is not far enough from the X probe. • **Invalid Test Graph (erroneous connection to neutral):** If there is no plateau on the plot, shown in “INVALID TEST GRAPH (Connection to neutral)” in Figure 6-53, the test is considered invalid since an erroneous connection of the grounding electrode system to a power company neutral remains. **NOTE:** If the electrical service provided by the Power Company does not contain a neutral wire that is bonded to an extensive power company grounding system, such as a 3-phase delta service, the three point/fall-of-potential test can be performed on the grounding electrode system without disconnecting it from the power company. This is because the neutral wire is locally derived at the transformer and is not part of the extensive Power Company grounding system. All other utility connections must still be removed, such as the telephone company ground connection and ground through water/gas metallic pipes.

NOTE: If sufficient access area exists, the entire procedure above can be repeated for several directions facing away from the center of the grounding electrode system. Repeating the procedure is recommended if metal pipes or similar conductive objects are buried in a given test area. Repeating the procedure is optional. However, samples taken for multiple directions result in the most accurate possible resistance profile.

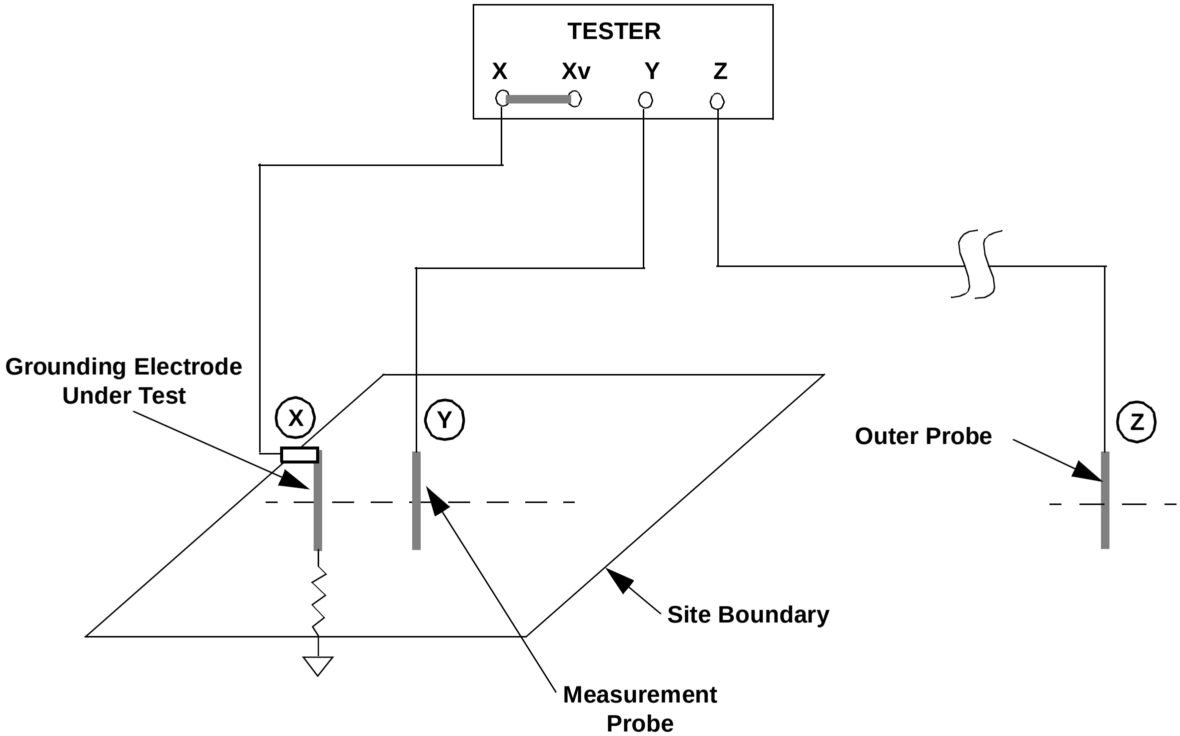
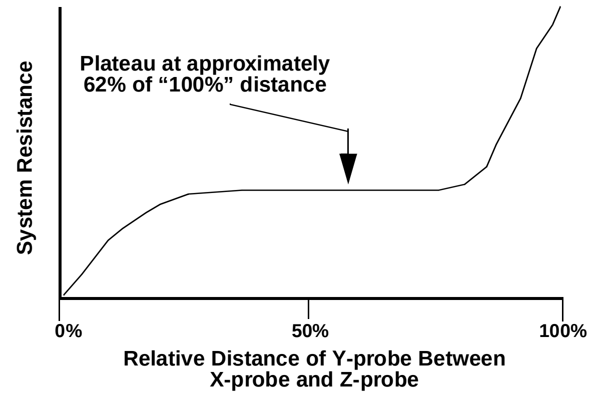


FIGURE 6-52 TYPICAL GROUND RESISTANCE TESTER CONNECTION

VALID TEST GRAPH

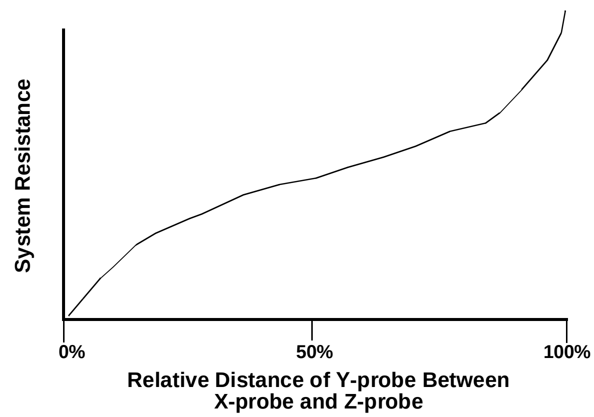
At approximately 62% of the total distance, a plateau or "flat spot" should be noticeable in the plot. The resistance at this plateau is the resistance of the system under test.



INVALID TEST GRAPH (Z-Probe Spacing)

The Z probe is not placed far enough from the grounding electrode system.

Reposition Z-probe farther away from X connecting point and repeat test.



INVALID TEST GRAPH (Connection to neutral)

Due to a connection that still exists to the Power Company neutral conductor or other utility, the resulting curve has very little change until the point nearest the remote current probe. No valid plateau exists.

Have connection removed and repeat test.

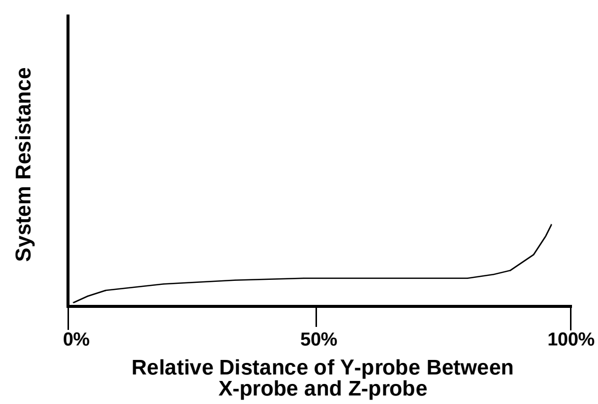


FIGURE 6-53 THREE-POINT TEST GRAPH RESULTS

6.6.4 CLAMP-ON OHMMETER TESTING PROCEDURE

The Clamp-on Ohmmeter test can be performed on both single grounding electrode and multi-bonded/multi-grounding electrode system (such as at a communications site). However, the test can only be accurately performed on sites supplied by commercial power.

For a single grounding electrode system, the test is considered very reliable and can be easy to perform. However, for a multi-bonded/multi-grounding electrode system, the test can be more difficult to perform and may result in an error reading due to parallel paths. The test procedure in this section has provisions to help avoid such errors.

NOTE: If the electrical service provided by the power company does not contain a neutral wire that is bonded to the extensive power company ground system (such as with a 3-phase delta service), the Clamp-on Ohmmeter will not give an accurate reading. In these cases, this is because the neutral wire is locally derived at the transformer and is not part of the extensive power company grounding system; therefore, it cannot provide an effective low resistance return path for the meter.

6.6.4.1 TEST DESCRIPTION

The Clamp-on Ohmmeter works on the basis of injecting a known voltage into the grounding electrode system in order to create a current flow whose value is a function of the grounding electrode system resistance. The test current flows from the grounding electrode system through the earth, returning to the grounding electrode system via the power company's multi-grounded neutral wire. The meter then measures this current and converts the measurement to a resistance reading using Ohm's Law (R= E/I). As such, the meter displays a resistance of the grounding electrode system in Ohms. Since the power company's grounding system is so extensive, the meter considers it to be of negligible value and disregards its effect on the reading.

6.6.4.2 REQUIRED TEST EQUIPMENT AND SUPPLIES

- Clamp-on Ohmmeter/Ammeter
- A photocopy of Table 6-7, "Clamp-on Ohmmeter/Ammeter Test Worksheet" on page 6-89. This will be needed to record measurements.

6.6.4.3 PREPARATIONS FOR TESTING

6.6.4.3.1 SITE AC POWER DISCONNECT REQUIREMENTS

This test requires disconnection of the site AC power from the utility AC feed. This is required in order to allow testing that is limited **only** to site grounding system. Attempting to perform measurements while the site remains connected to the utilities' extensive ground/neutral system artificially enhances ground readings that result in measurement error. Therefore, for an existing site supplied by commercial AC power that contains a neutral wire which is part of an extensive power company grounding system, the following steps must be taken first:

1. Coordinate the test with the customer and/or site owner and all other affected parties.

2. Arrange for the site AC power to be turned off and the site switched to a back-up power source if it is available. Any current on the neutral wire (even if less than 5 amps) can result in a false reading. It is therefore recommended that the commercial power be turned off in order to eliminate any currents on the neutral wire that can effect the meter's ability to give an accurate reading.

6.6.4.4 CLAMP-ON OHMMETER TEST PROCEDURES

WARNING

Follow Clamp-on Ohmmeter manufacturer's warning and caution information when using tester.

Depending on whether site uses a Single Grounding Electrode system or Multi-bonded/Multi-Grounding Electrode system, proceed to paragraph 6.6.4.4.1, "Single Grounding Electrode System Testing (or equivalent)" or paragraph 6.6.4.4.2, "Multi-bonded/Multi-grounding Electrode System Testing" as applicable.

6.6.4.4.1 SINGLE GROUNDING ELECTRODE SYSTEM TESTING (OR EQUIVALENT)

For a site using a single grounding electrode system (or equivalent), perform test as described in the following procedure.

PROCEDURE 6-2 CLAMP-ON OHMMETER TEST PROCEDURE (SINGLE GROUNDING ELECTRODE SYSTEM)

1 Locate the grounding electrode connection outside of the shelter, or the single wire connecting to the grounding electrode.

2 (See Figure 6-54.) Clamp the meter around the grounding electrode connecting wire, making sure that the meter is positioned at a location below any other utility connection (such as the telephone company ground or a water pipe).

3 Set the meter to the **Amps** scale and check the grounding electrode for current.

If 5 amps or more are on the grounding electrode conductor, the test may not be able to be performed due to the design of some meters. If the current on the ground wire is less than 5 amps, a measurement may be taken if the meter does not indicate any noise or other errors.

CAUTION

Any significant current on the grounding electrode conductor could indicate a serious problem and should be reported to the site owner.

4 Set the meter to the **Ohms** scale and note the reading; this is the resistance of the grounding electrode system under test.
Record the reading on the photocopy of the Clamp-on Ohmmeter/ Ammeter Test Worksheet.

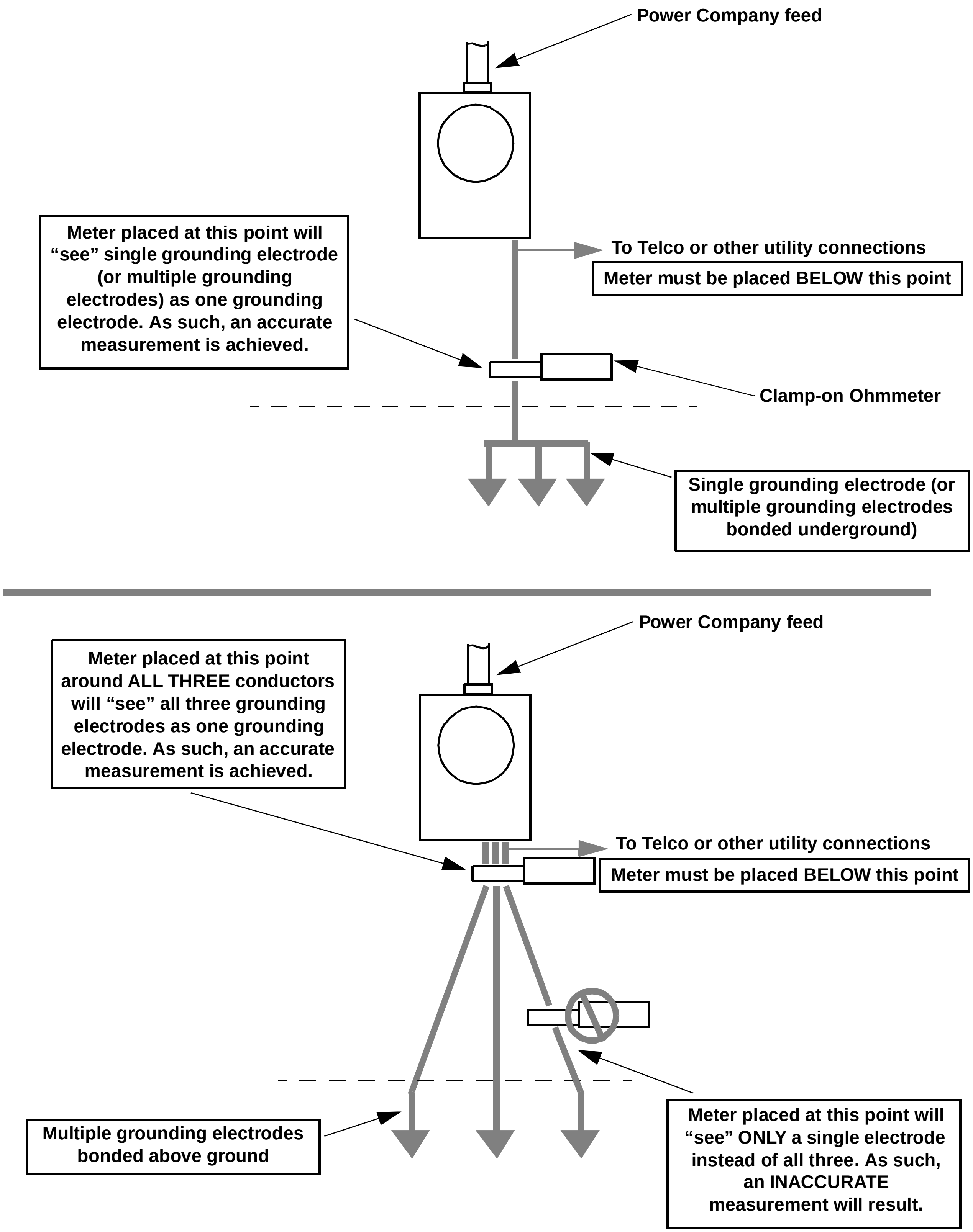


FIGURE 6-54 CLAMP-ON OHMMETER PLACEMENT FOR SINGLE GROUNDING ELECTRODE SYSTEM

6.6.4.4.2 MULTI-BONDED/MULTI-GROUNDING ELECTRODE SYSTEM TESTING

For a site using a multi-bonded/multi-grounding electrode system, perform test as described in the following procedure.

PROCEDURE 6-3 CLAMP-ON OHMMETER TEST PROCEDURE (MULTI-BONDED/MULTI-GROUNDING ELECTRODE SYSTEM)

NOTE: This test requires the site grounding electrode system to be bonded to the power company neutral wire, but may require all non-balanced (phase-to-neutral) loads within the site to be switched off.

1 Coordinate the test with the customer and/or site owner and all other affected parties. Have all non-balanced (phase-to-neutral) loads switched off from the system under test.

NOTE: No unbalanced current flow (current on the neutral wire) within the site **shall** be allowed to influence the clamp-on ohmmeter readings. As such, arrange for any non-balanced (phase-to-neutral) loads within the site to be electrically removed from system, yielding a neutral connection with no current flow on it. The easiest way to accomplish this is to completely turn off all AC power to the site. Any current on the neutral wire (even if less than 5 amps) can result in a false reading.

2 Disconnect any other utility connections to the grounding electrode system, such as the telephone company ground connection or paths through metallic pipes.

3 Have the Power Company neutral wire exposed by a qualified electrician at the point of entry into the site, ensuring that it has no secondary path to the site via a conduit or other connection.

NOTE: The neutral wire is used for a measurement because it is the only point in a site where all of the site ground connections are common over a single conductor. As such, measuring at this point allows the clamp-on ohmmeter to “view” all of the various connections as one single grounding electrode.

In many cases, the first neutral-ground bonding point may not be at the site building electrical service panel, but rather at the meter box where the neutral is bonded to the conduit that enters the building. As such, service that uses a PVC conduit typically has the first neutral-ground bonding point at the electrical service panel; service that uses metallic conduit may have the first neutral-ground bonding point at the meter.
If a measurement is attempted at the electrical service panel where neutral-ground bonding is at the meter, an erroneous closed-loop reading on the meter will result instead of a reading of the grounding electrode system.

PROCEDURE 6-3 CLAMP-ON OHMMETER TEST PROCEDURE (MULTI-BONDED/MULTI-GROUNDING ELECTRODE SYSTEM) (CONTINUED)

	NOTE: Refer to the meter user's manual to determine a meter indication showing that the meter is reading a closed loop rather than the actual grounding electrode system. The closed loop reading may be caused by a ground loop through a conduit, electrical service meter base or any other electrical panel board. It can also be an indication that there is another utility connected, such as a water pipe or the Telephone Company ground.
4	Depending on location of first neutral-ground bonding point, attach the Clamp-on Ohmmeter around the neutral wire as shown in Figure 6-55 or Figure 6-56.
5	Set the meter to the **Amps** scale and verify there is no significant current on the neutral wire.
6	Set the meter to the **Ohms** scale and note the reading; this is the resistance of the grounding electrode system under test. Record the reading on the photocopy of the Clamp-on Ohmmeter/ Ammeter Test Worksheet.

NOTE: Refer to the meter user's manual to determine a meter indication showing that the meter is reading a closed loop rather than the actual grounding electrode system. The closed loop reading may be caused by a ground loop through a conduit, electrical service meter base or any other electrical panel board. It can also be an indication that there is another utility connected, such as a water pipe or the Telephone Company ground.

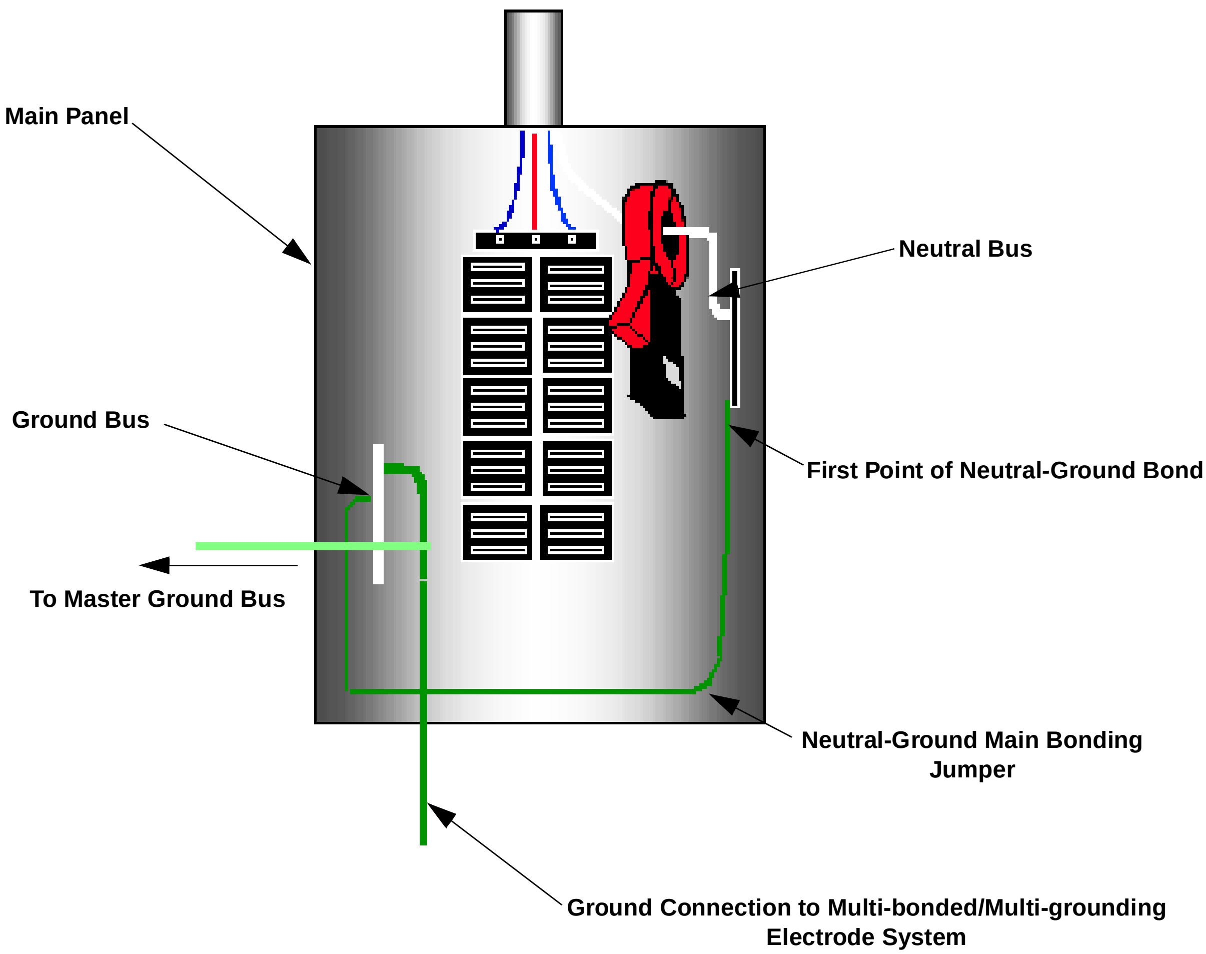


FIGURE 6-55 CLAMP-ON OHMMETER PLACEMENT FOR MULTI-BONDED/MULTI-GROUNDING ELECTRODE SYSTEM (NEUTRAL-GROUND BOND AT SERVICE PANEL)

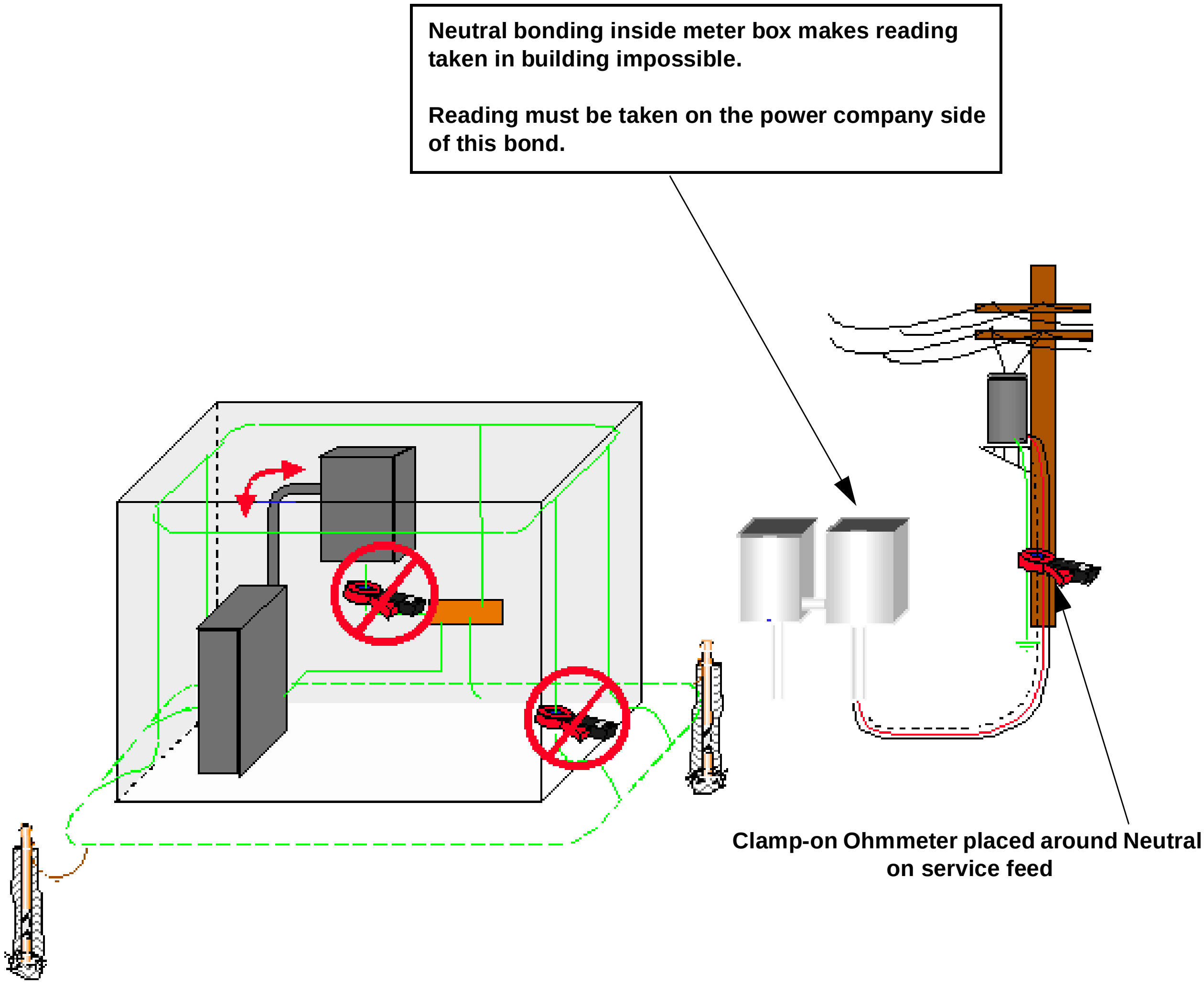


FIGURE 6-56 CLAMP-ON OHMMETER PLACEMENT FOR MULTI-BONDED/MULTI-GROUNDING ELECTRODE SYSTEM (NEUTRAL-GROUND BOND AT METER BOX)

6.6.5 COMBINING SOIL RESISTIVITY TESTING WITH THE CLAMP-ON OHMMETER

Providing site soil resistivity readings along with clamp-on ohmmeter readings to an engineering firm specializing in grounding electrode system design is at times the only method available for grounding electrode system resistance verification.

Typically, the engineering firm will use the supplied data which is entered into a specialized computer program that determines grounding electrode system resistance for the site. The data required is as follows:

- The results obtained from a soil resistivity test
- Individual grounding electrode system component testing data from the clamp-on ohmmeter
- Grounding electrode system layout map/specifications
- Detailed “as-built” drawings for the site

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TABLE 6-6 THREE-POINT TEST WORKSHEET

Distance from Grounding Electrode System Grid		Test Data
%	**ft (m)**	**Ω**
0%		
10%		
20%		
30%		
40%		
50%		
60%		
70%		
80%		
90%		
100%		

Test completed by:
Date:
Client / Project:
Site Location/ID:
Ground Resistance Tester **Model:** **S/N:** **Calibration date:**
Soil Description:
Ambient Conditions **Temperature:** **Present conditions (dry, rain, snow):** **Date of last precipitation:**
Notes:

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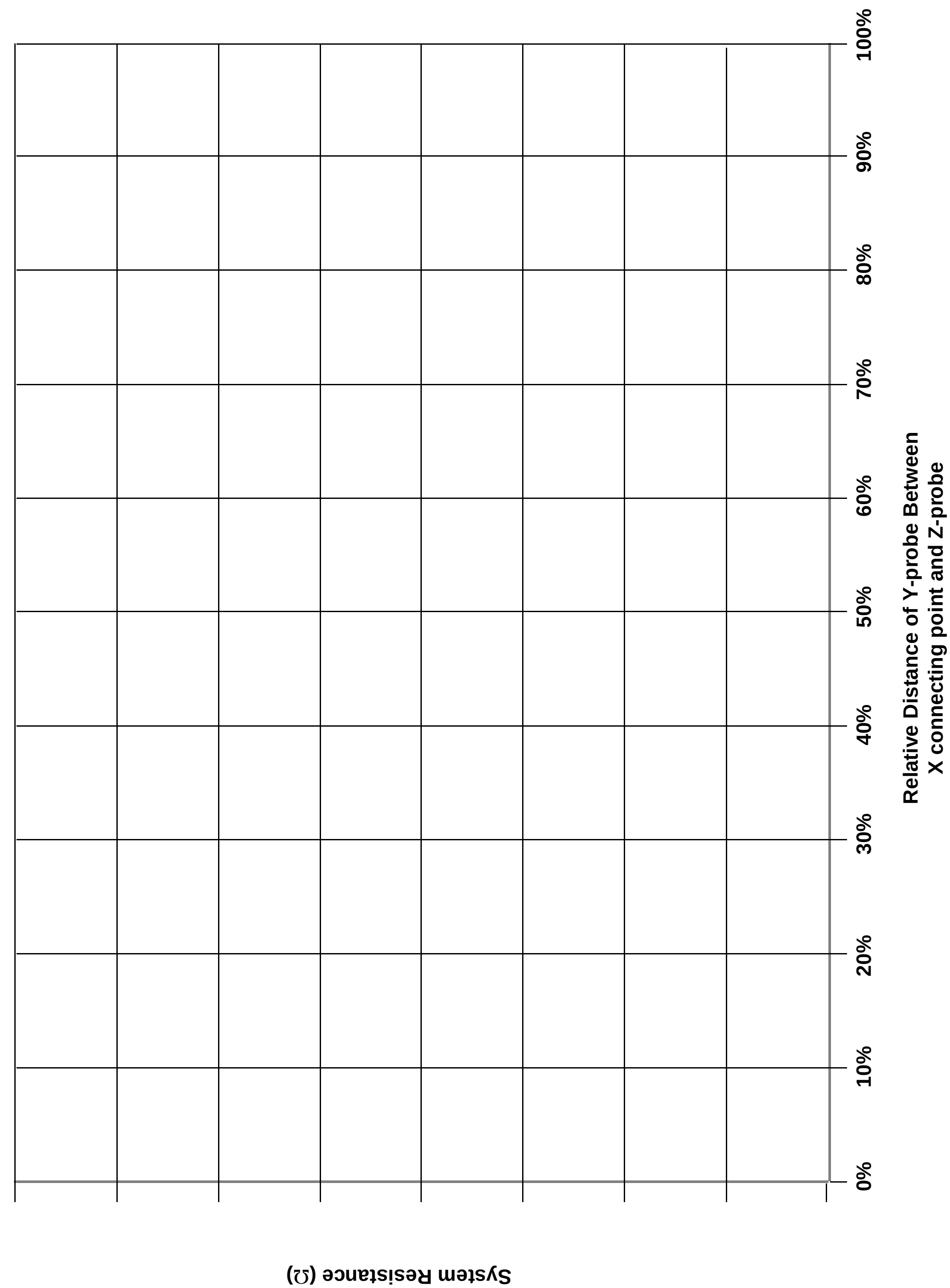

FIGURE 6-57 THREE-POINT TEST GRAPH FORM

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TABLE 6-7 CLAMP-ON OHMMETER/AMMETER TEST WORKSHEET

Points Tested	Ω	Amps
Test Point 1:		
Test Point 2:		
Test Point 3:		
Test Point 4:		
Test Point 5:		
Test Point 6:		
Test Point 7:		

Test completed by:
Date:
Client / Project:
Site Location/ID:
Ground Resistance Tester **Model:** **S/N:** **Calibration date:**
Soil Description:
Ambient Conditions **Temperature:** **Present conditions (dry, rain, snow):** **Date of last precipitation:**
Notes:

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CHAPTER
7

INTERNAL GROUNDING

This chapter provides requirements for grounding communications site equipment.

The requirements in this chapter are the minimum required to help ensure personnel safety and equipment reliability, and are derived from a compilation of industry-wide specifications, standards and applicable codes. Additional steps may be taken as required, based on system requirements and the site's geographical area.

Abnormal and unusual conditions can sometimes require special effort to achieve an effectively bonded and grounded site. Consultation with the Motorola committee responsible for this manual is suggested in these instances. The committee chairman may be contacted via email at **r56man1@namerica.mot.com.**

NOTE: For cellular applications, see Appendix C for more information.

All site development and equipment installation work **shall** comply with all applicable codes in use by the authority having jurisdiction. Government and local codes **shall** take precedence over the requirements of this document. In areas where the governing authority has no permit and inspection process in place and no codes specific to this type of installation have been adopted, the requirements of this document **shall** then apply.

This chapter describes the following topics:

NOTE: All references to NFPA 70 are to the 1999 edition.

7.1 INTRODUCTION

Proper bonding and grounding of equipment is essential for personnel safety and system reliability. Because of the increase in circuit density and the advent of lower-voltage integrated circuit devices, communications systems equipment is now more vulnerable than ever to damage resulting from lightning activity and power line anomalies. Inadequate or improper equipment bonding and grounding can permit a difference of potential to exist between system components, which may result in injury to personnel, system failure, and equipment damage.

The objective of grounding and bonding all system components to a single point is to minimize any difference of potential that may develop between components within the system and within the equipment site or area. To reach this objective, a single point ground system is required for all communications equipment, support equipment, power systems, and other items and materials within the building, shelter, room or area of the same building.

Separate adjacent buildings containing system equipment **shall** be considered an independent building or shelter and **shall** have its own ground system which may or may not be bonded to the adjacent building.

> **NOTE:** Large buildings or campuses with multiple power feeds require special design considerations that are beyond the scope of this document. Consult with Motorola's R56 committee in these instances.

Effective low impedance bonding is achieved through the use of the components listed below, all of which must be effectively bonded together so that there is no difference in potential among them. A typical diagram showing the major components of an effective internal grounding system is shown in Figure 7-1.

- Single point ground system:
  - Master Ground Bus Bar (MGB)
  - Sub System Ground Bus Bar (SSGB)
  - Rack Ground Bus Bar (RGB)
- Ground bus conductors
- Equipment grounding conductors
- Internal perimeter ground bus conductors
- Support system and subsystems
- Metallic structural items and materials

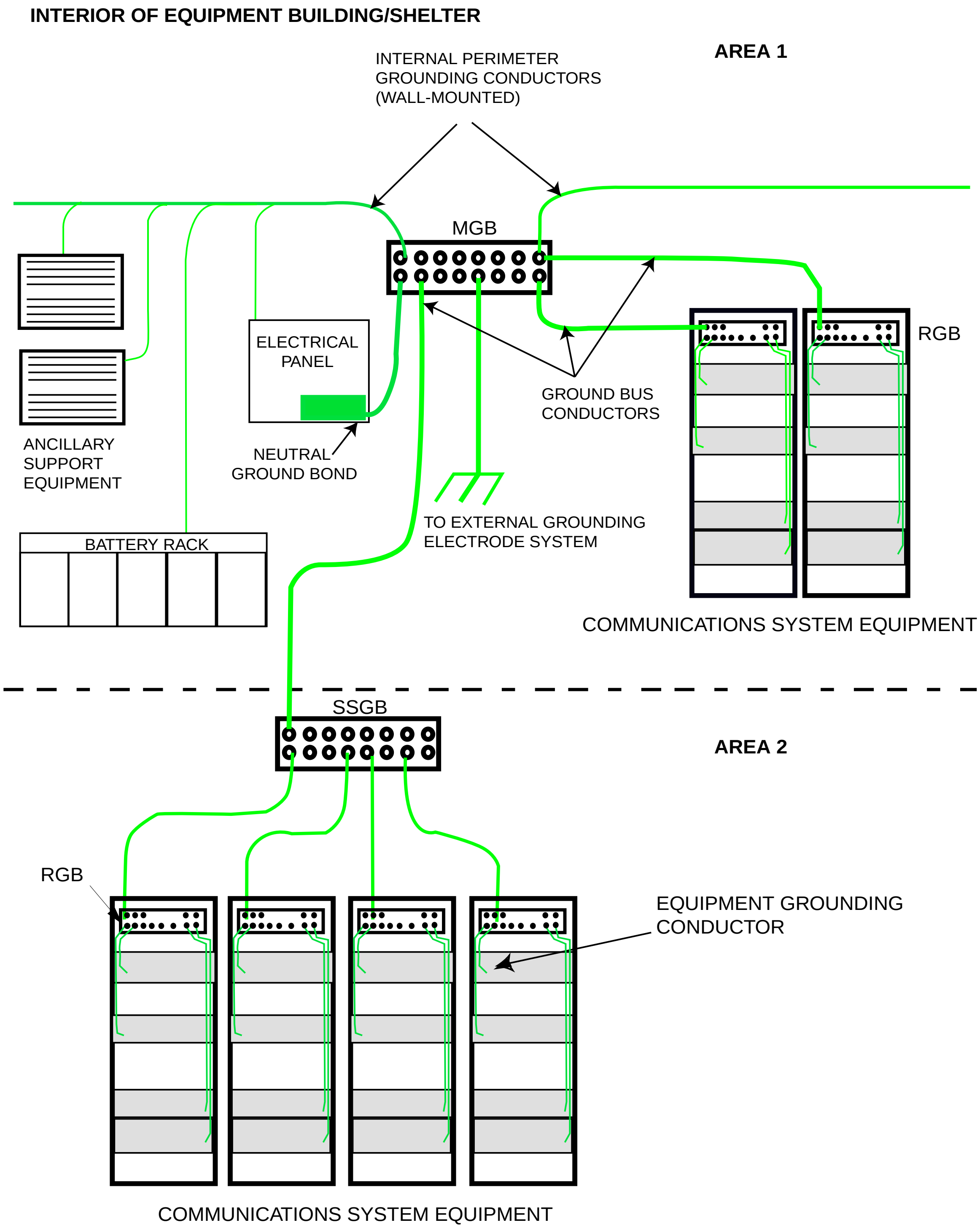


FIGURE 7-1 TYPICAL SINGLE-POINT INTERNAL GROUNDING SYSTEM

A single point ground system is defined as a single point, typically a MGB, within a shelter, equipment building or room, where all communications equipment, ancillary support equipment, antenna transmission lines, transient voltage surge suppression (TVSS) devices, and utility grounds are bonded.

The single point ground system must be effectively connected to a grounding electrode system as detailed in this chapter and Chapter 6, “External Grounding.”

In this chapter, **the system** is defined as all equipment required for proper communications system functionality at the site, and includes but is not limited to:

- Communications and support equipment
- Power systems
- Power distribution systems
- Voice, data and video circuits
- Antenna systems
- Global Positioning System (GPS)
- Surge suppressors
- Support components and material.

The equipment site or area is defined as the equipment building, shelter, room or area within another room where communications equipment or systems may be located and includes but is not limited to:

- Heating, ventilation and air conditioning (HVAC) systems
- Fire suppression systems
- Power distribution systems
- The building structure

7.2 GROUND BUS BARS

This paragraph describes the three types of bus bars that may be used in a communications site building:

- Master ground bus bars (MGB)
- Subsystem ground bus bars (SSGB)
- Rack ground bus bars (RGB)

7.2.1 MASTER GROUND BUS BAR

The MGB is the single termination point for all internal ground bus conductors, internal perimeter ground bus conductors, or equipment grounding conductors as described herein. All equipment and ancillary support apparatus within the communications system equipment area **shall** be bonded to the MGB. This MGB typically serves as the single point ground termination. A typical MGB with mounting brackets is shown in Figure 7-2.

A single MGB (Figure 7-2) **shall** be installed at all communications system equipment locations in a shelter, building, room or area. An MGB may also be installed in an assembly of communications equipment cabinets as may be deemed necessary to ensure an effective bonding point for all equipment grounding conductors.[1]

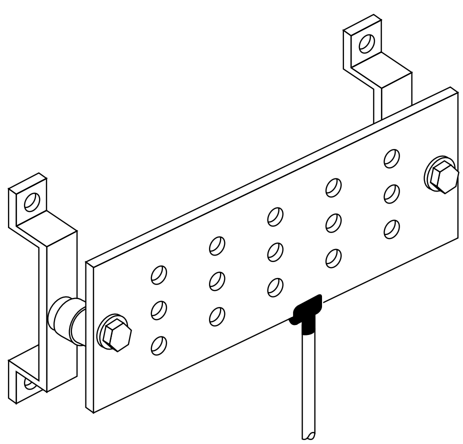


FIGURE 7-2 TYPICAL MASTER GROUND BUS BAR

A single rack, cabinet or chassis that is not part of an onsite communications system and does not constitute a communications system within itself does not require the installation of a MGB as defined in this chapter, though one may be installed if desired.

1. See NFPA 70, Article 100 Grounding Conductor, Equipment for the definition of an equipment grounding conductor.

In this application the single point where all equipment ground connectors terminate may be a point within the single cabinet or a point on the grounding electrode conductor immediately adjacent to the equipment rack, cabinet, or chassis. See Figure 7-3 below.

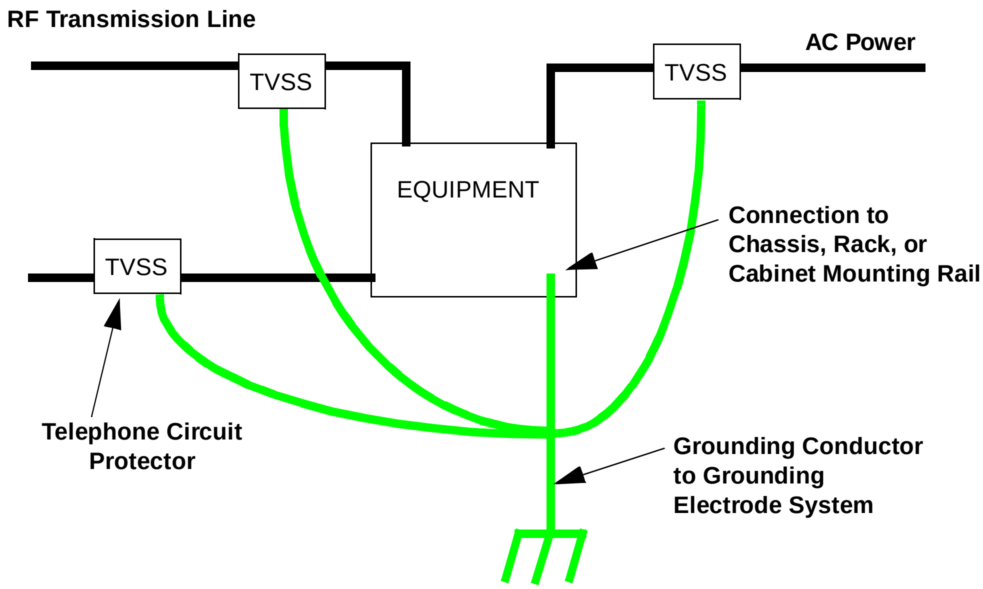


FIGURE 7-3 SINGLE EQUIPMENT GROUNDING CONNECTION

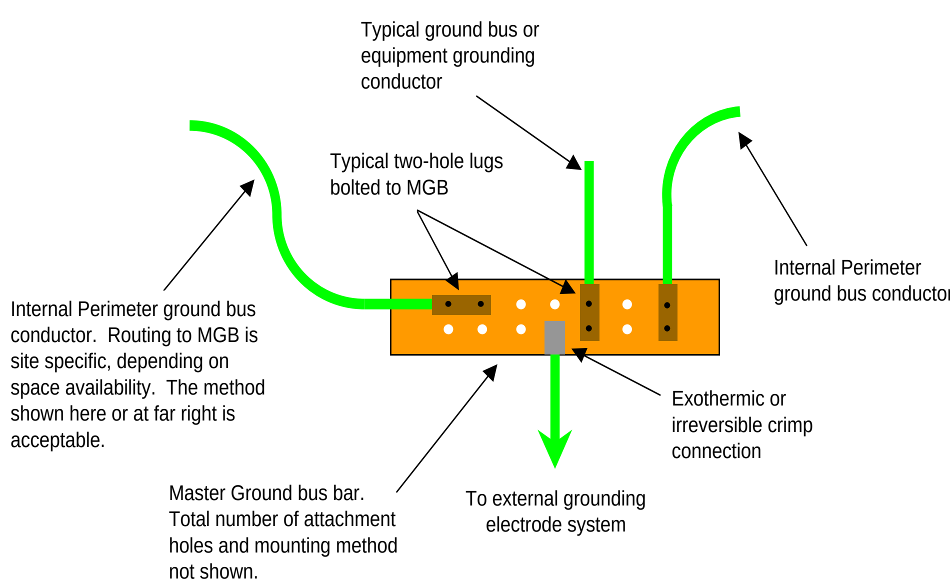


FIGURE 7-4 EXAMPLE OF MASTER GROUND BUS BAR CONNECTION CONFIGURATION

7.2.1.1 REQUIREMENTS

When equipment is in a stand-alone building or shelter, a grounding conductor[1] **shall** extend from the MGB to the external ground electrode system.

When the equipment area is within a larger structure or multi-story building, a grounding conductor **shall** extend to the building ground electrode system conductor. The ground bus conductors, equipment grounding conductors, and internal perimeter ground bus conductors are terminated to the MGB.

A single properly installed integrated cable entry port bulkhead panel of solid copper construction, electrically continuous between the interior and exterior of the structure through which it is mounted and with adequate area for termination of the bus and equipment grounding conductors, may be used as the internal and external ground bus bar. Refer to "Grounding Electrode System Component Requirements" on page 6-5 for additional information on the external ground bus bar (EGB). See Figure 7-5 for an example of the integrated cable entry port bulkhead.

FIGURE 7-5 INTEGRATED CABLE ENTRY PORT BULKHEAD

1. See NFPA 70, Article 100 Grounding Conductor, Equipment for the definition of a grounding conductor.

7.2.1.2 LOCATION

The MGB **shall** be located within the shelter, equipment room or equipment area within 60 cm (24 in.) of the point where the transmission lines enter, preferably near the entry points of the power and communications conductors. The MGB is typically mounted on insulated standoffs to the wall just below the point where the transmission lines enter. In facilities where the transmission lines enter the shelter, building or room through the wall at floor level or through conduits within the floor or ceiling, the MGB may be located on the wall, floor or ceiling immediately adjacent to the entry point of the transmission lines. Telephone cables and the main electrical service disconnect supplying power to the communications system must also be located within close proximity to the MGB. The most desirable location is along the same wall. This permits a single point bonding of the electrical service and telephone network interface grounding electrode conductors and the MGB grounding electrode conductor to the grounding electrode system. See Figures 7-6 and 7-7.

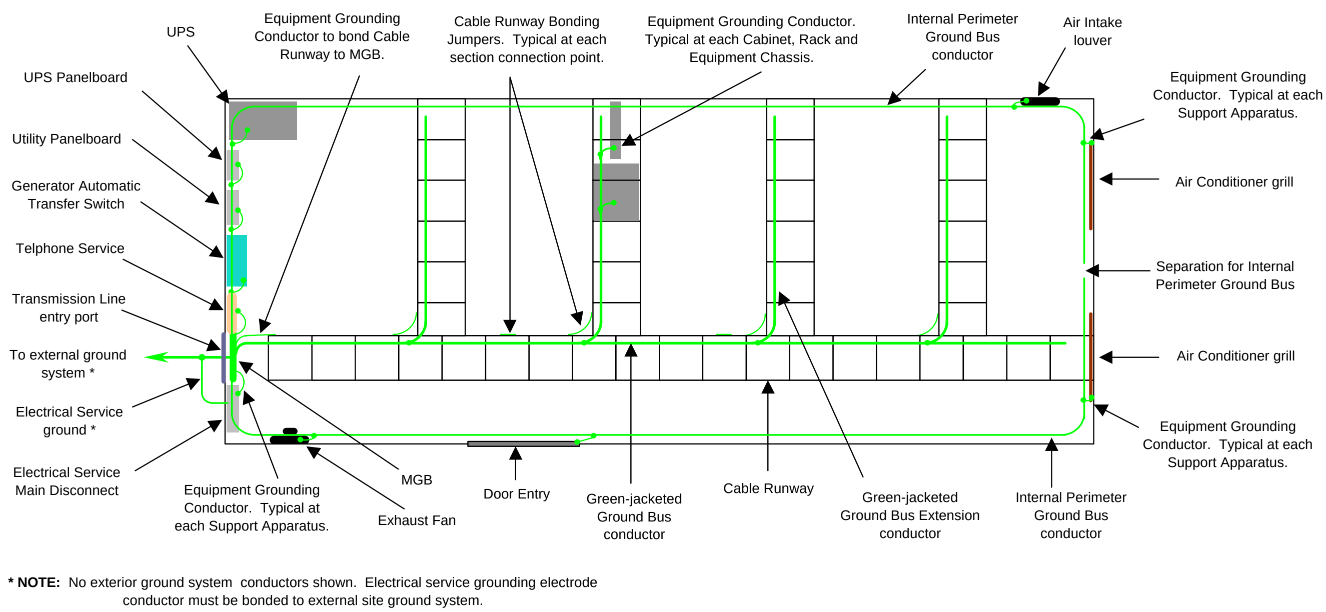


FIGURE 7-6 PREFERRED MGB LOCATION

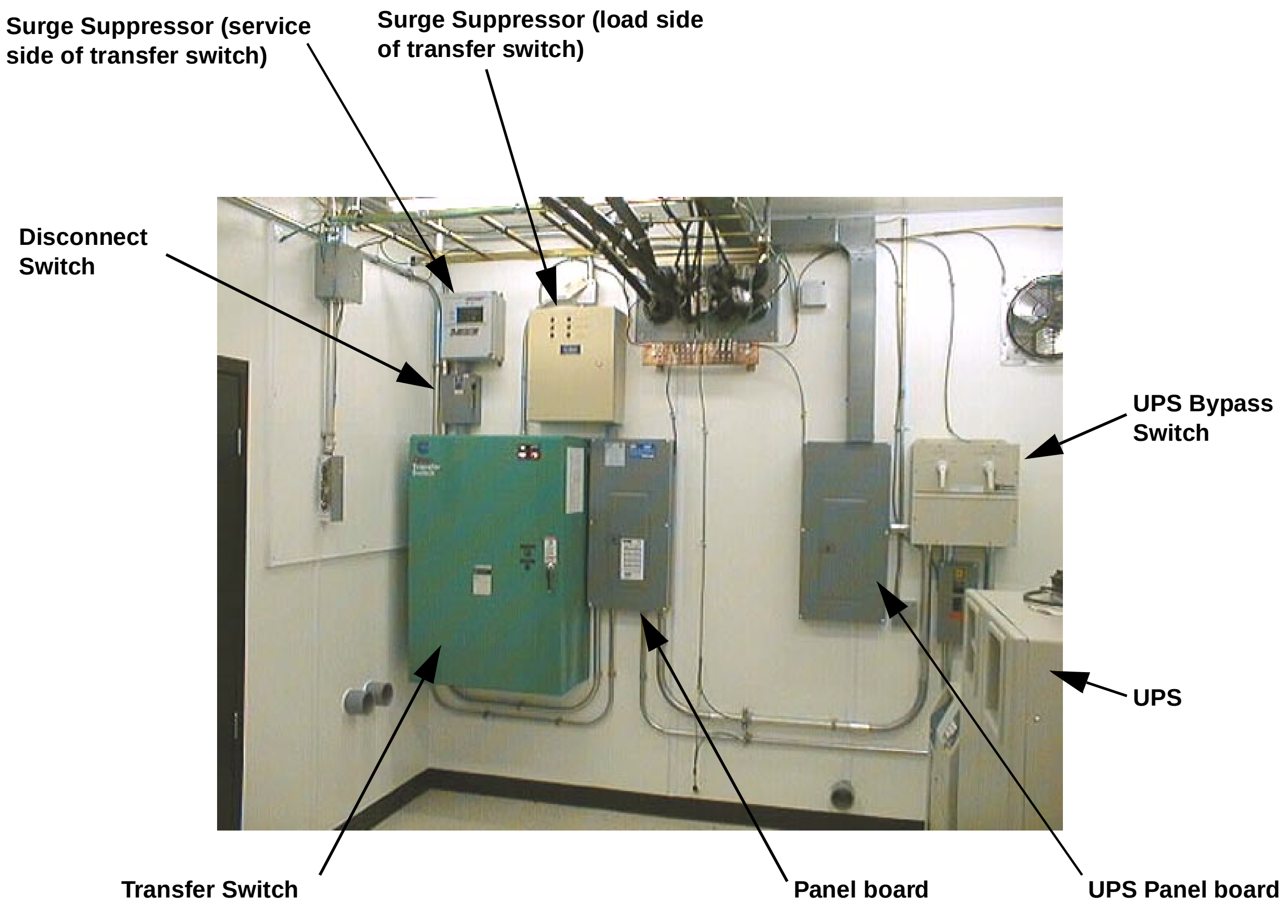


FIGURE 7-7 PREFERRED MGB LOCATION - EXAMPLE

7.2.1.3 MGB SPECIFICATIONS

See Table 7-1. The MGB **shall** carry the UL listing.

TABLE 7-1 MGB SPECIFICATIONS

Item	Specification
Material	Bare, solid Alloy 110 (99.9%) copper bus bar or plate of one piece construction May be electrotin-plated.
Minimum Dimensions	Width: 5 cm (2 in.) Length: 30.5 cm (12 in.) Thickness: 0.635 cm (1/4 in.)
Mounting brackets	Must be suitable for the application.
Insulators	polyester fiberglass 15 kV minimum dielectric strength flame resistant per UL 94 VO classification
Conductor mounting holes Number Dimensions	Dependent on number of conductors to be attached Holes to be 11 mm (7/16 in.) minimum on 19 mm (3/4 in.) centers to permit the convenient use of two-hole lugs
Method of attachment of grounding electrode conductor.	Exothermic welding Irreversible crimp connection Other suitable irreversible crimp connection process

7.2.1.4 BONDING: MGB-TO-GROUNDING ELECTRODE SYSTEM

The specifications and acceptable methods for bonding the MGB to the site's grounding electrode system are provided in Table 7-2. The requirements for each type of building or shelter are indicated by a check in the appropriate "Type of Structure" column. See Figure 7-7 for an illustration of typical MGB bonding and routing.

TABLE 7-2 BONDING THE MGB TO THE GROUNDING ELECTRODE SYSTEM

Type of Structure				
Standalone shelter or eqpt bldg.	**Eqpt. room or area within larger building.**	**Multistory or hi-rise structures and roof mounted cabinets**	**Pad or Pole mounted cabinets**	**Requirement**
✔	✔ Note [1]	✔ Note [2]	✔	The MGB **shall** be bonded to the external grounding electrode system with a 35 mm^2 csa (#2 AWG), or larger, stranded (preferred) or solid tinned copper grounding conductor.
✔	✔	✔	✔	The MGB **shall** be bonded to the electrical service grounding electrode conductor with a 35 mm^2 csa (#2 AWG), or larger, stranded, copper grounding conductor. This conductor may be solid and **shall** be tinned if any part of the conductor is below grade.
	✔ Note[1]	✔		The MGB **shall** be bonded to an indoor grounding electrode conductor, typically found in larger buildings, multistory or high rise structures.
	✔	✔		The indoor grounding electrode conductor may be one of the following listed in a descending order of effectiveness: • The exposed steel structure of the building • Effectively grounded metal water piping systems • Exposed electrical grounding electrode conductor • A dedicated grounding conductor
	✔	✔		Exposed nonflexible metallic service raceways may be used when none of the above means are available.
✔		✔	✔	The grounding conductor **shall** be free of any splices. Should a splice in the grounding conductor become necessary the splice **shall** be made using irreversible compression type connectors that are listed for the purpose or with the exothermic process. No other type of splice is acceptable.
	✔	✔		The grounding conductor **shall not** contain any splices. Should a splice in the grounding conductor become necessary the splice **shall** be made using irreversible compression type connectors that are listed[3] for the purpose or with the exothermic process. No other type of splice is acceptable.
✔	✔	✔	✔	Connections of the grounding conductor to the MGB **shall** be by the exothermic process or by the use of a listed[3] irreversible pressure type crimp connection.
✔	✔	✔	✔	Connections of the grounding conductor to an external grounding electrode system **shall** be by the exothermic process or by the use of a listed[3] irreversible pressure type crimp connection.
✔	✔	✔	✔	The grounding conductor **shall** be run in as straight a line as is possible and with a minimum number of bends. See Figure 7-8 and *NFPA 70, Article 250(c)* and for additional information.

TABLE 7-2 BONDING THE MGB TO THE GROUNDING ELECTRODE SYSTEM (CONTINUED)

Type of Structure				Requirement
Standalone shelter or eqpt bldg.	**Eqpt. room or area within larger building.**	**Multistory or hi-rise structures and roof mounted cabinets**	**Pad or Pole mounted cabinets**	
	✔	✔		The ground path integrity of the exposed structural steel or water piping system must be verified as being continuous.
	✔	✔		Effective bonding of joints and sections of exposed structural steel or water piping systems **shall** be provided as required to ensure the electrical integrity of this ground path. (NFPA-70; Article 250-68(b))
	✔	✔		Connections to the exposed steel structure of the building or dedicated grounding electrode conductor **shall** be made with the exothermic process. When the exothermic process type connection is not suitable, this connection may be made by using listed[3] irreversible pressure type crimp connectors, listed[3] lugs or clamps or split bolt type compression connectors.
✔	✔	✔		Air handling ducts are not suitable for use as a grounding means. (NFPA-70; Article 820-40)
✔	✔	✔	✔	Connections depending on solder **shall not** be used (NFPA-70; Articles 250-8 and 250-70).

1. The MGB **shall** be bonded to the external grounding electrode system (stranded conductor preferred) if such a system is installed at the building and the equipment room or area is reasonably close to ground level. The MGB **shall** be bonded to the external tower grounding electrode system if a tower or stand alone antenna structure is present.
2. The MGB may be bonded to the external grounding electrode system if the system is installed on the structure.
3. Listed means that the item or device is listed by UL or an approved testing laboratory or complies with the definition as specified in NFPA 70, Article 100.

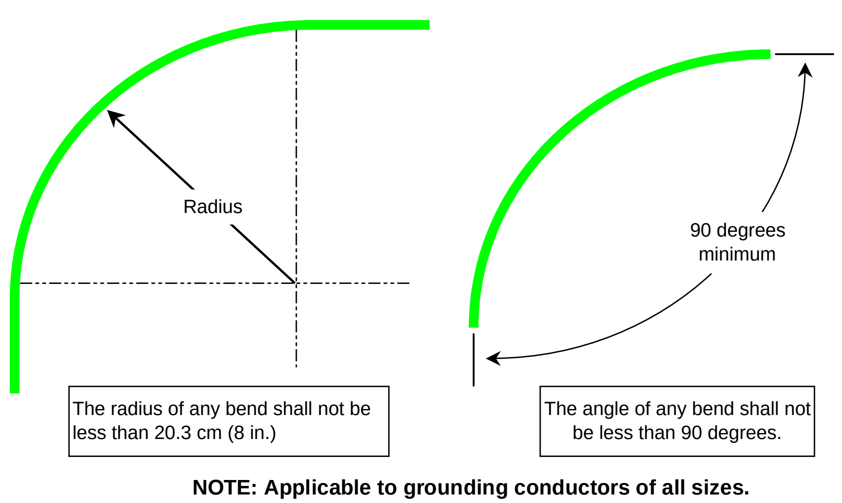


FIGURE 7-8 ACCEPTABLE GROUND CONDUCTOR BENDING

7.2.1.5 UNACCEPTABLE GROUNDING ELECTRODE SYSTEMS

The following are not acceptable for use as a grounding electrode system because these systems are generally not electrically continuous. (This **shall not** prohibit the bonding of these systems to the internal perimeter ground bus when they are located within the equipment shelter, room or area (per NFPA-70; Article 250-104)):

- Gas piping systems (per NFPA-70; Article 250-52(a))
- Fire sprinkler piping systems **shall not** be used as a grounding electrode conductor unless the continuous electrical continuity can be established.

7.2.1.6 BONDING TO THE MGB

All equipment including but not limited to that listed below, **shall** be effectively bonded to the MGB using methods described herein. The means of this bonding are detailed in the paragraphs below. Connections depending on solder **shall not** be used (per NFPA 70, Articles 250-8 and 250(e)).

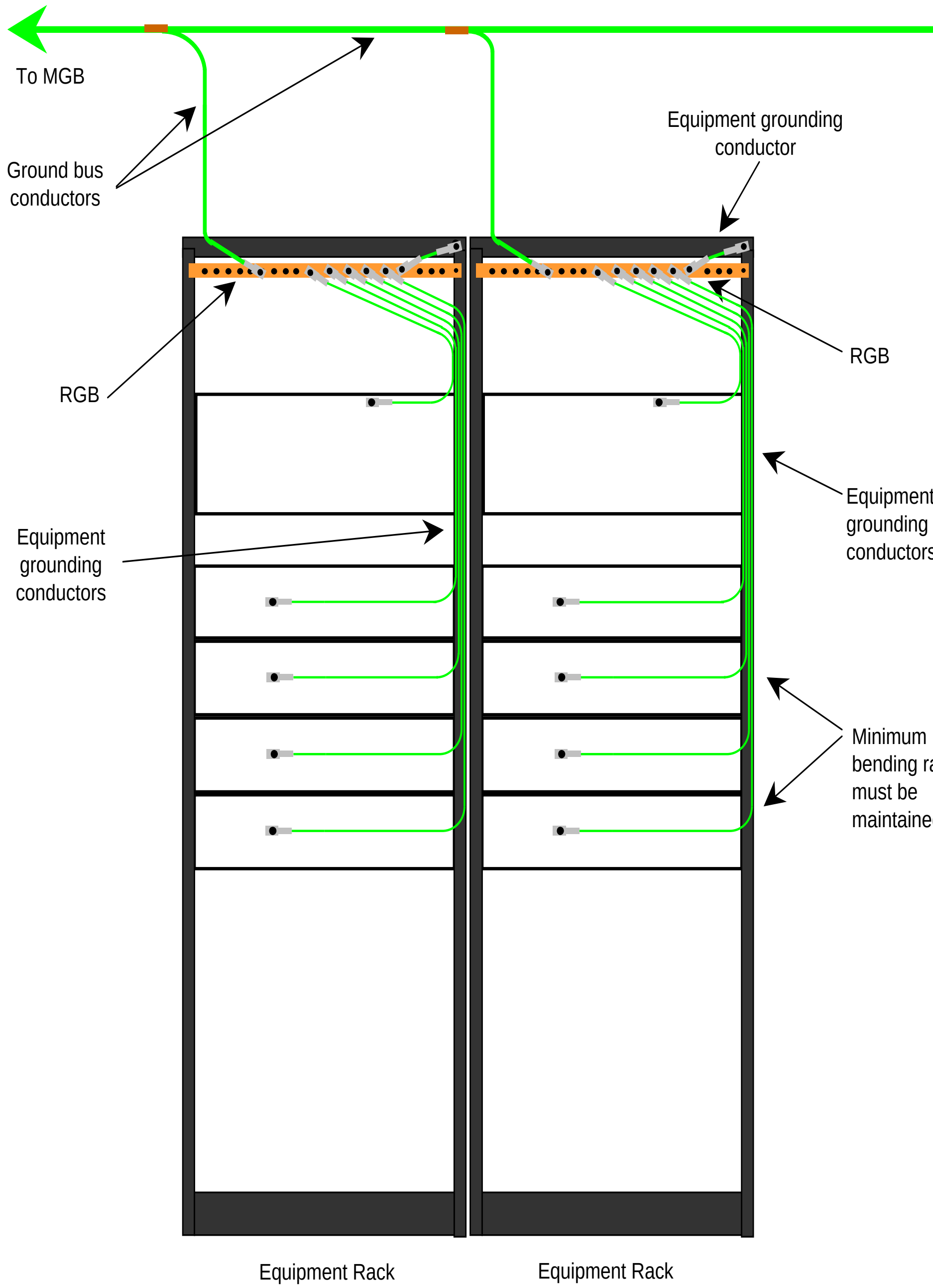
NOTE: Some customers may require that conductors be bonded to the MGB in a specific sequence or order determined by the conductor's origin or the type of equipment being bonded to the MGB. One of these methods, known as PANI, allocates specific areas of the MGB for bonding surge energy Producers, Absorbers, Non-isolated equipment, and Isolated equipment. This method is not required for compliance with this manual and is referenced as a point of information. See Appendix C and ANSI T1.313-1999 for more information on this method of bonding conductors.

- Ground Bus Conductors
- Equipment grounding conductors **shall** be bonded to ground bus conductors or directly to the MGB.
- Internal perimeter ground bus
- Equipment cabinets, racks and individual system component chassis.
- Ancillary support items.
- Metallic structural items and materials
- The grounded conductor of a separately derived AC electrical system **shall** be bonded to the MGB. (NFPA 70, Articles 100(a), 250-20(d) and 250-30.)

7.2.1.7 EQUIPMENT REQUIRED TO BE BONDED TO THE MGB

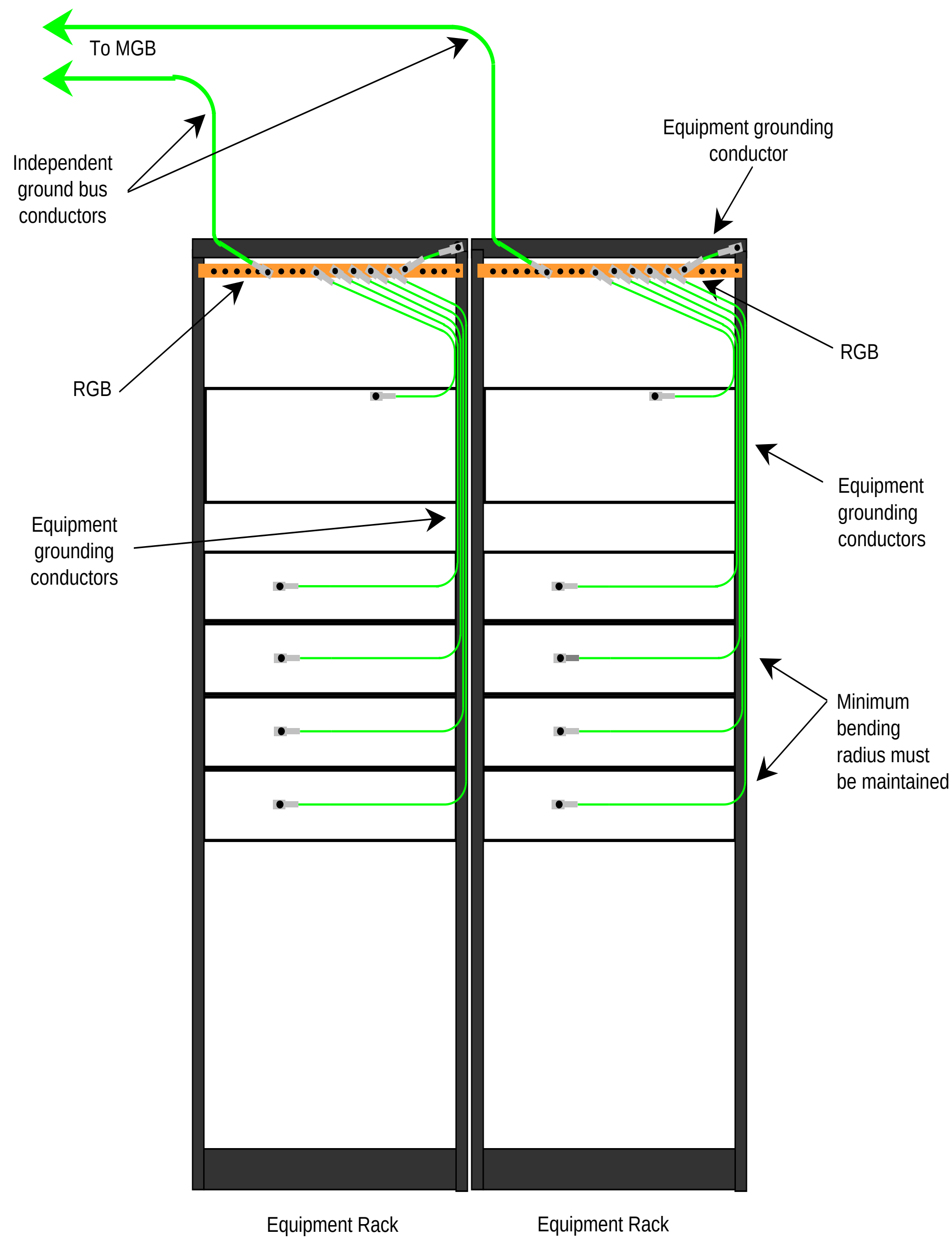
All equipment and ancillary support apparatus including but not limited to items listed in Table 7-3 **shall** be effectively bonded to the MGB, using the methods described in the table. This equipment **shall** be either bonded using a combination of a SSGB, RGB, equipment grounding conductor and a ground bus conductor, or individual equipment grounding conductors. See Figures 7-9, 7-10, and 7-11 for examples. Connections depending on solder **shall not** be used (per NFPA-70; Article 250(e)).

NOTE: A ground bus bar installed within a rack or cabinet **shall** be considered a RGB and **shall** be bonded to the MGB as described herein.



NOTE: In installations where the ground bus is located below the rack or cabinet, the RGB may be installed in the bottom of the rack or cabinet.

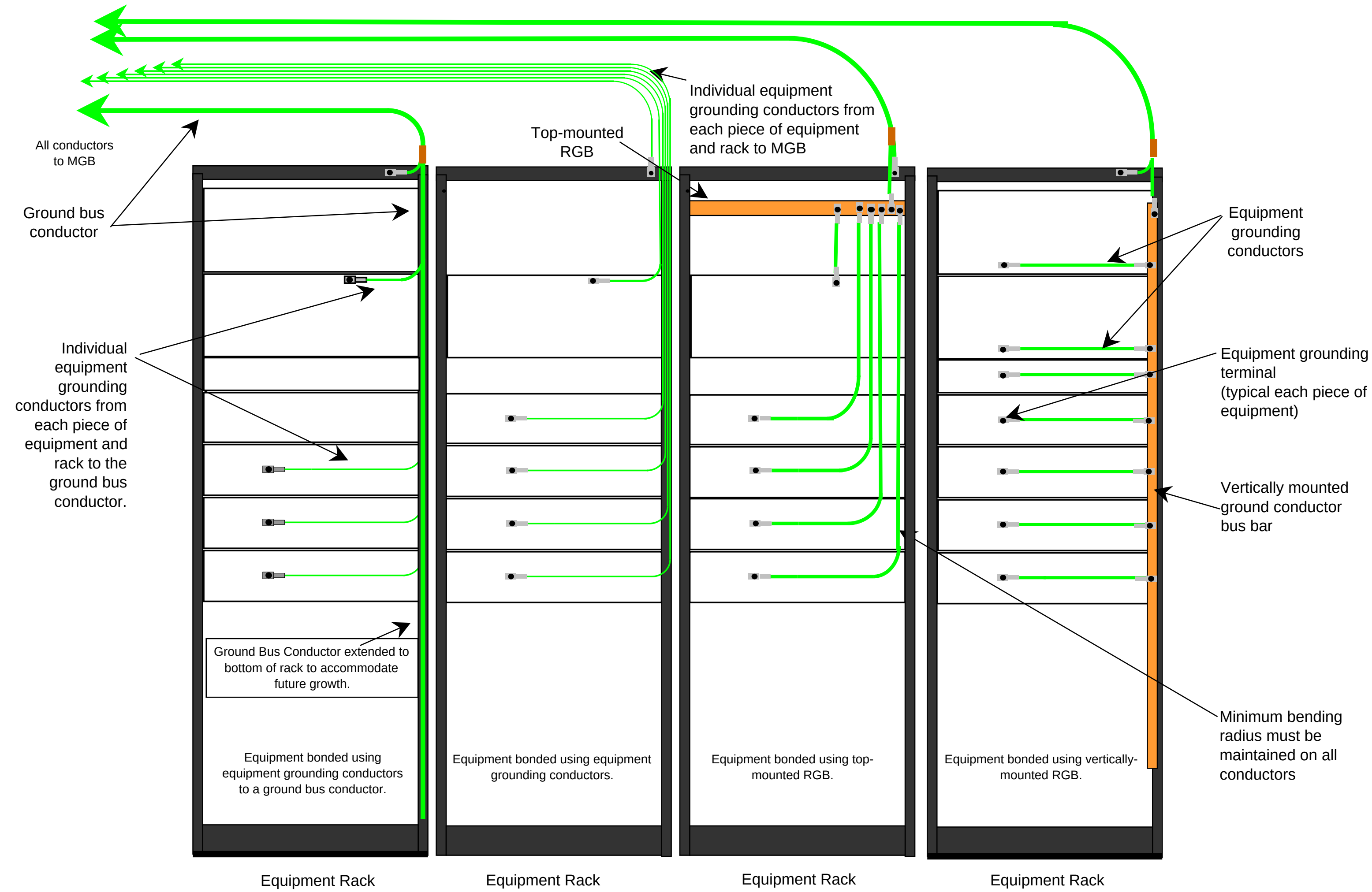
FIGURE 7-9 TYPICAL INSTALLATION OF RGB BONDED TO GROUND BUS CONDUCTOR



NOTE: In installations where the ground bus is located below the rack or cabinet, the RGB may be installed in the bottom of the rack or cabinet.

FIGURE 7-10 TYPICAL INSTALLATION OF RGB BONDED TO THE MGB WITH INDIVIDUAL GROUND BUS CONDUCTORS

FIGURE 7-11 ACCEPTABLE METHODS FOR BONDING FROM THE EQUIPMENT TO THE MGB



Note: Blank filler panels do not require bonding.

TABLE 7-3 BONDING TO THE MGB

From	To					
Item	**MGB**	**SSGB**	**RGB**	**Ground Bus Conductor**	**Internal Perimeter Ground Bus Conductor**	**Method**
SSGB	✔					Bond with 35 mm² csa (#2 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein.
Rack ground bus bar (RGB)	✔	✔		✔		The RGB **shall** be bonded to the MGB, SSGB, or ground bus conductor with 35 mm² csa (#2 AWG) or larger, green jacketed[1], solid or stranded copper conductor.
Ground bus conductor	✔	✔				Ground bus conductors **shall** be effectively bonded to the MGB, SSGB, or other ground bus conductor using methods described herein.
internal perimeter ground bus	✔	✔				internal perimeter ground bus conductors **shall** be effectively bonded to the MGB or SSGB using methods described herein.
Equipment grounding conductor	✔	✔	✔	✔		Equipment grounding conductors **shall** be bonded to the MGB, SSGB, RGB or ground bus conductor using methods described herein.
Cabinets	✔	✔	✔	✔		Bond with 16 mm² csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor, which **shall** be attached from the cabinet equipment mounting rail, or terminal to the, MGB, SSGB, RGB or ground bus using methods described in this chapter.
Racks	✔	✔	✔	✔		Bond with 16 mm² csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor, which **shall** be attached from the rack grounding pad or terminal to the, MGB, SSGB, RGB or ground bus using methods described in this chapter.

TABLE 7-3 BONDING TO THE MGB (CONTINUED)

From	To					
Item	MGB	SSGB	RGB	Ground Bus Conductor	Internal Perimeter Ground Bus Conductor	Method
Individual system component chassis	✔	✔	✔	✔		All system component chassis, support chassis, panels, card cages, cross connect panels, test jack field panels and other equipment that has a ground connection point **shall** be bonded with 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor, which **shall** be attached from the equipment grounding terminal, chassis or frame to the MGB, SSGB, RGB or ground bus using methods described herein. On equipment where a ground stud or connection point provided by the manufacturer is sized and/or located such that a 16 mm^2 csa (#6 AWG) conductor cannot be reasonably attached, the 16 mm^2 csa (#6 AWG) equipment grounding conductor **shall** be attached to a suitable attachment point or to the equipment mounting screw. Where a terminal strip or other connection point integral to the equipment must be connected to ground, a jumper sized per the manufacturer's instructions **shall** be installed between this point and the equipment grounding conductor attachment point.
Transmission line & surge suppressors	✔	✔ Note [2]				RF transmission line surge suppression devices **shall** be bonded to the MGB within 60 cm (24 in.) of entry into the equipment shelter, equipment room or equipment area. In instances where the RF transmission lines enter the building at a point other than where the equipment room or area is located there is no requirement for surge suppression devices at that location. The shield of the RF transmission line must be effectively bonded to the grounding electrode system at the point of entry into the building or as near as practicable thereto (NFPA-70; Article 820-33).
Primary telephone circuit surge suppressors	✔	✔				Bond with a 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein. An 8 mm^2 csa (#12 AWG) green jacketed[1] solid or stranded copper conductor may be utilized for bonding a single circuit (2 pair) surge suppressor.

TABLE 7-3 BONDING TO THE MGB (CONTINUED)

From	To					
Item	**MGB**	**SSGB**	**RGB**	**Ground Bus Conductor**	**Internal Perimeter Ground Bus Conductor**	**Method**
Secondary telephone circuit surge suppressors	✔	✔	✔	✔		Bond with a 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein. An 8 mm^2 csa (#12 AWG) green jacketed[1] solid or stranded copper conductor may be utilized for bonding a single circuit (2 pair) surge suppressor.
Separately derived AC electrical systems	✔	✔				Bond with a 16 mm^2 csa (#6 AWG) or larger as may be required, green jacketed[1], solid or stranded copper conductor using methods described herein. See *NFPA 70, Table 250-66* for minimum conductor size.
Cable runway	✔	✔				Bond with a 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein.
Control centers, Dispatch equipment, and metallic parts of dispatch furniture	✔	✔		✔		Bond with a 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein.
Ancillary support items, metallic structural items and materials	✔	✔			✔	Bond with a 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein.

1. Ground conductors may be green, green with a yellow stripe or black with green tape on a black conductor at points designated by NFPA 70, Article 250-119 or jurisdictional codes.
2. At locations where transmission lines enter an equipment area served by a SSGB the transmission lines **shall** enter the room or area within 60 cm (24 in.) of the SSGB and the transmission line surge suppressors **shall** be bonded to the SSGB with a 16 mm^2 csa (#6 AWG), or larger, green jacketed, solid or stranded copper conductor using methods described herein. Refer to "Location" on page 7-24.

7.2.2 SUB SYSTEM GROUND BUS BAR

NOTE: Refer to Chapter 8, "Power Sources," for electrical distribution options as a separately derived system when a SSGB is used.

A Sub System Ground Bus Bar (SSGB) as shown in Figure 7-12 may be installed within a generator or power distribution room, a communications subsystem equipment room or area separate from, but associated with, the main communications equipment room or area and located within the same building as the MGB. In some applications the SSGB may be referred to as an isolated zone ground bus bar (IZGB).

The SSGB provides a single termination point for all internal ground bus conductors, internal perimeter ground bus conductors, or equipment grounding conductors within a communications subsystem equipment room or area as defined herein. By having all equipment and ancillary support apparatus within the communications system equipment area bonded to the SSGB, differences in potential between communications system components will be minimal and the probability of personal injury, system failure, or equipment damage greatly reduced.

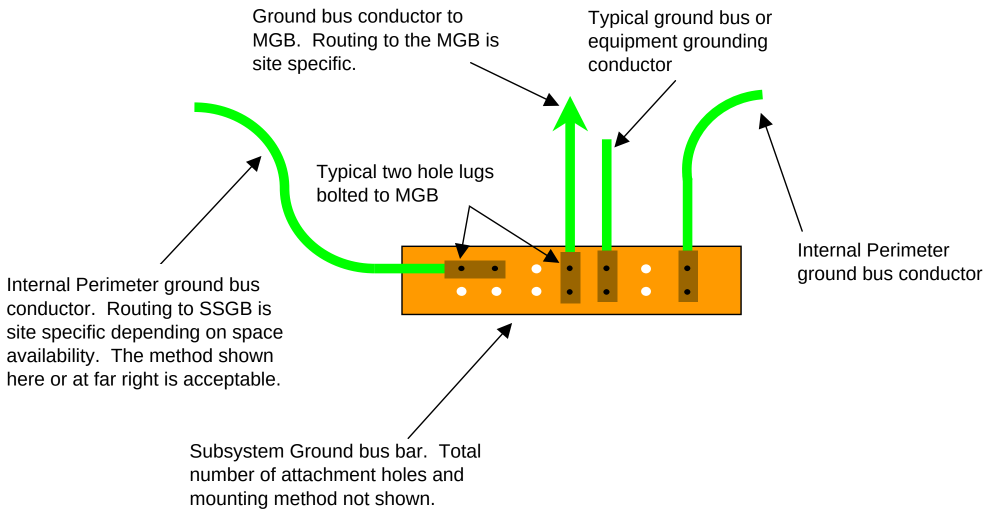


FIGURE 7-12 SUB SYSTEM GROUND BAR

A SSGB **shall not** be used when the associated equipment is located in a separate shelter or building, even if the shelter or buildings are adjacent to one another. A shelter added as a permanent attachment to an original building or shelter, which receives AC power from the same electrical service as the original building or shelter, is not considered a separate shelter or building for the purpose of this paragraph. **See** Figure 7-13, Figure 7-14, and Figure 7-15 for examples.

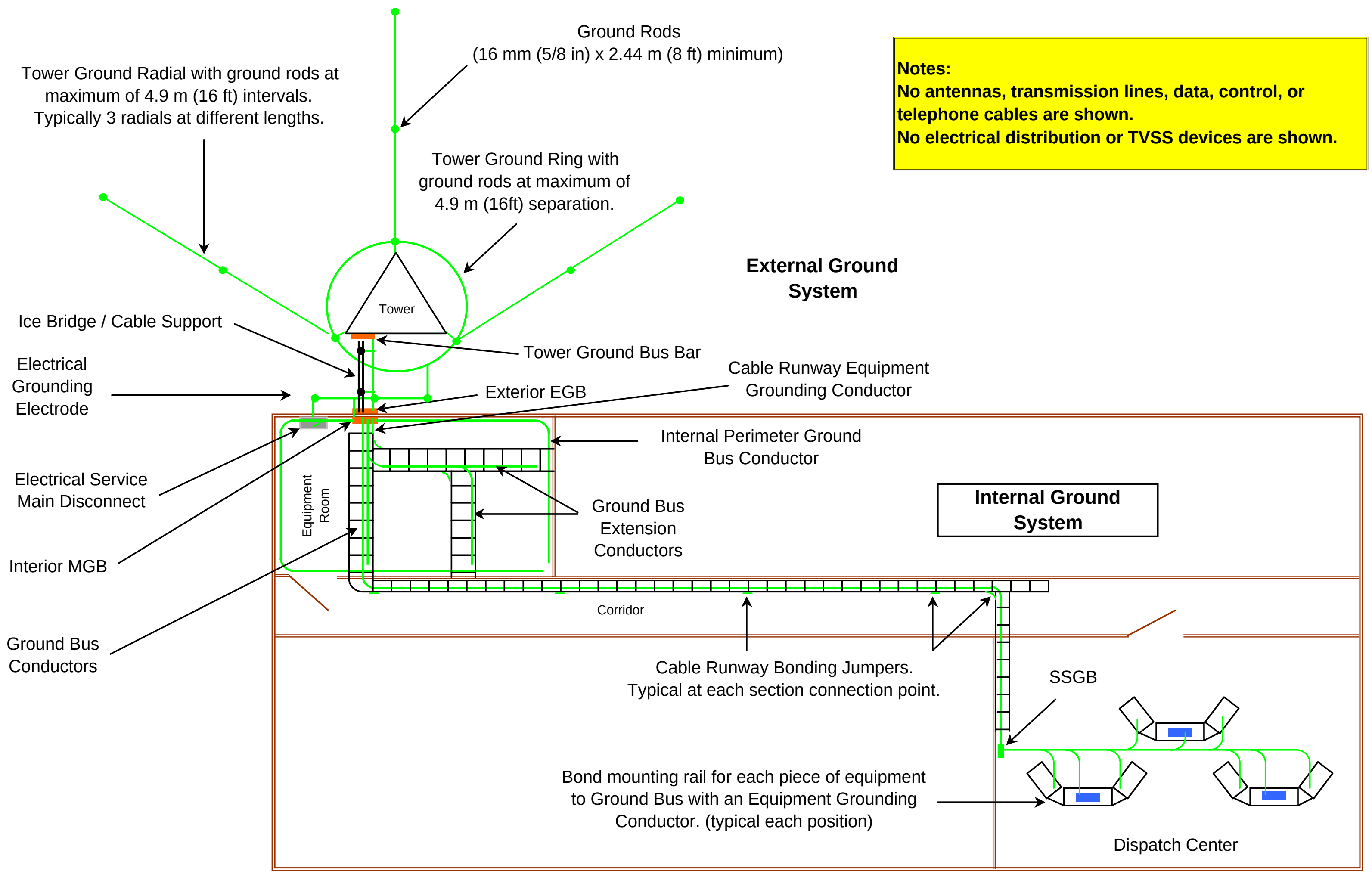


FIGURE 7-13 SITE GROUNDING SYSTEM, TOWER AND COMMUNICATIONS SITE AND DISPATCH CENTER CO-LOCATED

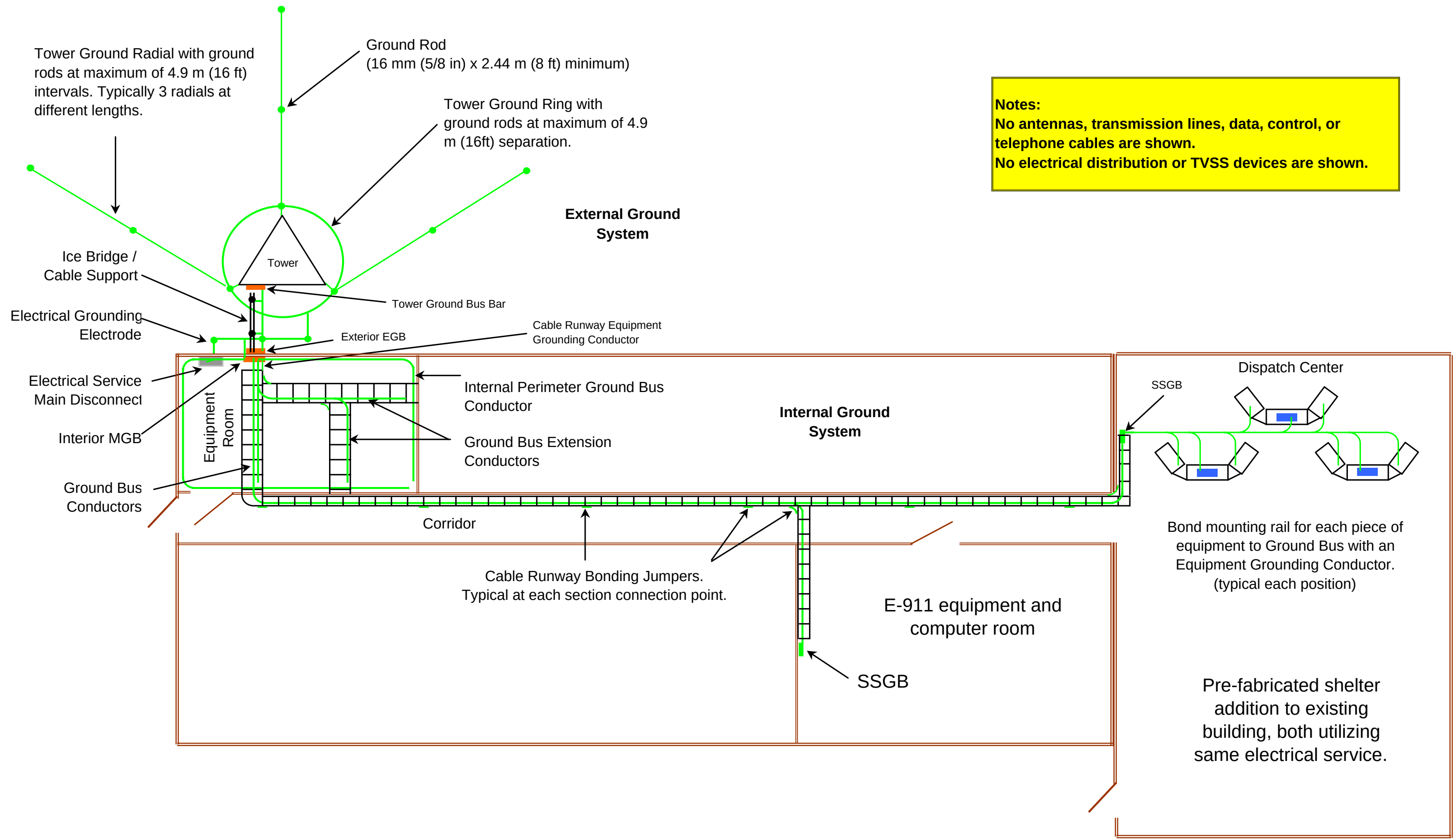
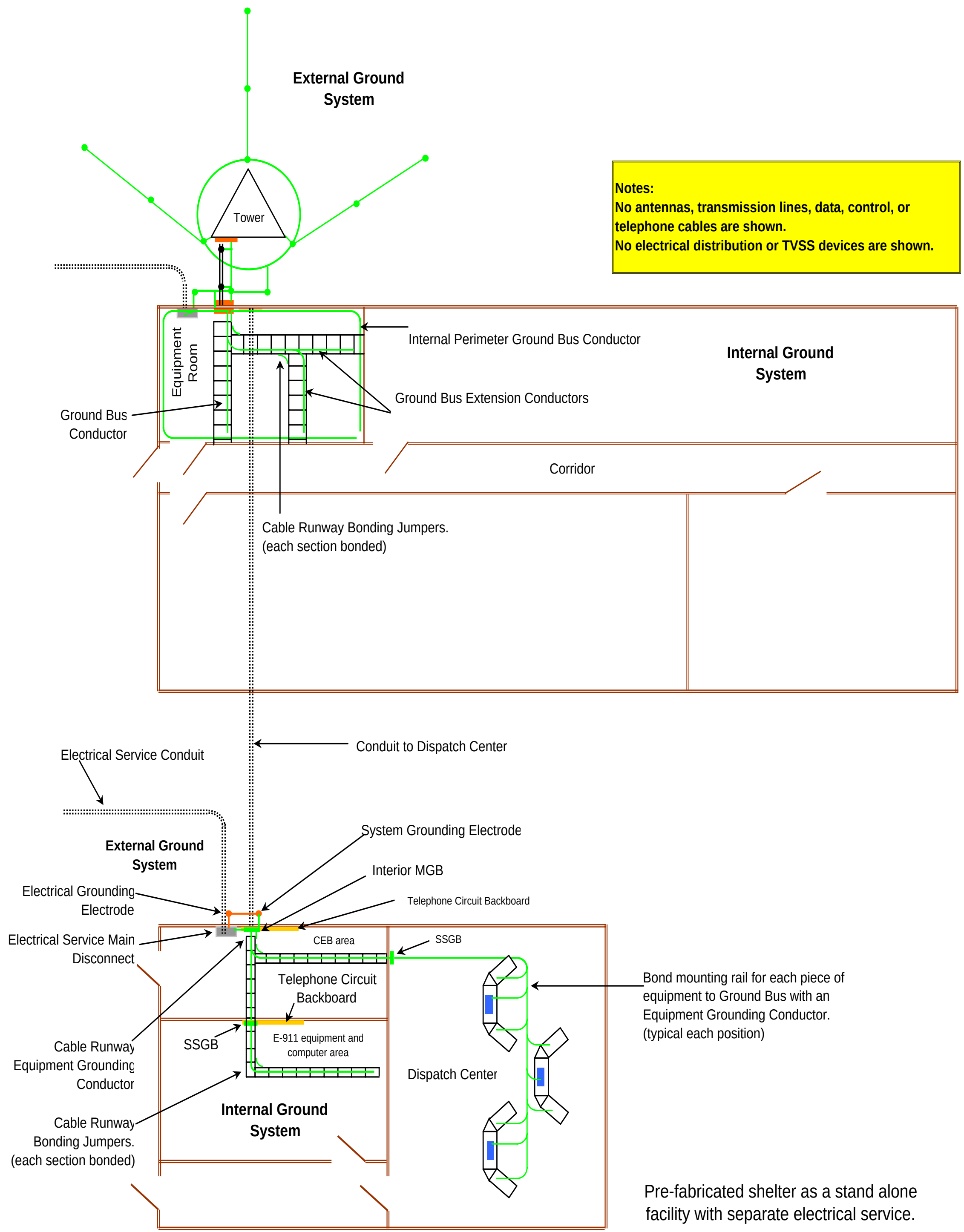


FIGURE 7-14 SITE GROUNDING SYSTEM, SEPARATE ADJACENT SHELTER OR BUILDING



NOTE: See Figure 7-14 for details of main building and tower grounding.

FIGURE 7-15 SITE GROUNDING SYSTEM, WITH STAND-ALONE PRE-FABRICATED SHELTER WITH SEPARATE ELECTRICAL SERVICE

A SSGB may also be installed in an assembly of communications equipment cabinets as deemed necessary to ensure an effective bonding point for all equipment grounding conductors. Installation of a single rack, cabinet or chassis within a room or area does not require the installation of a SSGB as defined in this section, though one may be installed if desired.

A ground bus conductor **shall** extend from the SSGB, or RGB to the MGB. When a SSGB, or RGB is not used, a ground bus conductor **shall** be installed from the single rack, cabinet or chassis to the MGB.

7.2.2.1 LOCATION

The SSGB **shall** be located within the equipment room or equipment area at the point where it is most convenient to terminate all ground bus conductors. Although not recommended, and not a good design practice, occasionally transmission lines must enter the subsystem area served with a SSGB. In these instances special design criteria must be considered to ensure that potential differences between the location of the SSGB and the MGB are minimized. For these applications, additional surge suppression devices may be required on any interconnecting power, data, audio, telephone or telephone type circuits, though they are routed within the same building. Consultation with Motorola's R56 committee is suggested in these instances.

7.2.2.2 SSGB SPECIFICATIONS

See Table 7-4. The SSGB **shall** carry the UL listing.

TABLE 7-4 SSGB SPECIFICATIONS

Item	Specification
Material	Bare solid copper bus bar or plate of one piece construction. May be electrotin plated
Minimum Dimensions	Width: 5 cm (2 in.) Length: 30.5 cm (12 in.) Thickness: 0.635 cm (1/4 in.)
Mounting brackets	Must be suitable for the application
Insulators	polyester fiberglass 15 kV minimum dielectric strength flame resistant per UL 94 VO classification
Conductor mounting holes Number Dimensions	Dependent on number of conductors to be attached Holes to be 11 mm (7/16 in.) minimum on 19 mm (3/4 in.) centers to permit the convenient use of two-hole lugs
Allowable bonding methods	Exothermic welding Irreversible crimp connection Other suitable irreversible crimp connection process

7.2.2.3 BONDING TO THE SSGB

All subsystem equipment and ancillary support apparatus including but not limited to items listed in Table 7-5, within the room or subsystem area served by the SSGB **shall** be effectively bonded to the SSGB using methods described in this chapter. Connections depending on solder **shall not** be used (per NFPA 70, Articles 250-8 and 250(e)).

7.2.2.4 EQUIPMENT TO BE BONDED

All equipment and ancillary support apparatus including but not limited to items listed in Table 7-5 **shall** be effectively bonded to the SSGB, using the methods described in the table. This equipment **shall** be either bonded using a combination of a SSGB, RGB, equipment grounding conductor and a ground bus conductor, or individual equipment grounding conductors (per NFPA-70; Article 250(e)).

TABLE 7-5 BONDING TO THE SSGB

From	To				
Item	SSGB	RGB	Ground Bus Conductor	Internal Ground Bus Conductor	Method
Rack ground bus bar (RGB)	✔		✔		The RGB **shall** be bonded to the SSGB, or ground bus conductor with 35 mm^2 csa (#2 AWG) or larger, green jacketed[1], solid or stranded copper conductor.
Ground bus conductor	✔		✔		Ground bus conductors **shall** be effectively bonded to the SSGB, or other ground bus conductor using methods described herein. Conductor **shall** be 35 mm^2 csa (#2 AWG) green jacketed[1], solid or stranded copper conductor, or solid copper bus bar.
Internal perimeter ground bus	✔				Internal perimeter ground bus conductors **shall** be effectively bonded to the SSGB using methods described herein.
Equipment grounding conductor	✔	✔	✔		Equipment grounding conductors **shall** be bonded to the SSGB, RGB or ground bus conductor using methods described herein.
Cabinets	✔	✔	✔		Bond with 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor, which **shall** be attached from the cabinet equipment mounting rail, or terminal to the SSGB, RGB or ground bus using methods described in this chapter.
Racks	✔	✔	✔		Bond with 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor, which **shall** be attached from the rack grounding pad or terminal to the SSGB, RGB or ground bus using methods described in this chapter.

TABLE 7-5 BONDING TO THE SSGB (CONTINUED)

From	To				
Item	**SSGB**	**RGB**	**Ground Bus Conductor**	**Internal Ground Bus Conductor**	**Method**
Individual system component chassis	✔	✔	✔		All system component chassis, support chassis, panels, card cages, cross connect panels, test jack field panels and other equipment that has a ground connection point **shall** be bonded with 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor, which **shall** be attached from the equipment grounding terminal, chassis or frame to the SSGB, RGB or ground bus using methods described herein. On equipment where a ground stud or connection point provided by the manufacturer is sized and/or located such that a 16 mm^2 csa (#6 AWG) conductor cannot be reasonably attached, the 16 mm^2 csa (#6 AWG) equipment grounding conductor **shall** be attached to a suitable attachment point or to the equipment mounting screw. Where a terminal strip or other connection point integral to the equipment must be connected to ground, a jumper sized per the manufacturer's instructions **shall** be installed between this point and the equipment grounding conductor attachment point.
Transmission line and surge suppressors	✔ Note [2]				RF transmission line surge suppression devices **shall** be bonded to the SSGB within 60 cm (24 in.) of entry into the equipment area. In instances where the RF transmission lines enter the building at a point other than where the equipment room or area is located there is no requirement for surge suppression devices at that location. The shield of the RF transmission line must be effectively bonded to the grounding electrode system at the point of entry into the building or as near as practicable thereto (NFPA-70; Article 820-33).
Primary telephone circuit surge suppressors	✔			✔	Bond with a 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein. An 8 mm^2 csa (#12 AWG) green jacketed solid or stranded copper conductor may be utilized for bonding a single circuit (2 pair) surge suppressor.

TABLE 7-5 BONDING TO THE SSGB (CONTINUED)

From	To				
Item	**SSGB**	**RGB**	**Ground Bus Conductor**	**Internal Ground Bus Conductor**	**Method**
Secondary telephone circuit surge suppressors	✔	✔	✔		Bond with a 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein. An 8 mm^2 csa (#12 AWG) green jacketed[1] solid or stranded copper conductor may be utilized for bonding a single circuit (2 pair) surge suppressor.
Separately derived AC electrical systems	✔				Bond with a 16 mm^2 csa (#6 AWG) or larger as may be required, green jacketed[1], solid or stranded copper conductor using methods described herein. See *NFPA70, Table 250-66* for minimum conductor size.
Cable runway	✔				Bond with a 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein.
Control centers, Dispatch equipment, and metallic parts of dispatch furniture	✔		✔		Bond with a 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein.
Ancillary support items, metallic structural items and materials	✔			✔	Bond with a 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein.

1. Ground conductors may be green, green with a yellow stripe or black with green tape on a black conductor at points designated by NFPA 70, Article 250-119 or jurisdictional codes.
2 At locations where transmission lines enter an equipment area served by a SSGB the transmission lines **shall** enter the room or area within 60 cm (24 in.) of the SSGB and the transmission line surge suppressors **shall** be bonded to the SSGB with a #6 AWG, or larger, green jacketed, solid or stranded copper conductor using methods described herein. Refer to “Location” on page 7-24.

7.2.3 RACK GROUND BUS BAR

A rack ground bus bar (RGB) may be installed within an equipment rack or cabinet to provide a termination point for individual equipment grounding conductors for equipment installed within that rack or cabinet. The rack or cabinet grounding conductor(s) may also terminate on the RGB. The RGB **shall** be bonded to the MGB or SSGB with a ground bus conductor. Installations of a cabinet or assembly of cabinets comprising one enclosure that contains a complete system may have a single RGB installed serving as the system ground bus. At stand alone cabinet or cabinet assembly installations where no MGB or SSGB is installed, the RGB **shall** be bonded to the electrical service grounding electrode system or conductor.

7.2.3.1 LOCATION

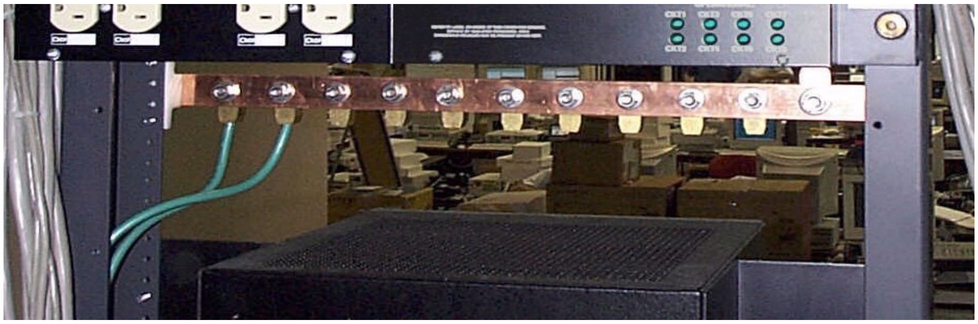
The RGB may be mounted at any convenient location within the rack or cabinet, typically near the top or bottom of the rack or cabinet, depending on the location of the ground bus conductor. See Figure 7-9 on page 7-14, Figure 7-10 on page 7-15, and Figure 7-16 for typical RGB installations.

7.2.3.2 SPECIFICATION

The rack ground bus bar **shall** be of solid copper material, a minimum of 6.35 mm D x 25.4 mm H x 48.3 cm W (1/4 in D x 1 in H x 19 in W). The bus bar **shall** have a suitable number of drilled 11 mm (7/16 in.) holes to accommodate the required number of connections. The bus bar **shall** be securely mounted on suitable standoff hardware to maintain a separation of dissimilar metals and to facilitate conductor attachment. The use of standoff insulators may be suitable for this purpose. (See “Dissimilar Metals” on page 6-58.)

7.2.3.3 EQUIPMENT TO BE BONDED

All equipment including but not limited to items listed in Table 7-6 that is installed within the rack, cabinet or cabinets **shall** be effectively bonded to the RGB using methods described in this chapter. Connections depending on solder **shall not** be used (per NFPA 70, Article 250-8). (See *NFPA 70, Article 250(e)* for additional information.)



Note: Partial installation of grounding conductors to RGB shown.

FIGURE 7-16 TYPICAL RACK GROUND BUS BAR

TABLE 7-6 BONDING TO THE RGB

From Item	To RGB	Method
Equipment grounding conductor	✔	Equipment grounding conductors **shall** be bonded to the RGB using methods described herein.
Cabinets	✔	Bond with 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor, which **shall** be attached from the cabinet equipment mounting rail, or terminal to the RGB using methods described in this chapter.
Racks	✔	Bond with 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor, which **shall** be attached from the rack grounding pad or terminal to the RGB using methods described in this chapter.
Individual system component chassis	✔	All system component chassis, support chassis, panels, card cages, cross connect panels, test jack field panels and other equipment that has a ground connection point **shall** be bonded with 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor, which **shall** be attached from the equipment grounding terminal, chassis or frame to the RGB using methods described herein. On equipment where a ground stud or connection point provided by the manufacturer is sized and/or located such that a 16 mm^2 csa (#6 AWG) conductor cannot be reasonably attached, the 16 mm^2 csa (#6 AWG) equipment grounding conductor **shall** be attached to a suitable attachment point or to the equipment mounting screw. Where a terminal strip or other connection point integral to the equipment must be connected to ground, a jumper sized per the manufacturer's instructions **shall** be installed between this point and the equipment grounding conductor attachment point.
Transmission line surge suppressors	✔	**NOTE:** Applicable to stand alone cabinet installations only. RF transmission line surge suppression devices **shall** be bonded to the RGB within 60 cm (24 in.) of entry into the equipment rack or cabinet. In instances where the RF transmission lines may enter a building at a point other than where the equipment cabinet is located there is no requirement for surge suppression devices at that location. The shield of the RF transmission line must be effectively bonded to the grounding electrode system at the point of entry into the building or as near as practicable thereto (NFPA-70; Article 820-33).
Secondary telephone circuit surge suppressors	✔	Bond to the RGB with a 16 mm^2 csa (#6 AWG) or larger, green jacketed[1], solid or stranded copper conductor using methods described herein. An 8 mm^2 csa (#12 AWG) green jacketed[1] solid or stranded copper conductor may be utilized for bonding a single circuit (2 pair) surge suppressor.

1. Ground conductors may be green, green with a yellow stripe or black with green tape on a black conductor at points designated by NFPA 70, Article 250-119 or jurisdictional codes.

7.3 CONDUCTORS

7.3.1 GROUND BUS CONDUCTORS

Ground bus conductors interconnect the MGB, SSGB, RGB and the equipment grounding conductor with the cabinets, racks or individual system or subsystem components. The end of the conductor opposite the MGB or SSGB typically remains unterminated, although this end of the conductor may be terminated to a cabinet, rack, individual system component or RGB.

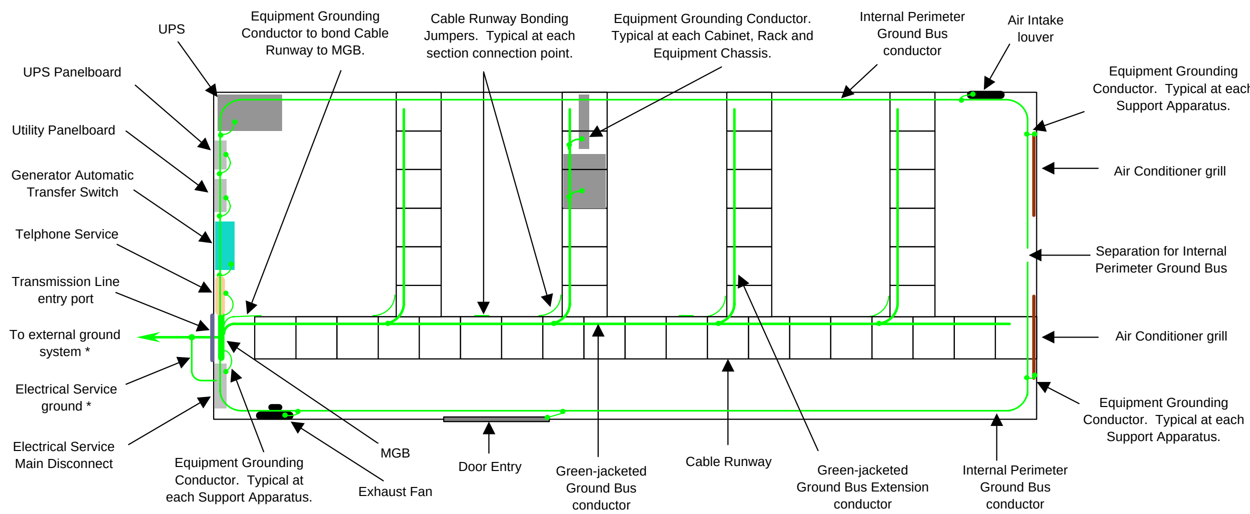
Ground bus conductors typically originate at the MGB and radiate throughout the equipment area generally within the cable runway system. These conductors may extend into an adjoining subsystem equipment area and may serve as the grounding conductor for a SSGB, or RGB. Ground bus conductors may have ground bus extension conductors to provide a ground bus within cross section segments of a cable runway system. These ground bus extension conductors **shall** be of the same specification as the ground bus conductor and **shall** be routed with all connections to the ground bus conductor pointed in the direction of the MGB or SSGB. Equipment grounding conductors from each cabinet, rack or individual system component chassis **shall** be bonded to the ground bus conductors using methods described within this chapter. Ground bus conductors are not required to be installed at all locations, provided that equipment grounding conductors from each cabinet, rack and individual system component extend to the MGB or SSGB. See Figure 7-9 on page 7-14, Figure 7-10 on page 7-15, Figure 7-21 on page 7-39, and Figure 7-22 on page 7-40 for acceptable methods.

7.3.1.1 LOCATION

Ground bus conductors **shall** typically be installed within the cable runway system above or below the equipment rows. Depending on equipment layout and cable runway configuration, one or more ground bus conductors may be installed. Typically one ground bus conductor is installed in each cable runway running the length of the equipment area. Each equipment row **shall** have a ground bus conductor installed in each cable runway cross section. This conductor could be a ground bus extension conductor from the main ground bus conductor. The ground bus extension conductor **shall** be bonded to the ground bus conductor using suitable methods described within this chapter. See Figure 7-17 on page 7-31. Minimum bending radius and angle must be considered.

NOTE: Conductors installed within a plenum **shall** be compliant with NFPA 70, Article 300-22. Ground conductors **shall** have an approved covering (insulation) or may be bare. When bare conductors are used they **shall** be solidly supported on suitable standoff insulators at intervals of no more than 61 cm (24 in.). These conductors **shall not** be in contact with metallic surfaces or other conductors unless intended to be bonded to these surfaces or conductors. Care **shall** be taken to ensure other conductive surfaces do not make contact with the ground conductor. These conductors **shall** be covered or jacketed upon exit from the plenum area and may be spliced at this point using an approved splicing method.

NOTE: All communications wires and cables installed within buildings, including ground and grounding electrode conductors, **shall** be compliant with NFPA 70, Article 800 (e).



*** NOTE:** No exterior ground system conductors shown. Electrical service grounding electrode conductor must be bonded to external site ground system.

FIGURE 7-17 TYPICAL INTERIOR SHELTER GROUND SYSTEM

7.3.1.2 SPECIFICATIONS

Ground bus conductors, including ground bus extension conductors, **shall** be a 35 mm^2 csa (#2 AWG) or larger, green jacketed[1], solid or stranded copper conductor. Stranded conductor may be more desirable due to the ease of installation and maintainability.

For specific applications a copper bus bar of equal or larger size may be used. An example of such an application is this type of bar mounted from bottom to top of an equipment rack or cabinet, with individual equipment ground connections suitably attached to the bar. This method can be easier to implement than individual wire-type conductors for each equipment connection. See Figure 7-11 on page 7-16 (equipment rack on far right-hand side of figure) and Figure 7-18 for examples of using a copper bus bar as a ground bus conductor within a rack.

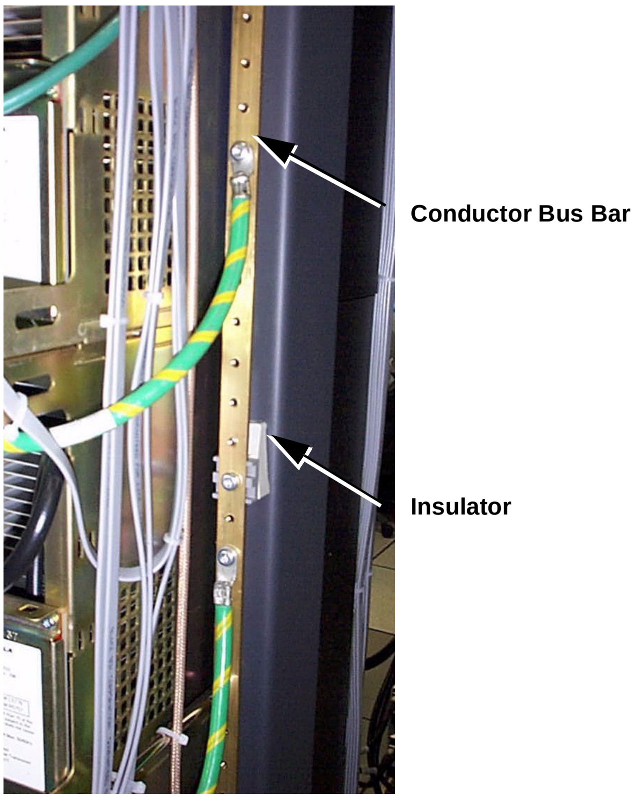


FIGURE 7-18 VERTICALLY MOUNTED CONDUCTOR BUS BAR

1. Ground conductors may be green, green with a yellow stripe or black with green tape on a black conductor at points designated by NFPA 70, Article 250-119 or jurisdictional codes.

7.3.1.3 BONDING TO THE GROUND BUS CONDUCTOR

Equipment grounding conductors **shall** be bonded to the ground bus conductor or ground bus extension conductor using suitable methods described within this chapter. As appropriate, the end of the ground bus conductor opposite the MGB may be terminated or attached to a cabinet, rack, individual system component chassis or RGB.

Ground bus extension conductors **shall** always be routed toward the MGB or SSGB at the point of connection to the ground bus conductor. These connection points **shall** be taped with a suitable green tape or otherwise protected from contact with the cable runway or other metallic surfaces. A separation of 5 cm (2 in.) **shall** be maintained between ground bus conductors and conductors of other cable groups.

7.3.2 INTERNAL PERIMETER GROUND BUS CONDUCTORS

The internal perimeter ground bus (IPGB) provides a suitable grounding conductor to the MGB for ancillary support apparatus, electrical conduits and other metallic items that may be located throughout the shelter, building or room. It is essential that all ancillary metallic items within the area be bonded to the single point ground established by the MGB or SSGB.

An internal perimeter ground bus conductor **shall** be installed in all equipment shelters, buildings or rooms specifically designed or designated for communications equipment, or a generator or power distribution room. An internal perimeter ground bus conductor is not required in rooms or areas that are within a larger building where support apparatus is not present or where it is more practical to bond this support apparatus to the MGB or SSGB with a single equipment grounding conductor. An internal perimeter ground bus conductor may be installed in areas where there is a need to bond several items of support apparatus to the MGB or SSGB regardless to the specific usage of the area.

NOTE: The internal perimeter ground bus conductor **shall not** be used for bonding communications equipment such as cabinets, racks, chassis or equipment grounding conductors to the MGB.

7.3.2.1 LOCATION

The internal perimeter ground bus **shall** be installed such that it encompasses the interior of the shelter, building, room or area with two independently separate ground bus conductors on opposite sides of the room. Each of these conductors **shall** be located horizontally along the wall, approximately 2.5 m (8 ft.) above the finished floor and terminated to the MGB or SSGB, as applicable, at one end only, using methods described within this chapter. See Figure 7-4 and Figure 7-17. At a point within the equipment area and approximately opposite the location of the MGB, the bus conductor **shall** be broken with the ends of the conductor being separated by approximately 10 cm (4 in.). The location of this break **shall** be positioned to afford a minimum of 10 cm (4 in.) separation between any items bonded to opposite bus conductors.

The conductors **shall** be supported approximately 5 cm (2 in.) from the wall surface on insulated standoffs. Standoffs **shall** be installed at intervals as necessary to keep the conductor securely in place without noticeable sags and bends. Where transmission lines enter the equipment area at a lower point along the wall or through the floor or ceiling and the MGB is suitably located lower on the wall or on the floor or ceiling, the internal perimeter ground bus conductors **shall** be routed as stated above, with the following exception: at a point where these conductors can be readily connected to the MGB or SSGB, these conductors **shall** be routed across the ceiling or downward along the wall and connected to the MGB or SSGB.

Minimum bending radius and angle **shall** be considered. Conductors routed down the wall must be sleeved to prevent damage. Sleeving in electrical nonmetallic conduit is recommended and should provide adequate protection. Metallic conduit or sleeving **shall not** be used for this purpose unless the conductor passing through the conduit or sleeving is suitably bonded to the metallic sleeve at each end with bushings or fittings listed and approved for the purpose. A cable runway of suitable design may be used for protection and support. Proper cable separation between ground conductors and other cable groups **shall** be maintained.

7.3.2.2 SPECIFICATIONS

The internal perimeter ground bus conductors **shall** be a 35 mm^2 csa (#2 AWG), or larger, non-jacketed copper conductor, free of splices. If a splice is unavoidable, it **shall** be exothermically welded or be spliced using an IEEE 837-approved irreversible connection. It is desirable that this conductor be stranded for better flexibility and ease of installation and maintenance. However, this conductor may be a solid conductor (copper bus bar or copper strap) of equal or larger surface area.

7.3.2.3 BONDING TO THE INTERNAL PERIMETER GROUND BUS CONDUCTOR

Equipment grounding conductors from ancillary support apparatus **shall** be bonded to the internal ground bus conductor using suitable methods described within this chapter. Daisy chain[1] connection arrangements **shall not** be used.

NOTE: The internal perimeter ground bus conductor **shall not** be used for bonding communications equipment such as cabinets, racks, chassis or equipment grounding conductors to the MGB.

7.3.2.4 EQUIPMENT TO BE BONDED

All ancillary support apparatus within an equipment shelter, a generator or power distribution room, a room or specific equipment area **shall** be bonded to the MGB or the internal perimeter ground bus conductor with an equipment grounding conductor. Daisy chain[1] connection arrangements **shall not** be used.

1. The series or daisy chain method, which refers to any method of connection whereby the conductors are connected from one chassis, equipment frame or rack connection point to a second chassis, equipment frame or rack connection point and on to a third connection point, creating a series arrangement whereby the removal of the second connection point interrupts the ground path from the first chassis, equipment frame or rack, **shall not** be used.

Manufacturers' installation instructions **shall** be followed when bonding ancillary support apparatus to the site ground system. Connections **shall** be made to the terminal provided or some other suitable point on the apparatus.

Ancillary support apparatus includes but is not limited to:

- Storage cabinets
- Battery racks
- Metallic window frames, doors and door frames
- Metallic ceiling grids
- Metallic raised flooring systems
- HVAC grills, ducts, units, motors, motor controllers, control panels, junction and terminal boxes
- Panelboards
- Switchboards
- Generator frames
- Automatic and manual transfer switches
- Transformers
- UPS units
- Metallic housing of AC power surge suppressor devices
- Primary telephone surge suppressor ground terminal(s).

The following **shall** also be bonded to the internal perimeter ground bus or MGB:

- All support apparatus within an equipment shelter, a generator or power distribution room, a room or specific equipment area and located within 2.44 m (8 ft.) vertically or 1.8 m (6 ft.) horizontally of ground or grounded metal objects (per NFPA 70, Article 250(f)).
- Metallic building structures and piping systems
- Steel roof trusses
- Exposed support beams and columns
- Ceiling grids
- Raised floor support structure
- Any exposed building support structure and building frame when located within 2.44 m (8 ft.) vertically or 1.8 m (6 ft.) horizontally of the communications equipment
- Electrical metallic conduits **shall** be bonded to the perimeter ground conductor at any point where they cross within 15 cm (6 in.) of the perimeter ground conductor.

- Metallic conduit run parallel to the perimeter ground bus **shall** be bonded at the points where it enters to within 15 cm (6 in.) of the perimeter ground bus conductor and at the point where it transitions away from the perimeter ground bus conductor. Each metallic conduit **shall** be connected to the perimeter ground bus conductor with a separate equipment grounding conductor using saddle clamps or other suitable pipe clamps. See Figure 7-23 on page 7-45.

7.3.3 EQUIPMENT GROUNDING CONDUCTORS

Equipment grounding conductors **shall** be used to bond communications equipment and ancillary support apparatus to the ground bus conductor, internal perimeter ground bus conductor, or to the MGB, SSGB, or RGB.

NOTE: Braided conductors **shall not** be used at any location.

7.3.3.1 LOCATION

The equipment grounding conductors **shall** be installed along the rack rail or other suitable support medium. One end of the conductor **shall** be bonded to the equipment or support apparatus using methods described within this chapter. The other end of the conductor **shall** be bonded to the ground bus or internal perimeter ground bus conductor. The equipment grounding conductors **shall** be bonded to the ground bus conductor using suitable methods described within this chapter. See Figure 7-9 on page 7-14 and Figure 7-10 on page 7-15.

7.3.3.2 SPECIFICATIONS

The equipment grounding conductor **shall** be a 16 mm^2 csa (#6 AWG), or larger, green jacketed[1], solid or stranded copper conductor. Stranded conductor may be more desirable due to the ease of installation and maintainability.

7.3.3.3 ATTACHMENTS TO THE GROUND BUS CONDUCTOR

Equipment grounding conductors from each piece of equipment **shall** be bonded to the ground bus conductor or MGB using suitable methods described within this chapter. Equipment grounding conductors from each piece of ancillary support apparatus **shall** be bonded to the internal perimeter ground bus conductor or MGB using suitable methods described within this chapter. Each piece of equipment or ancillary support apparatus **shall** have a separate and independent equipment grounding conductor. Multiple connections may not be made to one attachment point on the ground bus conductor unless this connection is made using a split bolt listed for the size and number of conductors to be connected, an irreversible crimp, or exothermic welding. See Figure 7-19 on page 7-37.

1. Ground conductors may be green, green with a yellow stripe or black with green tape on a black conductor at points designated by NFPA 70, Article 250-119 or jurisdictional codes.

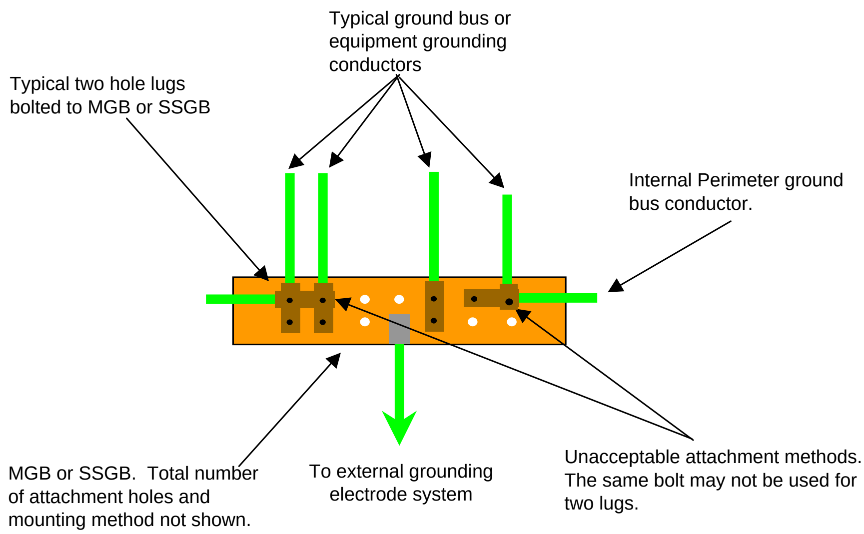
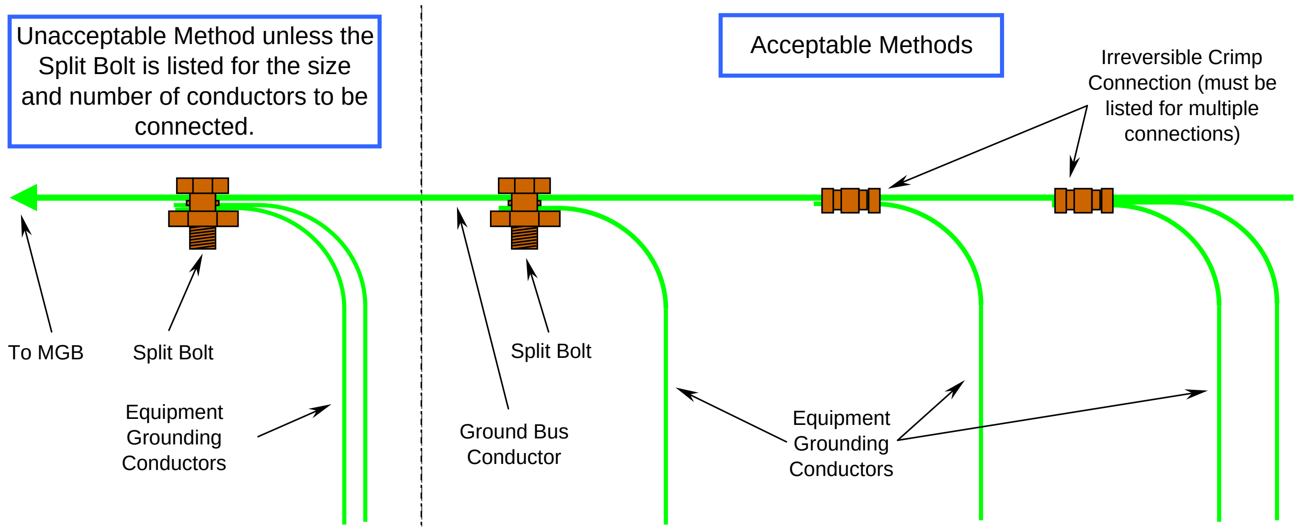


FIGURE 7-19 METHOD FOR MAKING MULTIPLE CONNECTIONS TO THE MGB

Equipment grounding conductors **shall** be connected so that the removal of a connection will not break the ground path to any other piece of equipment or ancillary support device that may have electrical power applied.

When a conductor is to be removed from a connection point where a split bolt is used as the attachment device, as shown in Figure 7-20 on page 7-38, the electrical power must be removed from all equipment or ancillary devices attached at this point.



NOTE: Route all conductors toward the MGB.

FIGURE 7-20 BONDING EQUIPMENT GROUNDING CONDUCTORS TO GROUND BUS CONDUCTOR

The series or daisy chain method, which refers to any method of connection whereby the conductors are connected from one chassis, equipment frame or rack connection point to a second chassis, equipment frame or rack connection point and on to a third connection point, creating a series arrangement whereby the removal of the second connection point interrupts the ground path from the first chassis, equipment frame or rack, **shall not** be used. See Figure 7-21 on page 7-39.

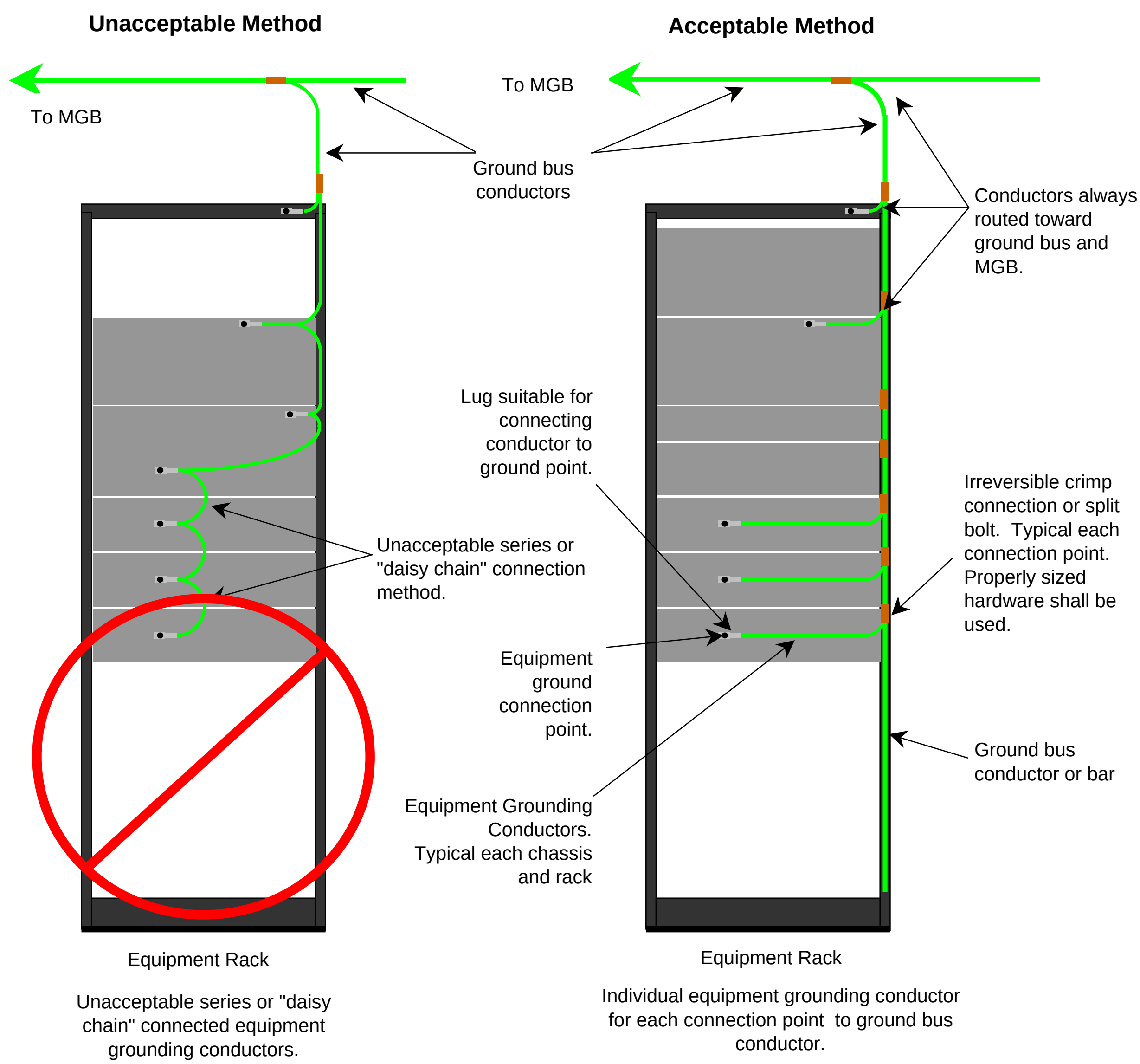
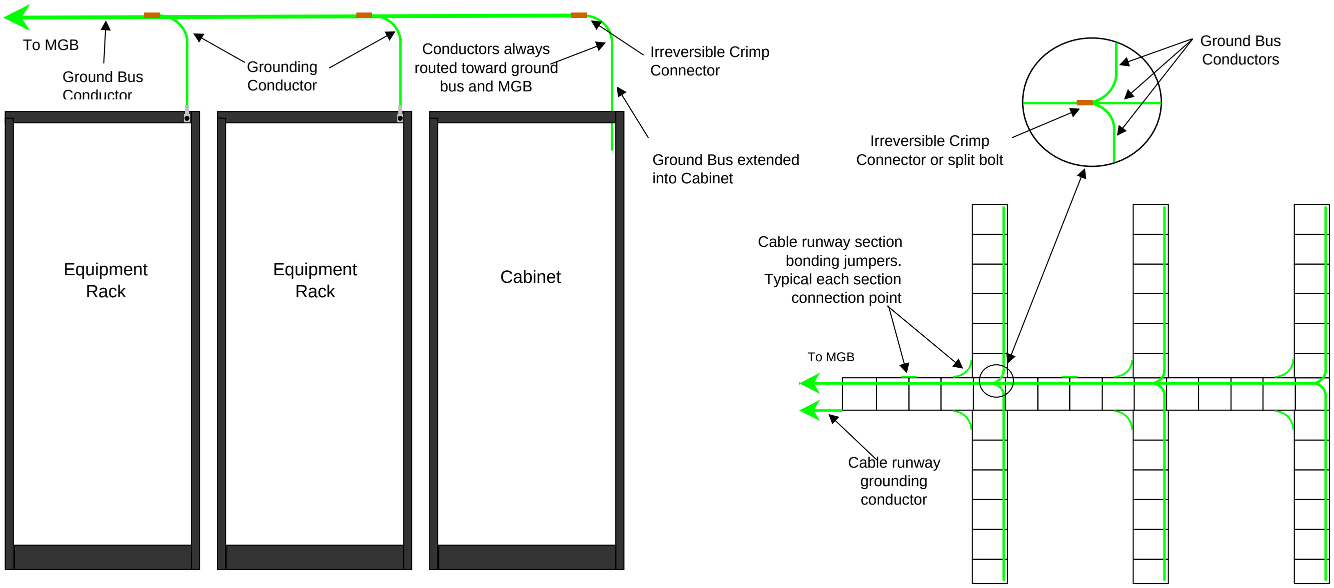


FIGURE 7-21 CORRECT EQUIPMENT GROUNDING METHOD



NOTES:

1. Route all conductors so that all bends and connections are in the direction of the MGB.
2. Equipment is installed in racks and cabinets as shown in Figure 7-11 and Figure 7-21.

FIGURE 7-22 GROUND BUS CONDUCTOR ROUTING

7.3.3.4 EQUIPMENT TO BE BONDED

All equipment and ancillary support apparatus including but not limited to that listed in Table 7-7 **shall** be bonded to the MGB, SSGB, RGB, ground bus conductor or internal perimeter ground bus (IPGB) conductor with an equipment grounding conductor.

TABLE 7-7 EQUIPMENT TO BE BONDED

Bond To					Equipment
MGB	SSGB	RGB	Ground Bus Conductor	IPGB	
✔	✔	✔	✔		Equipment Racks and Cabinets
✔	✔	✔	✔		Individual equipment chassis
✔	✔	✔	✔		All system component chassis
✔	✔	✔	✔		Support Chassis
✔	✔	✔	✔		Panels
✔	✔	✔	✔		Card Cages
✔	✔	✔	✔		Cross connect panels
✔	✔	✔	✔		Test jack field panels
✔	✔			✔	Primary surge suppressors
		✔	✔		Secondary surge suppressors
✔	✔				Cable runway
✔	✔			✔	Storage cabinets
✔	✔			✔	Battery racks
✔	✔			✔	Metallic window frames, doors and door frames
✔	✔			✔	Metallic ceiling grids
✔	✔			✔	Metallic raised floor systems
✔	✔			✔	HVAC grills, ducts, units, motors, motor controllers, control panels
✔	✔			✔	Junction and terminal boxes
✔	✔			✔	Electrical conduits
✔	✔			✔	Panelboards
✔	✔			✔	Switchboards
✔	✔			✔	Automatic and manual transfer switches
✔	✔			✔	Transformers
✔	✔			✔	UPS units
✔	✔			✔	Other equipment and ancillary support apparatus including but not limited to that listed in “Equipment to be Bonded” on page 7-34. See Table 7-3 for additional information.

7.3.4 BONDING JUMPERS

A bonding jumper **shall** be used to ensure an electrically conductive path between components to be bonded. Examples include sections of a cable runway which are required to be bonded together, or sections of structural steel, roof trusses, piping systems, conduits or other metallic surfaces that are required to be bonded together to maintain electrical conductivity. A bonding jumper **shall not** be used in lieu of an equipment grounding conductor.

7.3.4.1 LOCATION

Bonding jumpers **shall** be installed to bond components of the same or similar structure together. The location will be dependent on the specific application. Bonding jumpers **shall** be as short as possible, **shall** be routed in as straight a line as possible, and **shall** be as free from bends as is practicable. Care **shall** be taken to ensure that attachment points are clean and free of paint or corrosion. Suitable lugs **shall** be used to facilitate attachment to the components to be bonded.

7.3.4.2 SPECIFICATION

Bonding jumpers **shall** be #6 AWG or larger, green jacketed solid or stranded copper conductor. Stranded conductor may be more desirable due to the ease of installation and maintainability. Bonding jumpers may be green, green with a yellow stripe or black with green tape on a black conductor at points designated by NFPA 70, Article 250-119 or jurisdictional codes.

7.3.5 CONNECTION POINTS

7.3.5.1 EQUIPMENT

The equipment grounding conductor **shall** be attached to the equipment grounding terminal, chassis or frame utilizing methods described elsewhere in this chapter. On equipment where a ground stud or connection point is provided by the manufacturer and this ground stud or connection point is sized and/or located so that a 16 mm^2 csa (#6 AWG) conductor **cannot** be reasonably attached, the 16 mm^2 csa (#6 AWG) equipment grounding conductor **shall** be attached to the equipment mounting screw or other suitable attachment point. Where a terminal strip or other type connection point is an integral part of the equipment (PC board terminal, etc.) and this connection point must be connected to ground, a jumper sized per the manufacturer's instructions **shall** be installed between this point and the equipment grounding conductor. Manufacturer's installation instructions regarding grounding and bonding **shall** be followed in all instances unless the manufacturer specifies a grounding conductor smaller than 16 mm^2 csa (#6 AWG); in these cases a 16 mm^2 csa (#6 AWG) equipment grounding conductor **shall** be used. If the manufacturer has not provided specific grounding and bonding instructions for their equipment, the instructions contained within this paragraph **shall** prevail.

7.3.5.2 CABINETS AND RACKS

Connections to racks **shall** be made at the designated ground connection point or ground "pad." Connection to racks without a designated connection point or ground pad **shall** be suitably made following the methods described within this chapter. Racks or cabinets equipped with a RGB **shall** have an independent bonding jumper installed between the rack or cabinet equipment mounting rail and the RGB. The RGB **shall** be bonded to the MGB, SSGB, or ground bus with a 35 mm^2 csa (#2 AWG) or larger, solid or stranded, green jacketed[1] copper conductor. Stranded conductor may be more desirable due to the ease of installation and maintainability. All equipment within the rack or cabinet **shall** be bonded to the RGB with an equipment grounding conductor.

7.3.5.3 ANCILLARY SUPPORT APPARATUS

Bonding jumpers **shall** be installed at all cable runway splices and connection points unless these bolted splices and connection points use splined shoulder bolts which bite into the side rail of the cable runway and ensure a positive bond between sections. All bolts must be properly installed at each splice in the cable runway system per the manufacturer's instructions. Care must be taken to ensure a continuous electrical path. Bonding jumpers must be used where discontinuities such as expansion splice plates and hinged splice plates exist in the runway run.

Manufacturers' installation instructions **shall** be followed when bonding ancillary support apparatus to the ground system. Connections **shall** be made to the terminal provided or some other suitable point on the apparatus.

All ancillary support apparatus within an equipment shelter, room or specific equipment area **shall** be bonded to the MGB or the internal perimeter ground bus conductor with an equipment grounding conductor.

Manufacturers' installation instructions **shall** be followed when bonding ancillary support apparatus to the site ground system. Connections **shall** be made to the terminal provided or some other suitable point on the apparatus.

Ancillary support apparatus includes but is not limited to:

- Storage cabinets
- Battery racks
- Metallic window frames, doors and door frames
- Metallic ceiling grids
- Metallic raised flooring systems
- HVAC grills, ducts, units, motors, motor controllers, control panels, junction and terminal boxes
- Panelboards
- Switchboards
- Automatic and manual transfer switches
- Transformers

- UPS units
- Metallic housing of AC power surge suppressor devices

The following **shall** also be bonded to the internal perimeter ground bus or MGB:

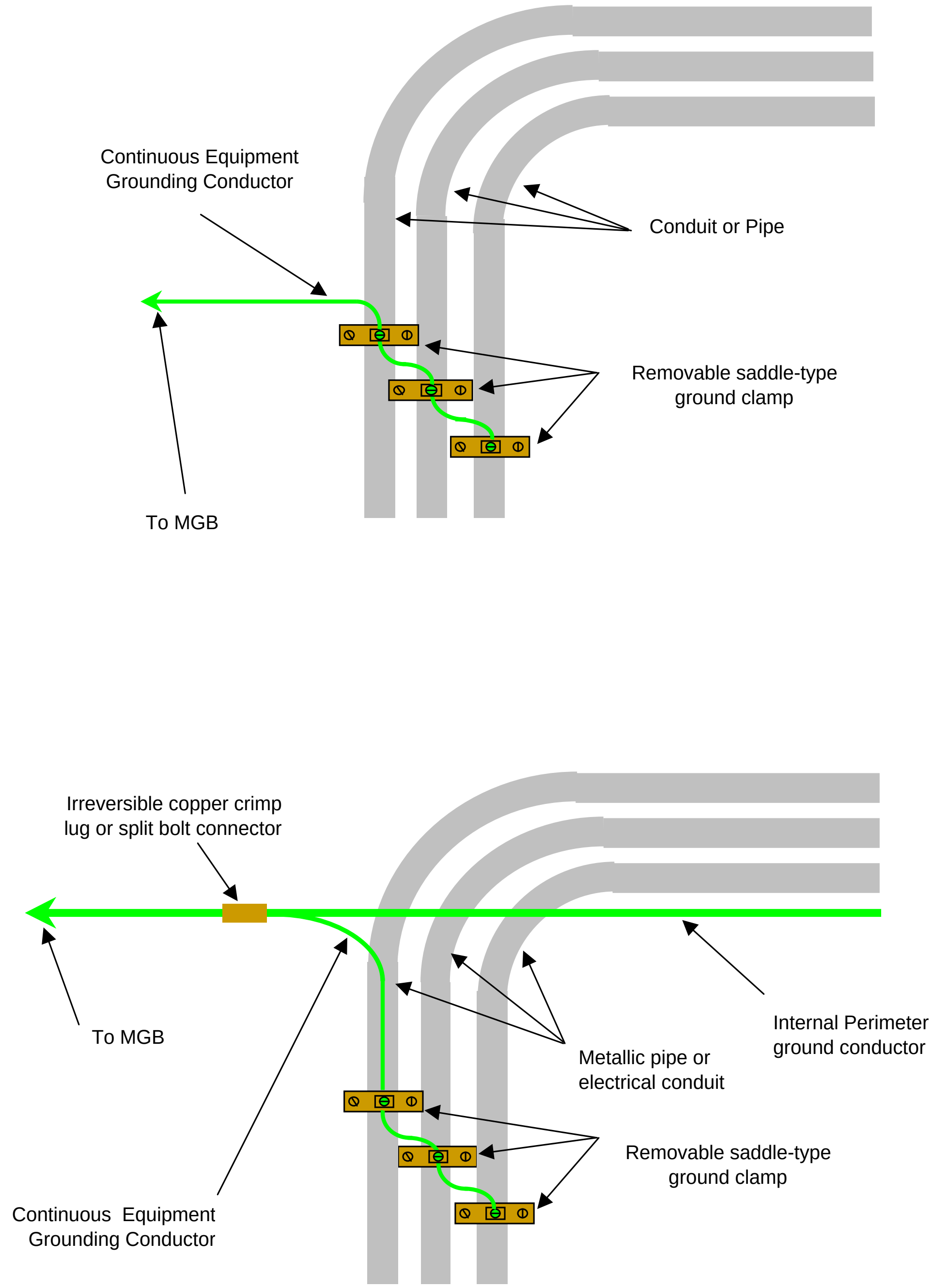
- All support apparatus within an equipment shelter, room, a generator or power distribution room, or specific equipment area and located within 2.44 m (8 ft.) vertically or 1.8 m (6 ft.) horizontally of ground or grounded metal objects.
- Electrical metallic conduits **shall** be bonded to the perimeter ground conductor at any point where they cross within 15 cm (6 in.) of the perimeter ground conductor.
- Metallic conduit run parallel to the perimeter ground bus **shall** be bonded at the points where it enters to within 15 cm (6 in.) of the perimeter ground bus conductor and at the point where it transitions away from the perimeter ground bus conductor. Each metallic conduit **shall** be connected to the perimeter ground bus conductor with a continuous bare equipment grounding conductor using removable saddle clamps or other clamps that specifically permit the use of a single continuous conductor for grounding multiple runs of conduit. If multiple conduits are grounded using a single conductor, the conductor shall be clamped to each conduit run such that removal of one clamp does not interrupt the path to ground for the other conduit runs. See Figure 7-23 on page 7-45.

7.3.5.4 METALLIC BUILDING STRUCTURE AND PIPING SYSTEMS

Metallic building structures and piping systems, steel roof trusses, exposed support beams and columns, ceiling grids, raised floor support structure, any exposed building support structure and building frame when located within 2.44 m (8 ft.) vertically or 1.8 m (6 ft.) horizontally of the communications equipment, **shall** be bonded to the MGB, SSGB, or internal perimeter ground bus using one of the conductors and methods described within this chapter.

No series or daisy chain[1] connection arrangements **shall** be used. Each peripheral device **shall** be bonded to the MGB, SSGB, or perimeter ground bus using an individual equipment grounding conductor. See Figure 7-23 on page 7-45.

1. "Daisy chain" refers to any method of connection whereby the conductors are connected from one chassis, equipment frame or rack connection point to a second chassis, equipment frame or rack connection point and on to a third connection point, creating a series arrangement whereby the removal of the second connection point interrupts the ground path from the first chassis, equipment frame or rack.



NOTE: See "Specifications" on page 7-36 and 7.3.5.3 on page 7-43 for conductor requirements.

FIGURE 7-23 GROUNDING METHOD FOR METALLIC PIPE OR CONDUIT

7.3.5.5 SURGE SUPPRESSORS

See Chapter 9, "Transient Voltage Surge Suppression," for information on Transient Voltage Surge Suppression (TVSS) devices.

- RF transmission line surge suppression devices **shall** be bonded to the MGB within 60 cm (24 in.) of entry into the equipment shelter, equipment room or equipment area. An equipment grounding conductor **shall** be used to bond these devices to the MGB.

  If the RF transmission lines enter the building at a point other than where the equipment room or area is located, there is no requirement for surge suppression devices to be installed at that location. The shield of the RF transmission line must be effectively bonded to the grounding electrode system at the point of entry into the building or as near as practicable thereto (per NFPA-70; Article 820-33).

- Power surge suppression device metal housings **shall** be bonded to the MGB, SSGB, the ground bus conductor or internal perimeter ground bus conductor using an equipment grounding conductor.

7.3.5.6 COMMUNICATIONS/TELEPHONE CIRCUITS

- Primary protection devices **shall** have the ground terminal bonded to the MGB or the internal perimeter ground bus conductor using an equipment grounding conductor.
- Secondary protection devices should be located near the equipment to be protected. An equipment grounding conductor **shall** be used to bond the ground terminal to the ground bus conductor that serves the associated equipment.

7.4 CONNECTION METHODS

The following requirements apply when attaching conductors to equipment and ancillary support apparatus, ground bus bars, and when attaching one conductor to another. In general, only connection devices that require the complete removal of the conductor jacket or insulation and result in a connection to the complete conductor surface area are suitable for use in ground systems.

- Conductors **shall** be connected to the MGB, SSGB, or RGB using suitable listed clamps, listed pressure connectors, listed compression terminals or listed lugs and hardware of the proper size for the application.
- Only connection devices that require the complete removal of the conductor jacket or insulation and result in a connection to the complete conductor surface area are suitable for use. Insulation piercing type connectors **shall not** be used.
- All clamp and compression connections for use on internal grounding applications **shall** be UL486A listed. Copper connectors **shall** maintain minimum 88% conductivity rating.

- Compression systems **shall** include crimped die index and company logo for purposes of inspection. Aluminum **shall not** be used for connection purposes.
- Listed two hole long barrel compression terminals are preferred.
- No more than one clamp, fitting or lug may be attached by the same bolt or bolts. An exception to this is where a jumper from a terminal strip or other internal connection point of the same equipment must be bonded to the equipment grounding conductor.
- No more than one conductor **shall** be connected by a single clamp, fitting or lug unless the clamp, fitting, or lug is listed for multiple conductors.
- Where threaded or tapped holes are provided for attachment purposes, a star or split type lock washer **shall** be installed under the head of the screw or bolt and/ or between the nut and the ground bus bar. See Figure 7-24 for the correct location of the star or split washer in these instances.

NOTE: Do not install a washer of any kind between the ground lug and the ground bus bar surface.

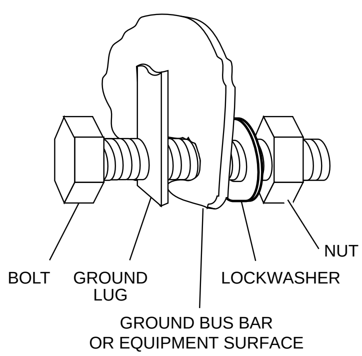


FIGURE 7-24 PROPER LOCATION OF WASHER WHEN CONNECTING GROUND LUG

- Paint, enamel, lacquer and other electrically nonconductive coatings **shall** be removed from threads and surface areas where connections are made to ensure good electrical continuity (per NFPA 70, Article 250-12).

NOTE: Use of a star washer does not alleviate the requirement to remove nonconductive coatings from attachment surfaces because the star washer does not provide enough contact surface area.

- Connections to pipes, conduit or other round members **shall** be made by using a listed bolted clamp of cast bronze or brass or other suitable listed means.
- Connections between dissimilar metal **shall not** be made unless the conductors are separated by a suitable material that is a part of the attachment device. Only attachment devices listed and approved for use with the specific dissimilar metals may be used for this purpose. (Refer to “Dissimilar Metals” on page 6-58.)

- Conductive antioxidant **shall** be applied on all connections of dissimilar metals in indoor or outdoor locations, on all outdoor connections and connections in damp locations, and is suggested for use on connections located within a controlled atmosphere.
- Minimum conductor bending radius and angle must be considered (per NFPA 780; Article 3-9.5).
- Conductors **shall** always be routed toward the MGB at all connecting points. Connection points **shall** be taped with a suitable green tape or otherwise protected from contact with the cable runway or other metallic surfaces.
- Proper cable separation between cable groups **shall** be maintained.
- When attaching two conductors together, connections **shall not** depend solely on solder (per NFPA 70, Articles 250-8 and 250-70) although properly crimped connections may be soldered. Crimp connections **shall not** be used on solid conductors unless they are listed and approved for the application.

The following methods of connection are unacceptable and **shall not** be used:

- Insulation piercing connectors **shall not** be used.
- Self tapping or sheet metal type screws **shall not** be used (per NFPA 70, Article 250-8).
- Tinnerman or similar type clips **shall not** be used.
- Connections **shall not** depend solely on solder (per NFPA 70, Articles 250-8 and 250-70).
- Star or split type washers **shall not** be installed between conductive surfaces. These washers may be used under the head and/or nut of the bolt as shown in Figure 7-24.
- Multiple connections **shall not** be made to one equipment or apparatus attachment point. See Figure 7-25. The series or daisy chain method of connecting a conductor from one piece of equipment to another and then to the ground bus conductor is not permitted.
- Conductors **shall not** extend through or beyond the clamp, fitting or lug unless the device is designed and listed to permit this conductor extension.
- Braided conductors **shall not** be used as a ground bus or equipment grounding conductor at any location.

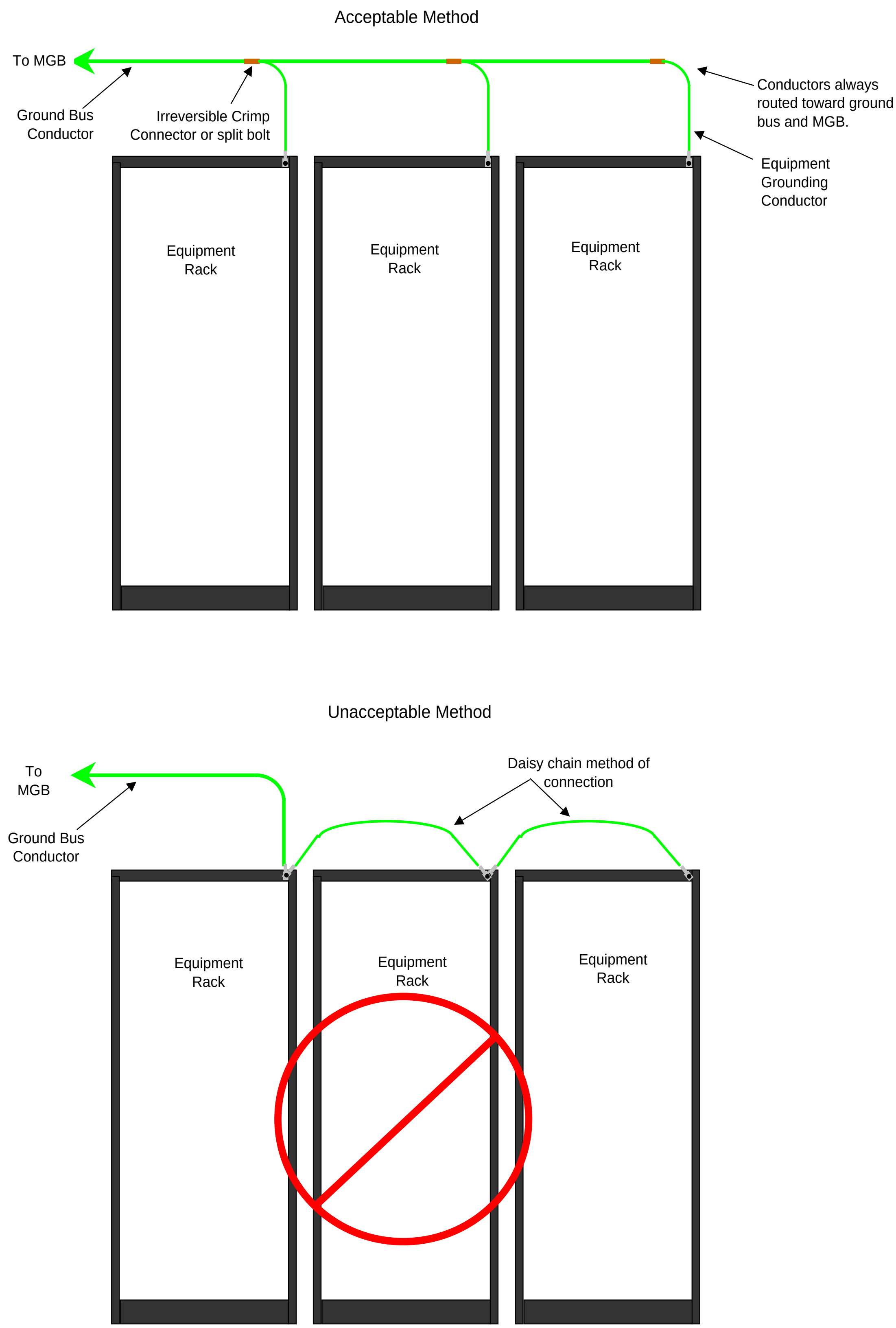


FIGURE 7-25 ACCEPTABLE METHOD OF CONNECTING EQUIPMENT GROUNDING CONDUCTORS

7.5 CONDUCTOR ROUTING METHODS

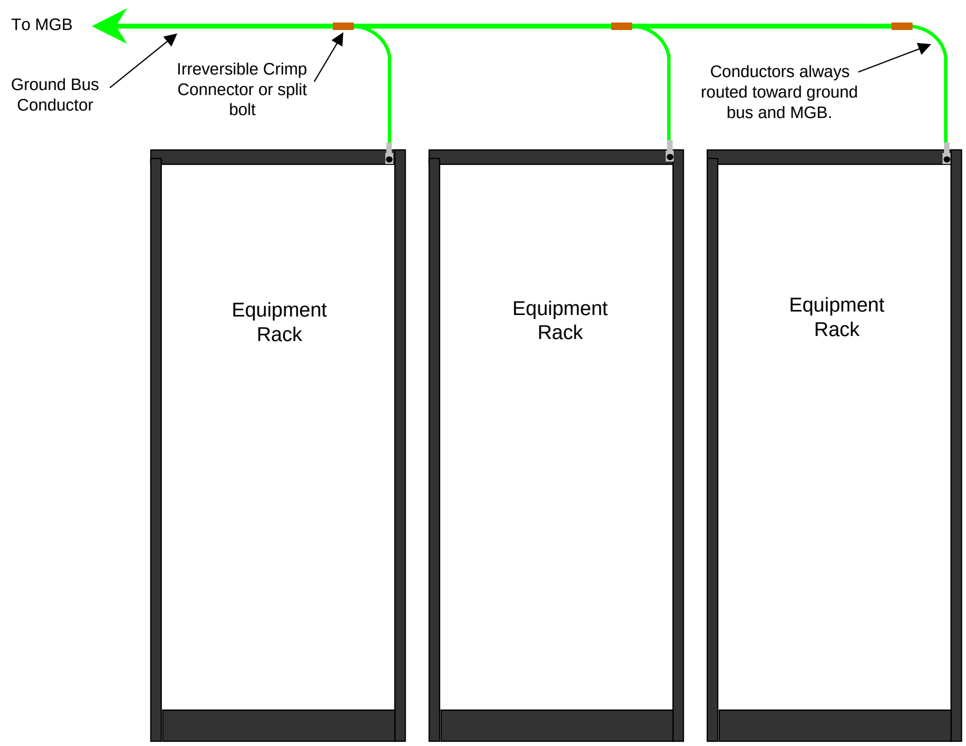
All conductors **shall** be installed and routed so that personal safety is not compromised and that all equipment is serviceable. The following requirements **shall** apply:

- **Length**: conductors **shall** be no longer than that required to achieve their purpose and **shall** be installed and routed in a professional and good workmanship manner.
- **Support**: conductors **shall** be secured or attached to surfaces as required to ensure they do not become damaged or disconnected. The method of securing **shall** be accomplished in a manner that permits associated equipment to be easily serviced.
- **Protection**: conductors installed in areas where they may be subjected to damage **shall** be sleeved in electrical nonmetallic tubing that is securely attached to the surface over which it is routed.
  - In locations where metallic tubing or conduit is required for adequate protection, the conductor(s) routed through the metallic tubing or conduct must be effectively bonded to each end of the conduit using suitable listed means and devices (per NFPA 70, Articles 250-92 (a)(3) and 250-64(e)).
  - Ground conductor tap joints **shall** be installed in order to prevent the conductor or the connection device from making contact with metallic surfaces.
  - At points where conductors are routed through holes within metallic surfaces, the surfaces **shall** be suitably protected with grommets or a like material to minimize damage to the conductor or insulation.
- **Routing**:
  - Conductors **shall** be routed toward the MGB, SSGB, or RGB. Connections to bus conductors **shall** always be made with the tap conductors being routed toward the MGB, SSGB, or RGB. See Figure 7-26 on page 7-52.
  - At points where conductors must pass through a hole in a metallic surface and the hole is slightly larger than the conductor, the conductor **shall** be bonded to the metallic surface through which it passes. If the hole or opening is much larger than the conductor and is intended to accommodate several conductors, the conductor is not required to be bonded. See Figure 7-28 on page 7-53.
  - Ground bus conductors may be routed within cable runways, on the outside of cable runways where suitable support is provided, or along equipment platforms.
  - Equipment grounding conductors **shall** be installed along the rack rail or other suitable support medium leading to the cable runway system or ground bus conductor.

- Ground bus conductors **shall** be routed using the shortest possible routes between the equipment and the MGB or SSGB. They may extend into an adjoining subsystem equipment area and may serve as the grounding conductor for a SSGB, or RGB. These ground bus conductors may have ground bus extension conductors to provide a ground bus within cross section segments of a cable runway system. These ground bus extension conductors **shall** be of the same specification as the ground bus conductor and **shall** be routed with all connections to the ground bus conductor pointed in the direction of the MGB or SSGB.

- **Bending radius:**
  - Ground bus conductors of all sizes **shall** maintain a minimum bending radius of 20 cm (8 in.). The angle of any bend **shall not** be less than 90° (per NFPA 780; Article 3-9.5.

- **Separation**:
  - All ground conductors **shall** be separated a minimum of 5 cm (2 in.) from conductors of other groups as defined in Chapter 11, "Equipment Installation."
  - An exception may be when conductors are grouped together to enter or exit a cabinet or enclosure. Grouping only at this point is acceptable, provided the conductors are suitably separated on either side of the opening.
  - To minimize potential inductive effects of nearby ferrous materials, the conductors **shall** be separated from ferrous materials by a distance of at least 5 cm (2 in.) where achievable.



NOTE: Route all conductors so that all bends and connections are toward the MGB.

FIGURE 7-26 GROUND BUS CONDUCTOR ROUTING

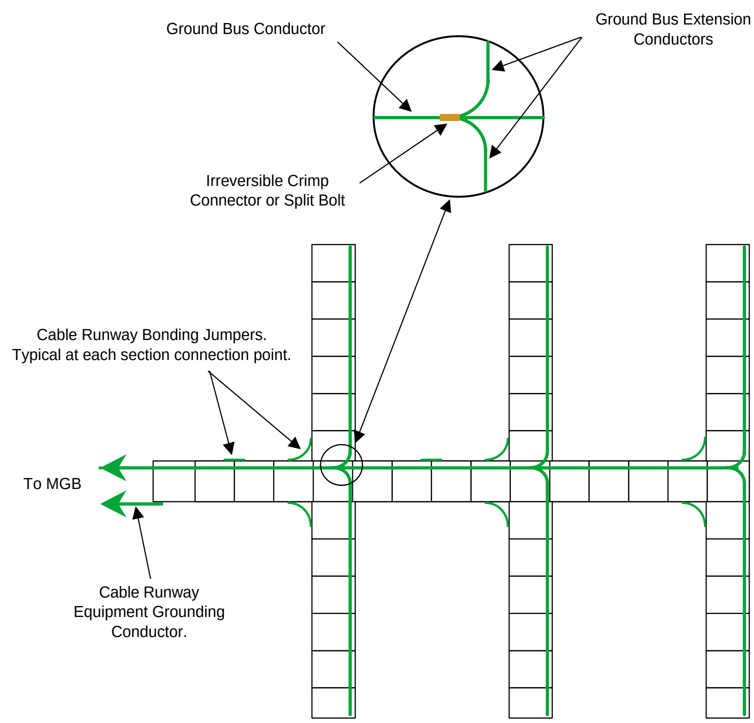


FIGURE 7-27 GROUND BUS CONDUCTOR ROUTING - TOP VIEW OF CABLE RUNWAY

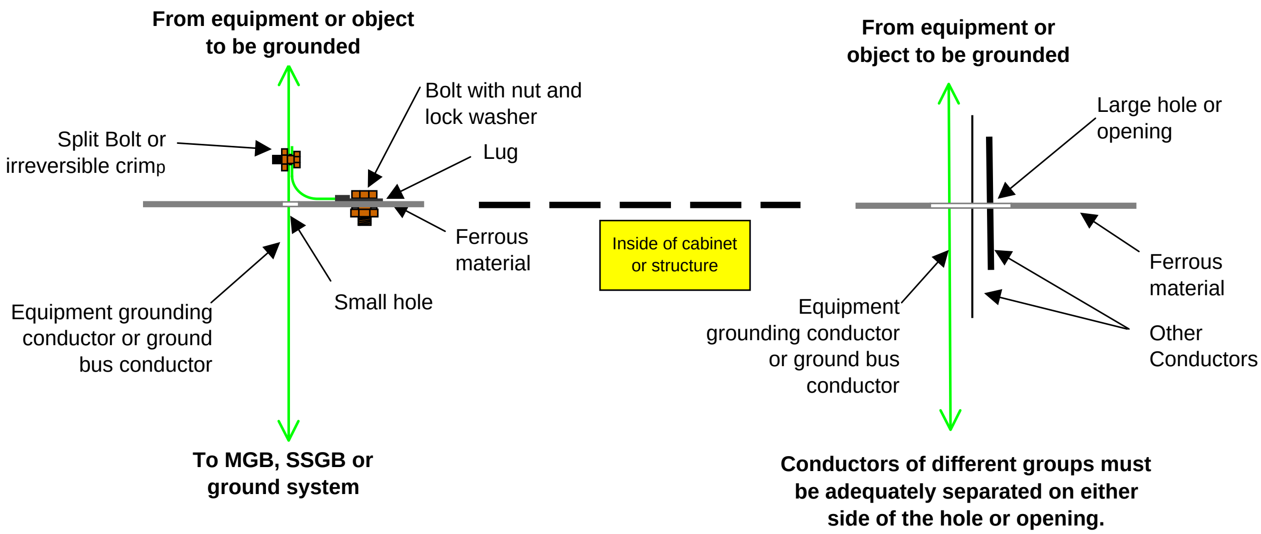


FIGURE 7-28 ROUTING GROUND CONDUCTORS THROUGH HOLES OR OPENINGS

7.6 CONTROL CENTERS, DISPATCH EQUIPMENT AND DISPATCH FURNITURE

All control center and dispatch equipment listed below **shall** be suitably bonded to the MGB, SSGB, or ground bus conductor using methods described within this chapter.

- Equipment supplied with a ground connection point
- Mounting rails or support brackets intended for mounting equipment on or within the furniture
- Metallic parts of dispatch furniture
- Any metal handrails alongside ramps **shall** include grounding and bonding to the facility ground system (per NFPA 70, Article 250).

All control center and dispatch equipment supplied with a ground connection point, metallic equipment mounting rails or brackets and metallic parts of dispatch furniture **shall** be suitably bonded to the MGB, SSGB, or ground bus conductor using methods described within this chapter.

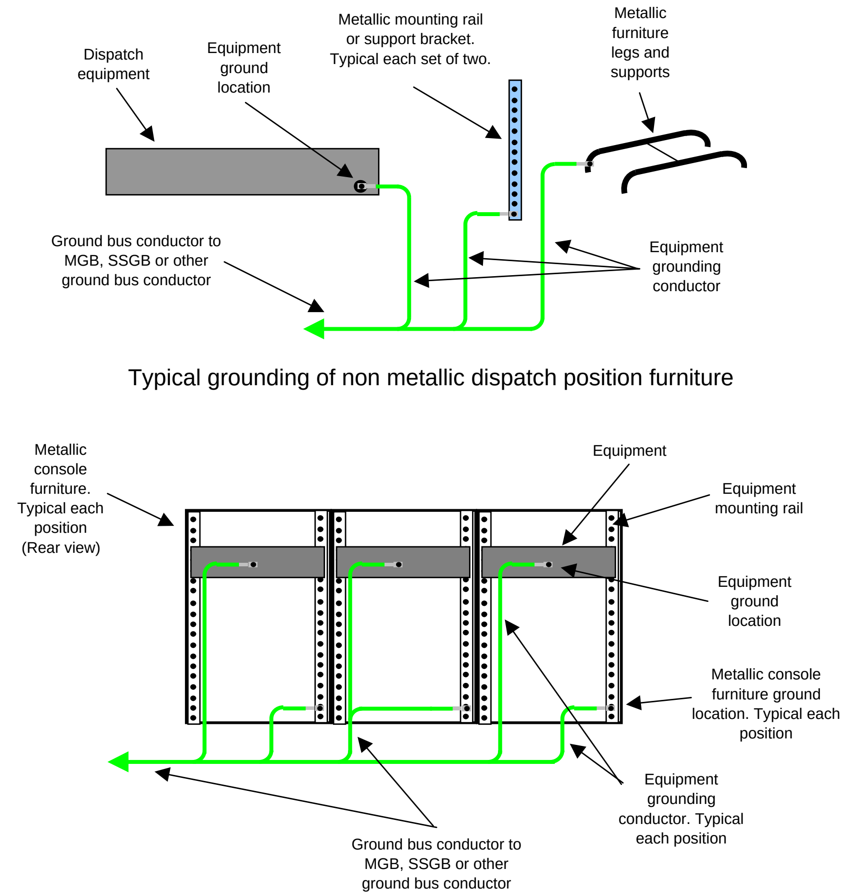
7.6.1 PURPOSE

Bonding of these components to the single point ground system is required to help ensure the utmost of personnel safety and equipment reliability.

7.6.2 METHOD

All equipment, metallic equipment mounting rails or support brackets and metallic parts of dispatch furniture **shall** be suitably bonded to the MGB, SSGB, or ground bus conductor using an equipment bonding grounding conductor. A separate conductor **shall** be installed for each item or component to be bonded to the MGB, SSGB, or ground bus conductor. To minimize the number of equipment grounding conductors from equipment and metallic components of the dispatch furniture, these conductors may be bonded to a ground bus conductor at each dispatch position. The ground bus conductor from each dispatch position **shall** be bonded to the MGB, SSGB, or another ground bus conductor. See Figure 7-29 for examples. The series or daisy chain[1] method of connecting a conductor from one piece of equipment, etc., to another and then to the ground bus conductor is not permitted.

Equipment mounting rails or support brackets intended for mounting equipment that is to be mounted between the rails or brackets or within the furniture **shall** be bonded to the ground system by attaching an equipment bonding grounding conductor to a single mounting rail or bracket used to support the equipment. In instances where an equipment chassis or housing is installed between mounting brackets or rails and the equipment chassis or housing has a designated ground connection point, the equipment bonding conductors **shall** be attached to the designated ground connection point in addition to the mounting brackets or rails.



NOTE: Conductors, connection methods and conductor routing methods shall comply with paragraphs 7.3, 7.4 and 7.5 of this manual.

FIGURE 7-29 GROUNDING METHODS FOR DISPATCH EQUIPMENT AND FURNITURE

7.7 GROUNDING ELECTRODE SYSTEM WITHIN LARGE STRUCTURES

Refer to paragraph 6.4.9, "Integrated Communications Sites" on page 6-43 for information on connecting the communications site ground to an existing building ground system.

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CHAPTER 8

POWER SOURCES

This chapter discusses the following topics:

8.1 INTRODUCTION

This chapter describes various types of power systems that are used for communications sites. It also specifies requirements for various types of power systems that are typically used at a communication site.

8.2 LOCKOUT/TAGOUT

On all power systems, provision **shall** be present to lockout and tagout any circuit to help ensure circuit is safe to work on. Figure 8-1 shows proper tagout of a circuit.

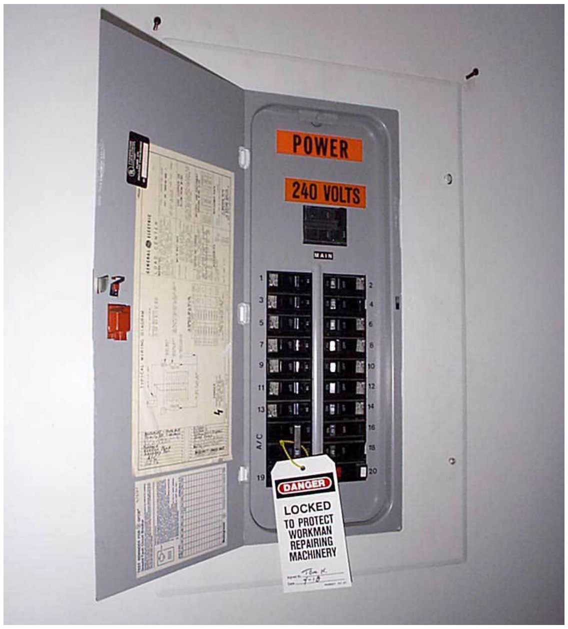


FIGURE 8-1 PROPER TAGOUT OF CIRCUIT

8.3 AC POWER

All site power loading **shall** be determined for initial equipment installation and future expansion. The determined loads at various locations throughout the site **shall** then be factored into the site electrical design.

Continuous load **shall not** exceed 80% of the electrical, wire, panel board, breakers, and service rating. Using this standard will allow all participants in site design (electric power company, pre fabricated shelter vendor, UPS vendor, generator vendor, etc.) to ensure that the power capacity supplied to the communications site is adequate.

Minimum acceptable service for US installations is typically 100 amps @ 120/240 VAC (or 120/208 VAC). A 200 amp (or larger) service may be required for existing/future loads or for additional circuit breaker positions. (Other service parameters may be applicable for nondomestic installations.)

Sizing of AC power loads is critical in calculating supply capacity. Typical power needs are:

- HVAC system (including redundant units). (Most sites consisting of shelters will not be continuously occupied. In such case, the service personnel heat load need not be considered.)
- Room lights and possible outdoor security lighting
- Tower lighting. Some tower lighting systems may require additional power capacity (strobes, multiple fixtures, etc.).

NOTE: A standby generator may be required for continuity of service at sites where tower lighting is required.

- Number of dedicated circuits for major pieces of equipment, including isolated equipment
- Battery chargers
- Uninterruptible power supplies
- Equipment powered by rectifier systems (-48 VDC telephony systems)
- Utility receptacles. The number of utility receptacles required at a site is determined based on the size of the equipment room or shelter.
- The AC electrical power requirements of the communications room when all transmitters are simultaneously keyed **shall** be considered (refer to *NFPA 70, Article 220* and *Article 310-15* for more information).
- Planned future expansion
- Consideration of unusual maximum continuous loads (such as trunked system failsoft operation).

8.3.1 ELECTRICAL SERVICE

The power company usually provides the service to the meter in underground installations and to the weatherhead in overhead installations. All wiring after the meter typically is the responsibility of the customer. Primary metering (high voltage) may be an exception. It is important to note the demarcation point used by the power company serving the region where the site is being constructed. This location has a bearing on installation costs.

The following requirements **shall** be observed when specifying and installing electrical service to the site building:

WARNING

Work practices that help ensure safety shall be observed while performing all electrical work as required by (but not limited to) agencies such as OSHA, NEC, BOCA and local codes.

Throughout the US, the local buried utility locator service shall be contacted before excavating. In other countries, local utility shall be consulted to obtain buried utility location service. Failure to properly locate buried utilities can pose hazards to personnel. Failure to comply with regulations regarding buried utilities can result in penalties.

- Electrical installation work **shall** be carried out in accordance with the current edition of the NFPA 70 and local building codes. Where required, only a qualified and licensed electrician **shall** be used for all electrical installations.
- Underground and above ground service entrance conductors **shall** be protected from physical damage (refer to *NFPA 70, Article 300-5* for more information).
- The service entrance conductor may be a material other than copper if permitted by local codes.
- The site electric meter **shall** be located where it is visible and accessible to power company meter readers and **shall** comply with all applicable codes.
- Potential difficulties in accessing the meter by power company personnel should be considered when determining meter location (especially where a fence is involved). Refer to *NFPA 70, Article 100* and *Article 230* for details regarding locations and service conductors.
- At all sites, there is either or both a main service disconnect and a fused main disconnect. A main service disconnect may be located at a meter location away from the building. A main disconnect located within the shelter, equipment room or area may be fed by a feeder circuit originating at a main service disconnect located in an electrical room in a different location in the building or even a separate building. Typically, the neutral and ground conductors are bonded in the main service disconnect. When the main service disconnect is located remotely from the equipment room or area, a separately derived system **shall** be installed in the equipment room. One of the reasons for the separately derived system is to reestablish the neutral/ground bond, thereby improving the effectiveness of normal mode suppression.

> **NOTE:** In Chapter 9, “Transient Voltage Surge Suppression,” see Table 9-1 on page 9-10 and Figures 9-7 through 9-11 for more information regarding connections for separately derived systems.

- (See Figure 8-2 on page 8-5.) A fused main disconnect **shall** always be installed in equipment rooms ahead of all other panels and equipment, including a generator transfer switch.
- The main disconnect **shall** be located on the same wall as the coaxial cable entry port, the telephone entry point, and the master ground bar. If is it not possible to locate these components on the same wall, then these components **shall** be located on an adjacent wall as close together as possible.
- The main bonding jumper **shall** be installed between the neutral bus and the ground bus within the main service disconnect. This is to ensure a effective low-impedance neutral-to-ground bond connection.
- Self-tapping or sheet metal type screws **shall not** be used for attaching ground or grounding conductors to any surface. (Refer to *NFPA 70, Article 250-8* for more information.)

- Paint, enamel, lacquer, or other nonconductive coatings **shall** be removed from threads and surface areas where connections are made. (Refer to *NFPA 70, Article 250-12* for more information.)

FIGURE 8-2 EXAMPLE OF FUSED MAIN SERVICE DISCONNECT

8.3.2 SEPARATELY DERIVED SYSTEMS

Communications site AC power can also be supplied by an isolation transformer (also known as a step-down, dry-type or one-to-one transformer). Isolation transformers are typically used to step down three-phase 208/480 VAC service to standard commercial 120/240 VAC service.

Isolation transformers are also used to create a separately derived neutral. In this situation, the neutral **shall** be bonded with the equipment ground conductors (green ground wires[1]) at the first disconnect past the transformer (refer to *NFPA 70, Article 517.3* for more information). Advantages of using an isolation transformer are as follows:

- To improve the effectiveness of line-to-neutral (normal mode) surge suppression, the step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. (See Chapter 9, “Transient Voltage Surge Suppression,” for line-to-ground suppression restrictions).
- The transformer shields the communications equipment from disturbances caused by other switching loads fed from the same source voltage.
- The transformer reduces the probability of harmonics, spikes, and transients being introduced back into the source voltage.

1. Ground conductors may be green, green with a yellow stripe or black with green tape on a black conductor at points designated by NFPA 70, Article 250-119 or jurisdictional codes.

8.3.3 INTERIOR ELECTRIC

The following requirements **shall** be observed when specifying and installing interior electrical service:

- All panel boards and switch boards **shall** display signage and placarding per NFPA 70 and any local codes.
- When designing a site floor plan, a clearance of 92 cm (36 in.) **shall** always be provided in front of any electrical panel that requires operating or service. (An exception may be a component that operates on 48 VDC). (Refer to *NFPA 70, Article 110-26* for more information.)
- Self-tapping or sheet metal type screws **shall not** be used for attaching ground or grounding conductors to any surface. (Refer to *NFPA 70, Article 250-8* for more information.)
- Additional clearance **shall** be provided based on the voltage present in electrical panel exceeding 120/240 VAC. See Figure 8-3.

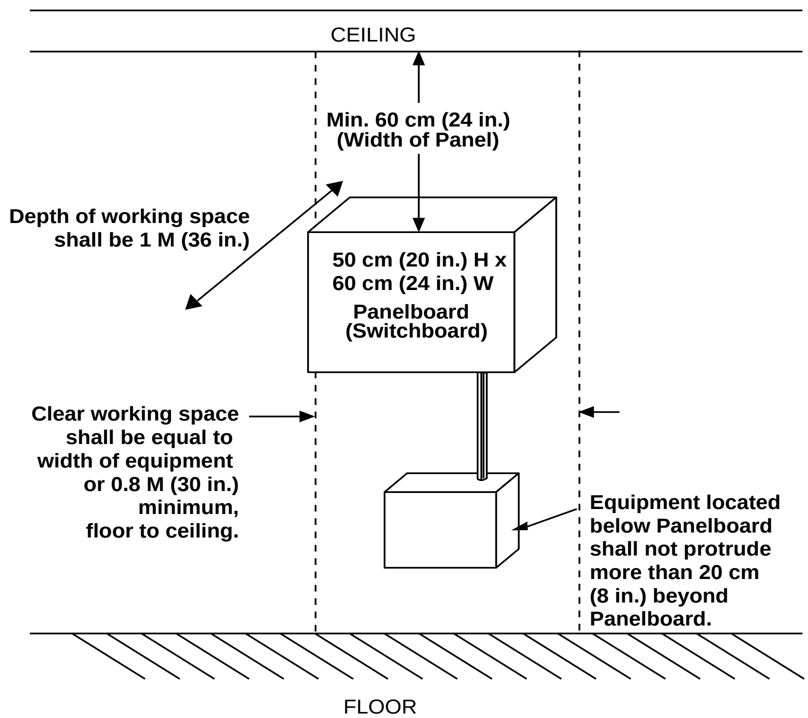


FIGURE 8-3 ELECTRICAL PANEL CLEARANCES

- Paint, enamel, lacquer, or other nonconductive coatings **shall** be removed from threads and surface areas where connections are made (per *NFPA 70, Article 250-12*). Use of a star washer **shall not** alleviate the requirement to remove nonconductive coatings from attachment surfaces. Star or split type washers **shall not** be installed between the conductive surfaces. Proper placement of lockwasher is shown in Figure 8-4.

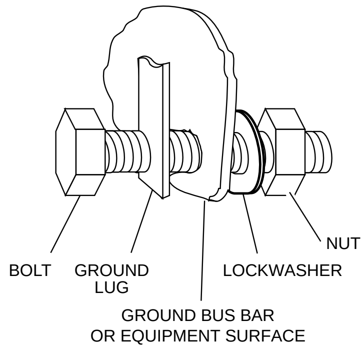


FIGURE 8-4 PROPER PLACEMENT OF LOCKWASHER FOR GROUND CONNECTIONS

- A UPS and its associated battery compartment that are mounted on casters **shall not** violate the clear working space restrictions.
- All internal wiring **shall** be copper.
- Power panels, load centers, and breaker boxes **shall** be identified using distinctive placarding identifying their purpose and location of the main service disconnect. Figure 8-5 shows an example of an acceptable load center placarding scheme.
- Wire, terminals and lugs **shall** be of similar or compatible metals (refer to *NFPA 70, Article 110-14* for more information).

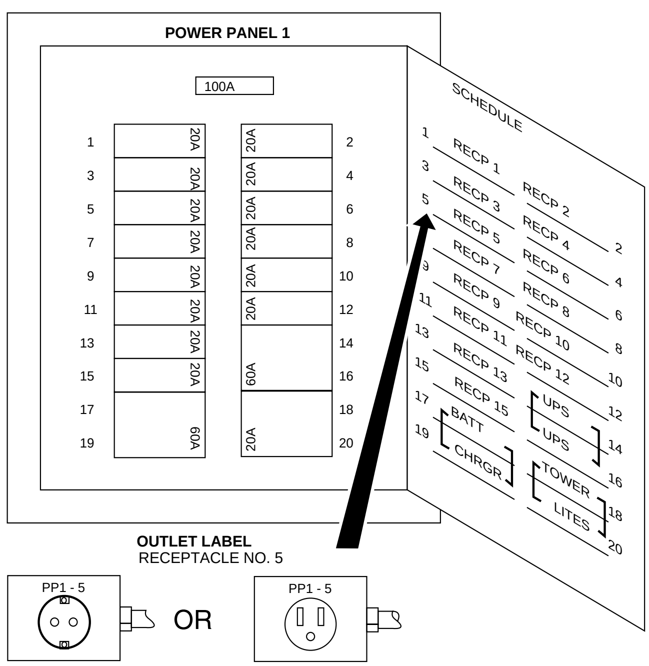


FIGURE 8-5 LOAD CENTER PLACARDING

8.3.4 Power Panels

The following requirements **shall** be observed when specifying and installing interior electrical service:

- Each power distribution panelboard **shall** have its own main breaker (refer to *NFPA 70, Article 348-16B* for more information).
- All interior panelboards and junction boxes **shall** be NEMA Type 1 general purpose for indoor application.
- More than one distribution panel may be necessary for large single equipment rooms in order to support the number of required branch circuits.
- Power panelboards **shall** be bonded to the interior single point grounding system. (See Chapter 7, "Internal Grounding," for the requirements on the proper methods of grounding and bonding equipment.)
- Two distinct power panels **shall** be utilized as follows:
  - **Equipment Power Panel (UPS Panelboard)**

    This panel provides power for the communications equipment and all associated electrically powered items. It is **fed** from the UPS. One-half of a type 2 surge suppression is fed from this panel.
  - **Utility Power Panel**

    This panel provides power for circuits and loads other than the communications equipment. This panel feeds the UPS and non-UPS site electrical equipment such as lighting, HVAC and wall mounted receptacles, etc. Type 1 surge suppression is usually fed from this panel.

NOTE: Do not locate utility branch circuits on circuits protected by a UPS.

8.3.5 Exterior Electrical (Branch Circuits)

This paragraph provides requirements for branch circuits that exit the equipment shelter for use with outdoor equipment.

- All exterior electrical equipment **shall** be protected from the environment and sealed from the elements.
- All outdoor receptacles **shall** be GFCI-type receptacles or breakers (refer to *NFPA 70, Article 210* for more information).
- Non-flexible conduit **shall** be used for all exterior circuit branches. An exception are feeds to vibrating equipment such as air conditioning units, which may use liquid-tight flexible sealed conduit.
- All exterior wall penetrations through which conduit passes **shall** be sealed.
- Exterior panelboards, receptacles and switches **shall** be housed in NEMA Type 3 or Type 3R housing.

8.3.6 CIRCUIT PROTECTION

The following requirements **shall** be observed when specifying and installing circuit protection devices:

> **NOTE:** Locked-rotor starting current **shall** be considered when specifying breaker values for such items as the air conditioner compressor motors and fans. Power amplifiers keyed to full power can also pose unusual start-up loads. Such loads may also affect the type of breaker used for the circuit.

- A means of removing power from a given circuit or load without disrupting other equipment **shall** be provided.
- A minimum 20 A circuit breaker or fuse for each branch circuit feeding communications equipment and associated equipment is recommended.
- Branch circuit breakers for all other equipment such as lighting, heating and air conditioning **shall** be rated per manufacturer specifications as per code.
- Breakers and their associated receptacles **shall** be uniquely labeled and correlated to the respective power panel unless required differently for specific equipment (refer to *NFPA 70, Article 210-21-B3* for more information).
- Panel schedule **shall** be filled out and kept up to date.
- Circuit breakers **shall** be sized to protect the conductor attached to them, not the load on the circuit.

8.3.7 CONDUCTORS

The following requirements **shall** be observed when specifying and installing conductors:

WARNING

Aluminum conductors shall not be used. Never mix aluminum and copper wire, connectors, panels, or receptacles. These conductors have a different coefficient of expansion which can cause a connection or joint to become loose.

- All branch conductors **shall** have an allowable ampacity equal to or greater than the non-continuous load plus 125% of the continuous load.
- It is recommended that a minimum of a 8 mm^2 csa (#12 AWG) conductor be used in the equipment panel for circuit branches.

> **NOTE:** On 3-phase branch circuits it is very important that the neutral conductor be sized appropriately for overcurrent that may be induced upon the neutral by a possible load imbalance.

- The neutral conductor **shall** be equivalent in size to its associated load carrying conductors. In special circumstances (such as highly reactive loads that may generate harmonics), the neutral should be increased to up to 175% of its original size.
- All single phase circuits **shall** be 3-wire.

8.3.8 CONDUIT

The following requirements **shall** be observed when specifying and installing conduit:

- All interior surface-mounted building wiring **shall** be run in rigid electrical metallic tubing (EMT).
- The conduit **shall not** be used as the equipment grounding conductor. An individual circuit equipment grounding conductor **shall** be installed in each conduit exiting the panelboard and be connected electrically per NFPA70, Article 250-148(A). The arrangement of grounding connections **shall** be such that the disconnection or removal of a receptacle, fixture, or other device fed from the box will not interfere with (or interrupt) the equipment grounding conductor continuity.
- The conduit **shall** be securely fastened within 91 cm (3 ft.) of any receptacle box, junction box, panel board or any termination of the conduit.
- For tenant improvements, applicable local codes **shall** be observed.
- Prefabricated shelters **shall** utilize surface-mounting for all wiring. Typically, thin wall EMT with compression or screw-down fittings and couplings is used (refer to *NFPA 70, Article 348* for more information). Flexible metallic or liquid-tight conduit can be used for connection to vibrating or rectifier loads in lengths not to exceed 91 cm (36 in.).
- Some conduit runs may be mounted to the exterior of cable runway systems. These cable runways (along with ceiling attachments) **shall** be designed and installed to support an EMT distribution system, including all hardware-related fittings and boxes, as well as the distributed load in the runway.
- Flexible metal conduit may be used to carry a circuit branch conductor to portable equipment, vibrating equipment, and suspended lighting fixtures.
- Liquid-tight flexible metal conduit **shall** be used where additional protection from liquids, vapors or solids is required.
- Cable raceways can be mounted to cable runways except in isolated ground zones. (See Chapter 7, “Internal Grounding.”).

8.3.9 HARDWIRING OF EQUIPMENT AND DEDICATED RECEPTACLES

NOTE: Extension cords **shall not** be used to power permanent communication equipment at a site.

When an open equipment rack is used, hardwiring of power is not always possible. Mounting a dedicated simplex receptacle or receptacle assembly on the rack may be the most convenient method of supplying power, especially if multiple pieces of equipment are mounted on the rack. This is also a convenient way to install personal protection type 3 SPD devices (such as Motorola part no. RLN4924A) to the equipment.

These receptacle assemblies can be pre-manufactured and mounted to the top face of an equipment rack. Mounting can also use a fabricated power pole mounted between racks. Figure 8-6 shows typical receptacle assembly mounting for powering open racks.

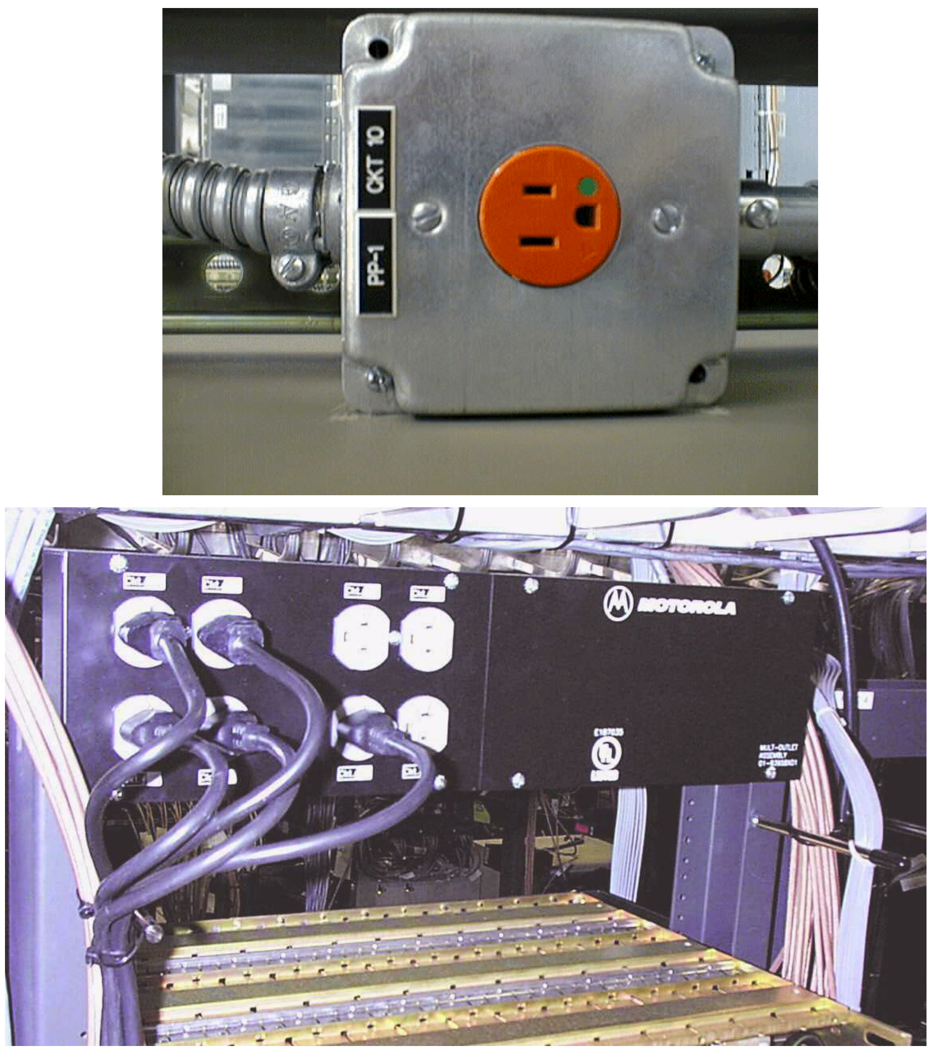


FIGURE 8-6 TYPICAL RECEPTACLE MOUNTINGS FOR POWERING OPEN RACKS

8.3.10 RECEPTACLES

The following requirements **shall** be observed when specifying and installing receptacles for powering communications equipment:

- To ensure reliability, each major piece of equipment and each half of a redundant power supply **shall** have its own dedicated individual branch circuit and dedicated simplex receptacle.
- Equipment racks may require special attention to support the dedicated simplex receptacle scheme. To comply with the dedicated simplex receptacle concept, receptacles have to be located on or very near the rack of equipment. One method is to use a specialized Multi-Receptacle AC panel with dedicated circuits that **shall** be mounted on the equipment rack or enclosure. (These Multi-Receptacle AC panels **shall** be hard wired to the breaker panel, and each simplex receptacle **shall** use an individual branch circuit.)
- To eliminate the possibility of two pieces of equipment turning on at the same time and momentarily exceeding the amperage capacity of the circuit, simplex receptacles **shall** be used instead of duplex receptacles.

> **NOTE:** Duplex receptacles may be used only if the connecting tabs on the receptacles are removed and the duplex is fed from two separate circuits. The neutral cannot be shared by two receptacles. In this case, only one equipment grounding conductor is required for the two circuits.

- All circuits **shall** be 3-wire.
- Receptacle ratings should be determined by conductor and circuit breaker current ratings. Consider future expansions.
- Isolated ground receptacles may be used when recommended by the equipment manufacturer (refer to *NFPA 70*, *Article 410-56C* and *Article 250-146* for more information).
- All 120 VAC receptacles **shall** have three conductors: hot (live), neutral, and ground.
- Power cord plugs **shall** be supported with strain reliefs adequate to prevent accidental disconnection where applicable.
- All communications equipment receptacles **shall** have the electrical box or cover plate permanently marked with the circuit number and appropriate breaker identification. This identification **shall** be readily visible without requiring removal of the plug. (Figure 8-5 shows proper receptacle marking.)
- Utility receptacles should be fed from the utility circuit breaker panel and not from the equipment panel or the UPS.
- Outlet boxes or enclosures **shall** be securely mounted per NFPA 70, Article 300. Cable ties **shall not** be used as a method of securing outlet boxes or receptacles

8.4 RECEPTACLE STRIPS

WARNING

Consumer grade AC power receptacle strips shall not be used for permanent installations.

Do not mount extension blocks or receptacle strips on the floor. Damage can result from foot traffic or water, and water seepage or fire sprinkler activation may pose an electrocution hazard to personnel.

Receptacle strips are intended to provide AC power to low-power equipment where several line-powered items are closely collocated (such as an operator's position). In general, the following considerations need to be observed in selecting and installing receptacle strips:

- Receptacle strips are limited to specific applications only where a receptacle strip is suitable for use. In all cases, receptacle strips **shall** be UL listed and of metal construction.
- (See Figure 8-7 and Figure 8-8.) Receptacle strips **shall** be easily mountable without requiring disassembly.

FIGURE 8-7 TYPICAL RECEPTACLE STRIP (U.K. AND AUSTRALIA)

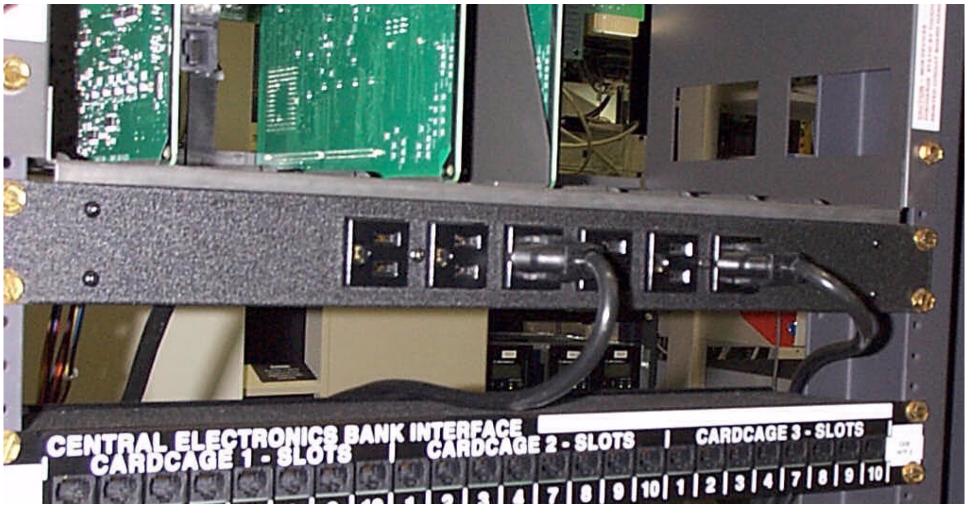


FIGURE 8-8 TYPICAL RECEPTACLE STRIP (NORTH AMERICA)

- Receptacle strip **shall** be securely mounted to the supporting structure using intended bolt mounting and not tie-wrapped.
- Receptacle strips **shall not** include ON/OFF switches. These switches can be inadvertently switched off.
    - Consumer-grade surge-protected or locally fused receptacle strips should be avoided. Proper equipment setup and facility electrical design should accommodate these requirements.
- No more than one receptacle strip **shall** be connected to the same branch circuit.
- Redundant equipment pairs **shall not** be connected to the same receptacle strip.
- Items considered individually critical (where no backup can easily be implemented) **shall not** be powered from a receptacle strip.
- If multiple receptacle strips are used, they **shall** be plugged into dedicated simplex receptacles on individual branch circuits.

8.5 RECTIFIER/DC POWER SYSTEMS

This section provides guidelines and specifies requirements for selecting and installing site rectifier/DC power system systems and components. Note that although specific recommendations are stated here, actual equipment specifications are largely determined by factors peculiar to the installation being performed. These stipulations are noted throughout the section.

8.5.1 RECTIFIER SYSTEM REQUIREMENTS

8.5.1.1 ACCEPTABLE RECTIFIER TYPES

Two general types of rectifiers are acceptable for powering Motorola equipment. The types are:

- **Controlled Ferroresonant Rectifier**

  A controlled ferroresonant rectifier exhibits an exceptionally good Mean Time Between Failure (MTBF), and typically provides an output exceeding 110% - 120% of its rating for the life of the rectifier. Forced load sharing is an essential feature of these rectifiers. In a multiple rectifier system, it prevents a single rectifier's output from drifting down and becoming inefficient.

  Both a potential drawback as well as benefit of this rectifier is its transformer. In an area prone to excessive AC transients, a controlled ferroresonant rectifier will continue to function satisfactorily. However, the transformer is large and heavy. Suitability of this rectifier type will be based on balancing these criteria.

  Although a ferroresonant supply is simple, low cost, and handles high current, it cannot handle AC line frequency shifts, particularly on the low side. An applied low line frequency (even 59 Hz) causes the ferroresonant supply to draw high current over excessive ON cycles. This overheats the transformer and causes close to short-circuit conditions within the tuned reactive circuit. A backup generator with a defective speed governor is a typical source of this trouble.

- **Switchmode Rectifier**

  A switchmode rectifier offers a size and weight advantage over ferroresonant rectifiers in that its transformer is smaller and lighter than controlled ferroresonant rectifiers. This type of rectifier will provides an output of 105% of its rating for the life of the rectifier.

  The drawback to the switchmode rectifier is that it does not have the large transformer to absorb transient surge voltages. These transient surges can shorten the life of the switchmode rectifier. In areas prone to significant transient voltages, controlled ferroresonant rectifiers may be a better choice. The lower MTBF of a switchmode rectifier can be offset by its ease of replacement. Also, the inefficiency at low output levels of these rectifiers is not nearly as severe as that of the controlled ferroresonant rectifier; therefore, forced load sharing is not required. A switch mode rectifier that is well-filtered to prevent radiated RFI and superimposed noise on the DC output circuit should be selected.

Silicon Controlled Rectifier (SCR)-based rectifier systems are **not acceptable** for powering Motorola systems, due to tendencies of SCRs to allow AC transients to propagate to the DC side.

8.5.1.2 REDUNDANCY

An *n+1* redundancy setup is recommended, at a minimum, for the rectifier system. An *n+1* redundant scheme employs one rectifier more than is required to power the system. In many cases, the redundant rectifier also provides for recharging of the batteries after a power outage.

8.5.1.3 RECTIFIER SIZING

In general, the power system selected should be appropriately sized based on the installation being performed.

8.5.1.3.1 SYSTEMS REQUIRING LESS THAN 1200 A

In systems requiring 1200 A or less, 2.5 kW (50A@-48V; 100A@24V) switchmode modular rectifiers (or equivalent) are recommended.

8.5.1.3.2 SYSTEMS REQUIRING MORE THAN 1200 A

In systems requiring more than 1200 A, modular rectifiers as described above are not typically recommended. This is based on the following:

- An *n+1* redundancy using low capacity rectifiers may not provide sufficient reserve capacity to fully recharge discharged batteries within 24 hours. An *n+2* or *n+3* design may be necessary to handle recharge. However, this will affect overall system cost.
- Higher-output systems based on higher-current rectifiers have a theoretically higher MTBF. A -48 V, 1000 A non-redundant system using 50 A rectifiers will contain 20 modular switchmode 100 A rectifiers. The same system using 200 A controlled ferroresonant rectifiers will contain only five 200 A rectifiers. The 200 A rectifier system has 25% as many potential points of failure as the 50 A system.

8.5.2 DC DISTRIBUTION

The power board or DC power distribution center is the infrastructure around which the power system is built. A power board can be divided into two components: the meter/alarm and the control section/distribution section. The distribution section of the power system can be reconfigured, expanded, and modified in many ways, however, once the meter, alarm, and control section is at capacity, any further expansion requires the replacement of the power board. Over sizing of the power board is relatively inexpensive since most of the over sizing consists of copper bus bars.

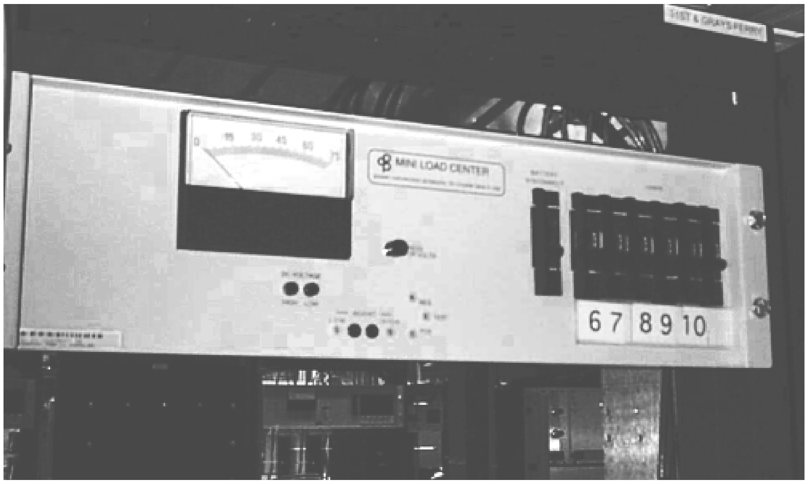


FIGURE 8-9 DC LOAD CENTER

8.5.3 LOW VOLTAGE DISCONNECT

DC systems, with battery back-up, **shall** be equipped with a Low Voltage Load Disconnect (LVLD). A Low Voltage Battery Disconnect (LVBD) **shall not** be substituted for the LVLD. A battery system is considered to be fully discharged when the voltage reaches 1.75 VPC (volts per cell). In a 48 volt system (24 cells) the battery plant is fully discharged when the voltage reaches 42 volts (1.75x24). Battery damage begins to occur when the voltage drops below this point.

Continuing to operate the system beyond this point with the intent of providing service to the end user at the expense of damaging or destroying the batteries may not be possible. Internal power supplies that provide logic and memory voltages (typically +12V, -12V, and +5V) are designed to provide regulated power throughout a specific input voltage range. This range is typically within a few volts of the batteries operating range. Once the input voltage drops below the specified range, the output voltage of the internal power supplies will no longer be within the specified limits. In many cases, the internal power system will shut down. If the internal power supplies do not shut down, damage or erratic operation may occur. Although a low voltage disconnect does protect the battery plant, it also is required to protect the load equipment.

8.5.4 OVERCURRENT PROTECTION

Because fuses may not always be available (especially in remote or non-domestic markets), appropriate circuit breakers are recommended.

Overcurrent protection should be a minimum of 50% larger that the **anticipated** load for the circuit. In-rush currents (the current draw when a device is first powered on) **shall** also be considered when sizing circuit protection.

8.5.5 POWER CABLING

NOTE: UL-listed General Use or Battery cable **shall** be used.

8.5.5.1 CABLE CURRENT CAPACITY

The power cables that supply DC power to site equipment **shall** be sized based on their current carrying capacity (referred to as "ampacity"). Ampacity is determined by the short-term amperage the conductor can carry before generating sufficient heat to degrade the insulation. Ampacity is determined by the following factors:

- ambient temperature
- insulation type
- heat dissipating characteristics of the cable transport

A conductor will have a higher ampacity in free air that one that is enclosed in conduit since the conduit will contain the heat. Keep in mind that in most electrical codes, a raceway is an enclosed duct that the cables are run through, not the ladder rack (cable runway) used in many DC systems. As such, the ampacity rating of cable in raceway will be lower than that installed on the cable runway.

Independent of short-term ampacity, allowable voltage drop must also be considered when sizing power cables for DC systems. In many cases, this will require the DC power cables to be larger than the cable required for an AC system.

8.5.6 FLOOR AND CEILING RUNS, PLENUM GRADE AND RISERS CABLING

WARNING

Motorola prohibits the use of non-plenum rated power cabling for installation within plenums, even if local codes allow otherwise. Failure to use suitable plenum-rated cables in these areas can result in generation of toxic fumes in the event of a fire.

NOTE: Feasibility and methods of wiring within plenums and risers **shall** conform with jurisdictional codes.

The following requirements specify installation practices that help, should a fire occur, minimize smoke and products of combustion from electrical wiring in areas that handle environmental air. These areas are typically referred to as plenums. A plenum is defined as a compartment or chamber to which one or more air ducts are connected and that forms part of the air distribution system. See *NFPA 70, Article 100* for more information.

- No wiring system of any type **shall** be installed in ducts used to transport dust, loose stock, or flammable vapors. See *NFPA 70, Article 300-22(a)* for more information.
- No wiring system of any type **shall** be installed in any duct, or shaft containing only such ducts, used for vapor removal. See *NFPA 70, Article 300-22(a)* for more information.
- Wiring systems may be installed in ducts specifically constructed to transport environmental air only when such wiring consists exclusively of the following:
    - Type MI (mineral insulated) cable
    - Type MC (metal-clad) cable employing a smooth or corrugated impervious metal sheath without an overall nonmetallic covering
    - Type CMP (communications plenum cable), electrical metallic tubing, flexible metal tubing, intermediate metal conduit, or rigid metal conduit. Flexible metal conduit and liquid-tight flexible metal conduit **shall** only be permitted in lengths not exceeding 1.22 m (4 ft.), to connect physically adjustable equipment and devices permitted to be in the ducts. See *NFPA 70, Article 300-22(b)* and *Article 800-53(a)* for more information.
- Wiring installed in other spaces used for environmental air, such as the area above a suspended ceiling or as otherwise defined in NFPA 70, Article 300-22(c), **shall** be installed in accordance with NFPA 70, Article 300-22(c). Such wiring methods include using Type MI (mineral insulated) cable, Type MC (metal-clad) cable without an overall nonmetallic covering, and Type AC (armored cable) cable. See NFPA 70, Article 300-22(c) and Article 800-53(a) for complete details.

WARNING

Electrical installations installed in hollow spaces, vertical shafts, and ventilation or air-handling ducts shall be installed in a manner such that the possible spread of fire or products of combustion will not be substantially increased. Openings around penetrations through fire resistance-rated walls, partitions, floors, or ceilings shall be firestopped using approved methods to maintain the fire resistance rating. Firestopping such penetrations may be accomplished by using specially manufactured fire seals or fire-barrier caulking. See NFPA 70, Article 300-21, Article 800-52 and ANSI/TIA/EIA-569-A for more information.

8.5.7 DC POWER BUDGET

To properly size DC power cables, a DC power budget **shall** be established. Figure 8-10 shows an example power budget. Typical minimum DC operating range will be from 2.33 - 1.75 VPC. This translates to 56 - 42 V for a 48 V system, or 28 - 21 V for a 24 V system. (Some equipment will have an operating range wider than those stated here.)

The first step in establishing the DC power budget is to determine the lowest voltage in the equipment operating range, called the end voltage. Where multiple pieces of equipment are connected to a given branch, the highest of the end voltages should be used for the power budget. The difference between the equipment end voltage and the battery end voltage (1.75 VPC minimum) is the allowable voltage drop. Voltage drop from the batteries to the main distribution, main distribution to remote distribution, and remote distribution to the load is then determined by load and the distances between components.

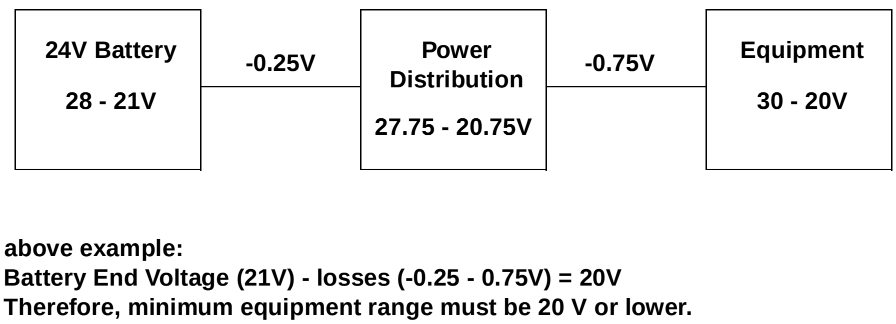


FIGURE 8-10 DC POWER BUDGET

If the equipment end voltage is equal to or higher than the battery's end voltage, then a higher battery end voltage will have to be selected. Using a higher battery end voltage will increase the battery size required for the system. Normal battery end voltages range from 1.94 - 1.75 VPC. In these cases, the allowable voltage drop should be kept to the absolute minimum practical.

8.6 UNINTERRUPTIBLE POWER SUPPLIES

NOTE: Extended power delivery during a utility blackout is intended to be provided by a generator. The UPS is typically intended to provide transition power only between utility blackout and generator stabilization.

NOTE: If the site will use a generator in addition to a UPS, the UPS **shall** be programmed or configured to allow the generator to provide power and not block the generator from connecting to its intended load. Note that generator power may be rejected by a default-configured UPS because of sensing circuitry in the UPS that rejects the generator power as not being "pure", as compared to its normally received utility-supplied power.

Any AC "line quality sampling" feature on the UPS should be disabled to prevent the UPS from rejecting the generator as a power source.

This section provides guidelines and specifies requirements for selecting and installing a site Uninterruptible Power Supply (UPS). Note that although specific recommendations are stated here, actual equipment specifications are largely determined by factors peculiar to the installation being performed.

The UPS system is intended to provide short-term power to specific loads when commercial power glitches or short-term power outages occur. Most UPS systems come with a standard configuration that usually provides between 5 to 10 minutes of supply voltage at full load capacity. The UPS typically provides an alarm that indicates when the UPS is nearing battery depletion.

8.6.1 DETERMINING UPS OUTPUT REQUIREMENTS

System Engineering **shall** be consulted in determining the required UPS output capacity.

8.6.2 GENERAL CONSIDERATIONS

The following requirements and considerations **shall** be observed when specifying and installing the UPS:

- UPS **shall** provide true sinusoidal output. Step-synthesized output **shall not** be acceptable.
- UPS **shall** be able to provide full rated output exceeding the maximum transition period from failed utility power to stabilized generator power.

- Service panelboard **shall** have enough capacity and breaker space to accommodate the UPS.
- Intended location of UPS **shall** have adequate capability to exhaust the heat generated by the UPS.
- Ambient temperature range near UPS **shall** be in accordance with manufacturer's specification.
- Adequate spacing for safe servicing of the UPS and battery banks **shall** be considered in planning the installed location of the UPS.
- Preventive maintenance (including suggested battery replacement intervals) **shall** be in accordance with manufacturer's specifications.

8.7 SOLAR/WIND POWER

NOTE: Systems that are HVAC dependent will not perform economically using solar or wind power systems due to the continuous high energy demand. Motor generator systems may provide higher continuous energy at much lower cost.

Certain sites without access to commercial AC power utilities can use solar and/or wind-generated power instead. The solar panels and/or wind generator charges batteries that provide power to site equipment. Propane or liquid natural gas (LNG) generators can be used, especially in colder climates, to back up the solar/wind system.

Because solar/wind systems provide limited power, it is important when planning the power system to calculate the predicted power usage for the site. Solar power is best suited for small sites with low power requirements where the physical size and cost of the standalone power system does not become impractical. The site’s transmitter duty cycles **shall** be planned so as not to exceed the maximum average current requirements.

Wind generators can be used to back up a solar panel system. If there are sunless days with wind then battery charging can still take place. Such a system could take advantage of more sun in the summer and more wind in the winter. Wind generators should be mounted higher than buildings or other obstructions where wind flow is more efficient.

Figure 8-11 shows a typical solar/wind generator installation.

FIGURE 8-11 TYPICAL SOLAR PANEL AND WIND GENERATOR INSTALLATIONS

8.7.1 SYSTEM PLANNING

Development of a stand-alone power system should be contracted with a firm experienced in the design of alternate power systems. To design a system capable of supplying the site's power needs, the contracted firm needs the following information:

- Total typical ampere-hours (AH) used by all site equipment over a 24-hour period. (1 ampere used continuously for 1 hour is 1 AH.)
- Voltage the power system must be capable of providing. (Communications sites of this type typically use 12 volt or 24 volt battery systems.)
- The average number of consecutive sunless days expected at the location.

The daily AH rating is calculated as follows:

Example:
Given the following characteristics for a single-repeater site:
- Single repeater requires 7A for TX (A_{TX}) and 1A for RX (A_{RX})
- Radio link requires 1.6A for TX and 1A for RX
- Duty Cycle (TX/RX) of 20%

Using the following formula:
[(A_{TX} x $\%_{TX}$) + (A_{RX} x $\%_{RX}$)] x 24 hrs = average AH required

For the example characteristics given:

Repeater requirement is:

[(7 x 0.2) + (1 x 0.8)] x 24 = 52.8 AH/day

Radio Link requirement is:

[(1.6 x 0.2) + (1 x 0.8)] x 24 = 26.9 AH/day

Total requirement is: 79.7 AH/day

8.7.2 REQUIREMENTS

The following requirements and considerations **shall** be observed when specifying and installing a solar power system:

- Solar panels **shall** be located away from objects that could block sunlight to the panel. Panels **shall** be pole-mounted or roof-mounted if required.
- Observe the total time a particular location has direct sunlight throughout the day. Note in any calculation or specification that the site batteries are charged only when the solar panel is exposed to the sun.
- The angle of the sunlight with respect to the solar panel throughout the year **shall** be considered. Shadows cast by nearby objects may be different when the sun's angle changes with the seasons.
- Note that the fixed panel mounting angle for year round usage in northern latitudes is typically 10 degrees more than the latitude. For example, at a latitude of 45 degrees north the panel should be mounted at an angle of 55 degrees from the horizontal.
- The optimum angle varies throughout the year. The amount of variation increases with latitude. Have the panel supplier recommend the mounting angle. (Trackers are available that automatically move the panel to follow the sun, but these are rarely used at communications sites because of the additional maintenance and possibility of failure.)
- Solar panels **shall** be at least 10% oversized to ensure that they can handle the site's power requirements.
- Battery storage **shall** be adequate to supply power to the site for 5 to 10 days without wind or sun.
- Far northern latitudes (or far southern latitudes in the southern hemisphere) have less daily sun charging time.

- Deep-cycle batteries **shall** be used in systems experiencing up to 80% of the battery system is discharged and recharged.
- Solar panels and wind generators **shall** be mounted high enough to discourage vandalism. Bullet-resistant solar panels are available.
- Where applicable, panels **shall** be mounted high enough to clear deep winter snowfalls or ice accumulation.
- Panels **shall** be mounted and supported such that damage by high winds is avoided.
- Outside cabling **shall** be well secured and protected with conduit, or run inside the mounting pole.
- Plan the battery location in accordance with "Battery Systems" on page 8-26. In earthquake-prone areas (Moment Magnitude rating 3 or greater), batteries **shall** be mounted in seismic-rated battery racks secured to the floor.

8.7.3 INSTALLATION

Install the solar panels and wind generator in accordance with instructions provided by the contracted design firm.

- If panels are roof-mounted, the metallic portions of the solar panel framework **shall** be bonded to the site grounding electrode system in accordance with Chapter 6, "External Grounding." If panels are pole-mounted, the pole ground **shall** be bonded to the site grounding electrode system in accordance with Chapter 6, "External Grounding."
- It is recommended that cabling from the outdoor portion of the system be protected in conduit and secured. Cable from pole-mounted solar panels or wind generators can be run inside the mounting pole. appropriate precautions **shall** be taken to protect the cable from moisture ingress.
- Batteries **shall** be installed in accordance with "Battery Systems" on page 8-26 and secured against earthquakes in seismically active areas (Moment Magnitude rating 3 or greater) using a seismic-rated battery rack rated for the site's seismic zone. Secure the rack to the floor per manufacturer's instructions.

8.7.4 MAINTENANCE

- Solar panels **shall** be cleaned and inspected twice a year or as required to prevent accumulation of bird droppings, dust or pollen that could reduce efficiency by blocking sunlight.
- Cracked or damaged panels **shall** be replaced.
- Manufacturers' instructions for maintaining batteries **shall** be observed.

8.8 BATTERY SYSTEMS

Batteries used for equipment backup can be divided into two categories: flooded cell (wet) and valve regulated (sealed). Flooded cell batteries pose greater hazards, since they emit hydrogen gas during normal operation. Sealed batteries do not typically vent hydrogen.

WARNING

Motorola employees and contractors shall not handle hazardous materials unless properly trained. This includes warehouse storage, transportation, and installation of battery systems.

The following requirements and considerations **shall** be observed when specifying and installing a battery system:

- Where applicable, it is recommended that certified Hazardous Materials handlers be contracted to handle tasks involving the hazardous materials contained in most battery systems.

WARNING

Wet cell battery failure involving large-scale electrolyte leakage may constitute a Hazardous Material (HAZMAT) condition. Under no circumstances shall regular site personnel perform HAZMAT handling.

Special training and HAZMAT certification, spill mitigation and reporting, and cleanup techniques/monitoring is required under the Federal Clean Water Act and NFPA regulations.

NOTE: Material Safety and Data Sheets (MSDS) describing the nature of HAZMAT materials present at a communications site, their reactivity, flammability, and emergency spill/release mitigation and reporting are **required** at each site.

8.8.1 BATTERY CONTAINMENT AREA

The following requirements and considerations **shall** be observed when specifying and laying out a battery containment area:

- Certain codes may require that UL listed Intrinsically Safe vent fans and electrical appliances be used in battery containment area.
- NFPA allows that the amount of batteries stored and operating in an area may be increased beyond that normally allowed if a water deluge sprinkler system is installed.

- NFPA signs advising the fire department of reactivity with water **shall** be posted. Separate battery rooms (especially for flooded cell types) that are sealed from adjoining rooms and properly vented to the building exterior are recommended. These conditions may also be required by local codes.
- Where battery systems use a total electrolyte volume greater than 3.79 L (1 gallon), cell assemblies, and containment/neutralization provisions **shall** conform with NFPA 111.

WARNING

Appropriate signage shall be present on doors leading to battery rooms and within the room itself, notifying personnel of explosion, chemical, and electrical hazards within the area. Appropriate fire extinguisher(s) shall be present in battery room, as dictated by local code.

8.8.2 BATTERY BACKUP DURATION

Typically, a 2 hour battery backup provision is standard practice for shelter installations. This is based on the assumption that 2 hours is the nominal amount of time in which a technician would be able to respond and correct a site power problem for most urban locations. For remote sites, 4 hours or more may be necessary to respond and take action.

Battery backup requirements can range from a few minutes to many hours, depending of the system application and customer requirements. Backup of less than one hour is considered to be a high rate of discharge application.

NOTE: Since the battery backup typically will not provide for power to the HVAC system, temperature related shutdown (due to temperature shutdown circuitry in repeaters) **shall** be considered in determining the maximum operational period under backup conditions. In some cases, thermal shutdown can occur well before basic battery exhaustion.

8.8.2.1 HIGH RATE OF DISCHARGE

If the battery plant will be used in a high rate application, or if an existing plant is to be converted to a high rate application, consult the battery manufacturer because this may require batteries specifically designed for high rate applications. High rate plants may require that the size of hardware used to connect the cell into a string be sufficiently large as to accommodate the additional heat generated by high rates of discharge.

8.8.2.2 LONG DURATION BACKUP

Battery backup of many hours may be desired, and can be designed for, but may not always be achievable. Long term outages are caused by loss of AC from the utility company and/or the standby generator. During long term outages, the HVAC (heat, ventilation, and air conditioning) system is also disabled. Depending on the site and the equipment being powered by the batteries, significant thermal rise or fall may occur. If the outage persists long enough, thermal shutdown due to loss of HVAC may be the true limiting factor in backup duration. Given the heat generated by the equipment and a potential range of outside ambient conditions, an HVAC contractor should be consulted to determine the amount of time it will take for the site to reach the high or low limits of the equipment's operating temperature range. For worse-case calculations, battery backup durations exceeding this time are not recommended.

NOTE: Equipment heat generation data for Motorola equipment is furnished in the respective equipment manuals.

8.8.3 BATTERY SIZING

Battery sizing can be straightforward or fairly complex, depending on the characteristics of the load being backed up. Stationary batteries (those used for fixed locations) are rated in Amp-Hours (AH).

An 8-hour duration represents a rated amperage. The amp hour rating of stationary batteries is generally stated as the number of amps a battery can deliver for an 8-hour period. For example, 100 A for 8 hours is a 800 AH battery. If durations of other than 8 hours are desired, a correction factor must be applied. Table 8-1 provides the correction factors for several durations. Note that new batteries do not deliver 100% of their rating. It takes several charge/discharge cycles to bring a battery plant to full capacity. Also, as a battery continues to age its capacity gradually falls to 80% of its initial rating, at which point it is considered to be at end of life. These characteristics should be considered when choosing batteries.

TABLE 8-1 BATTERY RATING CORRECTION FACTORS

1 Hour	2 Hours	4 Hours	6 Hours	8 Hours
1.763	1.378	1.157	1.061	1.0

The DC load for most digital systems can be assumed to be steady-state, as it does not vary (even during busy times). Multiply the load by the back-up duration, and apply the correction factor, if necessary.

For example, given a load of 32 amps and a back-up duration of 4 hours, multiply the load (32) by the duration in hours (4) and the correction factor of 1.157. This means that a battery with at least a 148 amp hour rating will be required for this application.

To calculate battery size, the power required and duration of each change must be known. Graph out the entire discharge profile. Once the discharge profile is graphed, divide the discharge into block based on duration.

8.8.4 BATTERY RATING

Batteries **shall** be accurately sized to ensure they will maintain proper voltage for the required time duration. Use worse-case scenarios with respect to age/deterioration, lowest temperature, expected load, and the availability of alternate power generators.

8.8.5 MULTIPLE BATTERY STRINGS

General practice stipulates that battery types, ratings, and service lengths **shall not** be mixed among a rack. If a site is expanded, then all fresh, similar batteries **shall** be installed and the old batteries removed. A mixture of batteries results in unequal current distribution and charging, and the probability of ongoing power system problems as batteries of different ages fail.

Floor loading, growth, and system load are a few of the factors that determine the number of strings of batteries required. All battery backup systems require maintenance. Some of the maintenance operations require the batteries to be off-line. Since there is no way to predict a short duration power interruption, a minimum of two strings of batteries is strongly recommended. This will ensure some amount of battery backup should an interruption occur during battery maintenance.

Too many strings of batteries also presents a problem. Should a fault occur in one cell in one string of batteries, diagnosing and locating the fault becomes more difficult as the number of strings increases. To protect the battery plant from a catastrophic failure of a single string of batteries, overcurrent protection is necessary for each individual string in the plant. The sizing of this protection should be as follows:

$$\frac{\text{System amp capacity}}{\text{No. of battery strings - 1}} = \text{Required protection}$$

Manufacturer recommendations for the maximum number of strings varies widely. Motorola recommends that the power system be initially designed for a minimum of two strings and a maximum of six strings of batteries when the system is fully implemented. This will allow some margin for excess growth should the system exceed the anticipated load of a fully implemented system.

8.8.6 BATTERY CHARGING

Batteries that have been discharged to a state below full charge must be fully recharged within 24 hours. During this process considerable charging current may flow and flooded cell batteries will give off a higher level of gas than during normal float charge. A float charge must be maintained to keep the battery in a fully charged state. Over or under charging of batteries will cause an increased need for battery maintenance and may greatly shorten the service life of the battery. It is important that the charging system is properly adjusted per the manufacturer's specifications. Overcharging and undercharging alarms **shall** be installed to ensure that battery charging problems are detected quickly.

8.8.7 BATTERY TEMPERATURE REQUIREMENTS

Battery performance and service life are significantly affected by operating temperature. For full-rated performance and maximum service life, the battery temperature should be maintained close to 24° C (75° F). The battery operating time is reduced as the temperature falls; conversely, the operating time is increased as the temperature rises. However, when batteries are subjected to elevated temperatures the service life of the battery is reduced.

Reference temperature is often overlooked in rating batteries. Battery manufacturers typically use 22.2° C (72° F) as the reference temperature. A battery operated at 0° C (32° F) produces 30% capacity, but lasts for 130% or more of the rated life. Conversely, a battery operated at 38° C (100° F) produces 130% battery capacity, but may last less than 1 year.

NOTE: If codes do not allow batteries within the same compartment as the climatized radio equipment enclosure, outdoor battery pedestals may have to be protected from direct sunlight or elevated to prevent their burial in snow during winter (where applicable).

8.8.8 BATTERY SAFETY

WARNING

Battery manufacturer warning statements shall be understood and complied with. The manufacturer's statements shall determine the type and extent of Personal Protective Equipment required in minimizing battery handling hazards for the batteries being installed.

At all sites using wet cell batteries, or gel-cell batteries where manufacturer specifies eyewash or other Personal Protective Equipment, such equipment shall be provided in the battery containment area.

NOTE: This section mostly discusses conditions associated with wet cell batteries (which typically require the most stringent handling and safety precautions). In all cases, manufacturer's documentation **shall** be read and understood before installing or maintaining battery systems.

Observe the following general considerations regarding battery installation and maintenance:

- Because of the chemical composition, weight, and bulk of many battery configurations, certified transporters and hazardous materials handlers may be required.
- Batteries **shall** have insulated covers and/or insulated terminal protectors. Batteries **shall not** be used as a work surface.
- Batteries **shall** be covered when work is in progress overhead.
- Seismic racks **shall** be used for seismically active locations (Moment Magnitude rating 3 or greater), and **shall** be bolted to floors and grounded.
- The US Federal Clean Water Act, with local option by location, does not allow battery acid spills, which are neutralized, to be flushed down the drain or spilled on soil. Some locations have no such restrictions.

Where required by OSHA or applicable local codes, the following equipment **shall** be supplied:

- A lightweight, acid resistant bib type apron **shall** be permanently stored on site near the battery plant. The fabric **shall** be acid, caustic, puncture resistant, and meet Federal Standard 5903.2-191 for flame resistance.
- An acid resistant, full face shield, **shall** be permanently stored on site near the battery plant. The shield **shall** meet all requirements of ANSI Z87.1. Protective eye wear that does not provide full face protection is not allowed.
- One pair of acid resistant gloves **shall** be permanently stored on site near the battery plant. These gloves **shall** be of sufficient length to cover the hand, wrist, and forearm for protection from chemical splash.

- One 0.5 kg (1 lb.) box of baking soda or equivalent acid neutralizing compound **shall** be permanently stored on site near the battery plant. Water is required to mix with the baking soda.
- (See Figure 8-12.) An emergency eyewash station **shall** be permanently mounted near the battery plant. The eyewash station **shall** use an isotonic saline wash capable of neutralizing acids or caustics and **shall** be able to flush the eye for 15 minutes. A plumbed eyewash station and a shower should be provided in battery areas if possible.

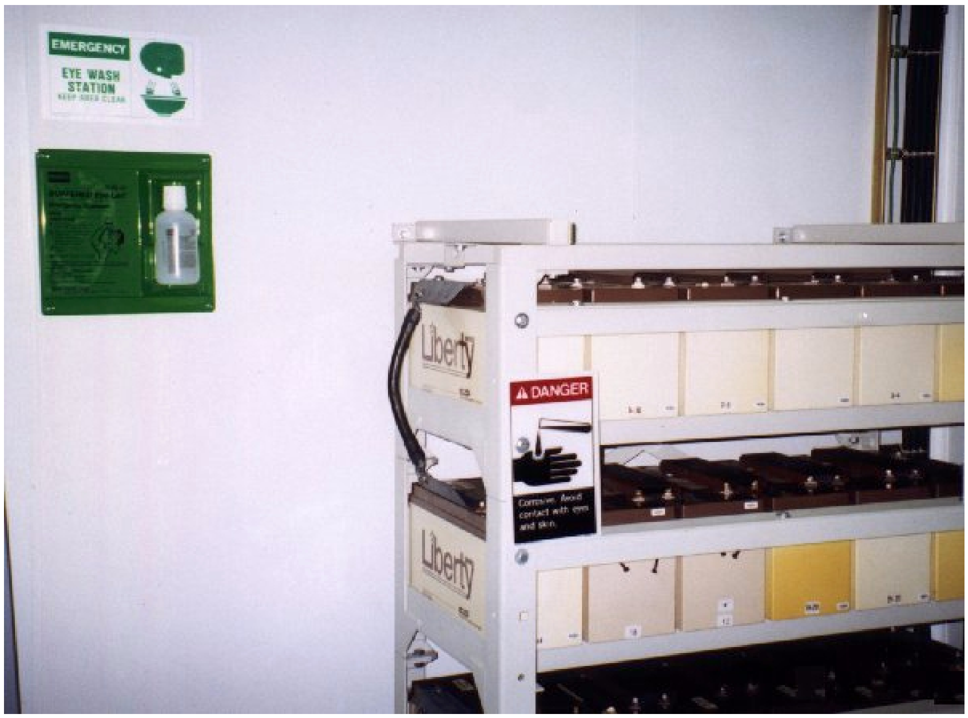


FIGURE 8-12 TYPICAL BATTERY SAFETY EQUIPMENT

When specified by OSHA and/or applicable local codes, the following requirements **shall** be observed at all sites where batteries are part of the installation:

- Provisions **shall** be made to exhaust gases produced by wet cell batteries. For wet cell batteries the manufacturer-specified stationary battery flame-arresting vent **shall** be installed on each cell. This vent **shall** be secure, clean, and in good repair to help ensure maximum protection against potential explosion. Sealed batteries do not have an opening for adding electrolyte; however, there is generally a small vent hole that opens as required to vent internal gasses. There are two methods which may be used to vent battery gasses. One method is to use an exhaust fan on a timer, changing the total room air four times per hour. The other method is to use a manifold system that consists of tubing connected to each cell and vented to the outside.

NOTE: In most cases, sealed batteries do not require venting. Check local codes for applicability. Also check the labels on the batteries for the proper protection based on that particular type of battery.

- "NO SMOKING" signs **shall** be prominently displayed in the battery room and on the exterior of the battery room entry door. Smoking, or the source of any spark producing materials, **shall** be strictly prohibited in this area.
- Wet cell batteries should always be maintained in the upright position. Care **shall** be taken to help ensure batteries are not tilted during installation.
- Insulated tools **shall** be used when working around batteries to minimize the potential for an accidental short circuit.
- Sealed batteries may crack or develop a leak. It is desirable that a spill containment system be installed under the batteries to contain and neutralize any acid that may leak.
- Batteries **shall** be kept clean to reduce short circuit hazards, rack corrosion and the possibility of electrical shock.

CAUTION

Batteries should be cleaned with clear water. Do not use abrasive cleaners, detergents or petroleum-based cleaning products on battery container.

- Battery banks consisting of multiple cells with circuit protection greater than 20 amperes **shall** have 1 cm (1/2 in.) or greater thickness Lexan or hard rubber protective shield installed on a support frame and securely mounted in front of the battery rack to protect personnel should there be a violent structural failure of any cell(s). This protective shield **shall** extend from 7.6 cm (3 in.) above to 7.6 cm (3 in.) below the height of the cells being protected.
- When batteries are located in an area that is accessible to persons other than qualified system maintenance personnel, an additional protective shield as described above **shall** be installed to cover the top of all cells and battery circuit conductors to prevent conductive materials from contacting battery posts or circuit conductors on top of the cells.
- At sites where batteries constructed with bolt-on terminal connections are used, the following items are required:
  - Connector bolt wrench (nonconductive)
  - Lifting sling and spreader block if applicable
- At all sites using wet cell batteries, the following items are required:
  - OSHA-approved emergency eyewash kit (A plumbed eyewash station and a shower should be provided in battery areas if possible.)
  - Rubber gloves, apron, and face shield
  - Container of baking soda to neutralize spilled acid
  - Container of water to mix with baking soda
  - Container of non-oxidation material for coating electrical connections

- At sites with flooded lead-acid batteries, the following items are required:
  - Hydrometer with markings every 10 points
  - Acid-resistant container for storing the hydrometer
  - Thermometer, Battery

8.8.9 BATTERY INSTALLATION

Figure 8-13 shows a typical battery room and installation. Personal protective equipment, as dictated by battery manufacturer warning statements, **shall** be available within the battery area. A plumbed eyewash station and emergency shower should be provided if possible.

WARNING

To avoid spilling acid, do not tip batteries.

Battery acid can cause severe burns and blindness if it comes into contact with skin or eyes. Wash affected skin or eyes immediately with running water. Seek medical attention immediately.

No jewelry shall be worn while working on batteries.

Installation personnel shall wear necessary safety equipment when installing batteries.

Batteries may require a two-person lift. Use proper lifting techniques and equipment to avoid injury.

Insulated tools shall be used when installing battery systems.

Battery installation **shall** conform to manufacturers specifications, the National Electrical Code (or equivalent), and all applicable national, state, and local codes. Observe the following cautions when installing batteries:

- When installing wet cell batteries, do not to tilt the cells.
- Do not slide or drag batteries.
- Because of size, weight, and service needs, batteries are normally installed on shelves or racks. In earthquake-prone areas (Moment Magnitude rating 3 or greater), however, seismic racks **shall** be used. Seismic racks **shall** be properly secured to the floor or wall, but **shall not** be secured to both. Seismic racks **shall** be installed exactly as specified by the rack manufacturer.

CAUTION

For areas with seismic rating of Moment Magnitude rating 3 or greater, appropriate rack design shall be used. Follow manufacturer's installation requirements.

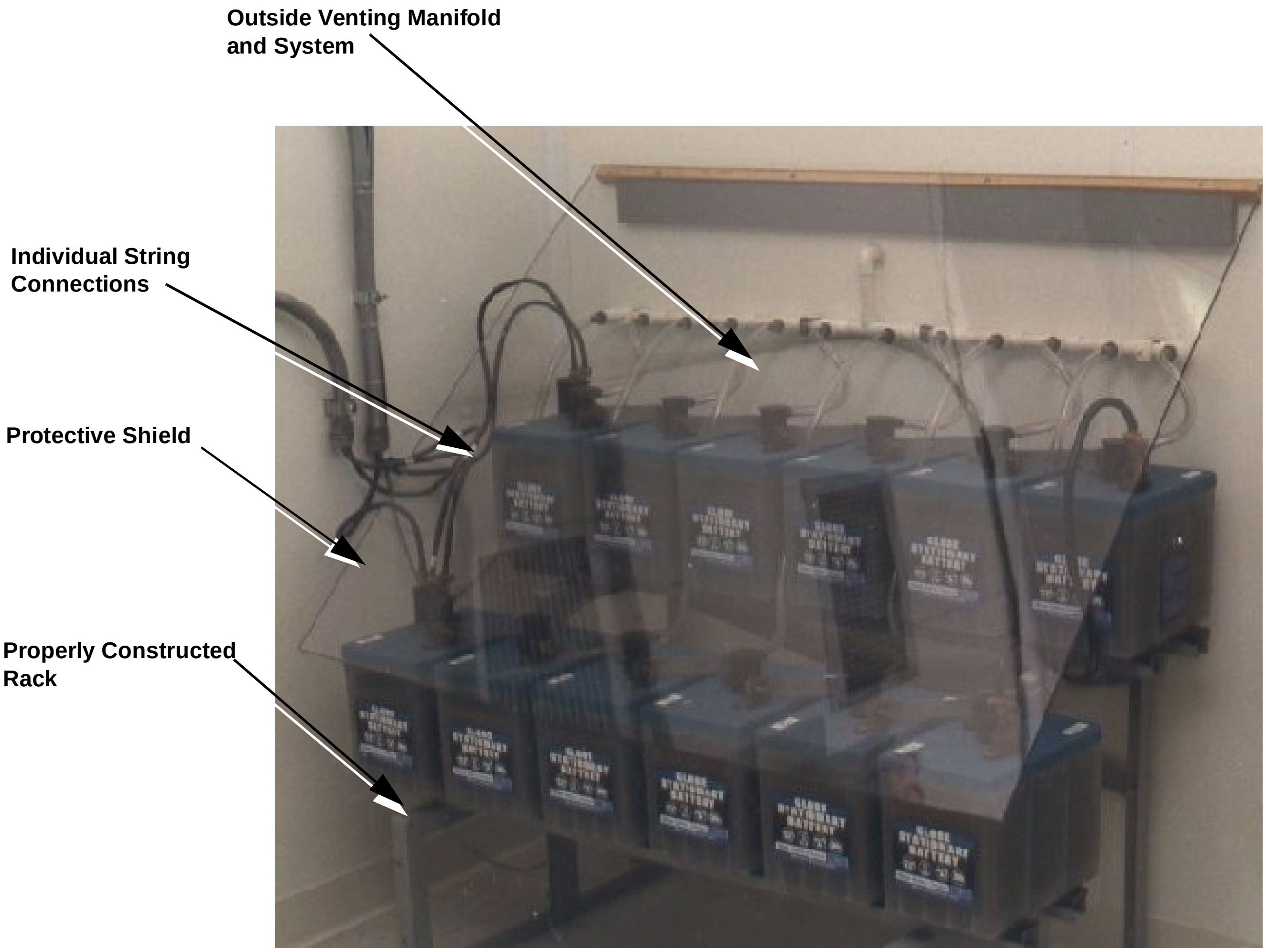


FIGURE 8-13 TYPICAL WET CELL BATTERY INSTALLATION

- Racks and shelves **shall** be constructed to support the total weight of the batteries and other supporting equipment placed on them. Racks and shelves **shall** be assembled in accordance with the manufacturers specifications.
- Battery racks **shall** be bolted to the floor or wall.
- The batteries **shall** be prevented from falling due to accidental movement by installing a rim to prevent tipping, or by interconnecting batteries to prevent movement.
- Metal racks **shall** be grounded in accordance with specifications provided in Chapter 7, "Internal Grounding."
- Perform calculations to ensure that the floor area will support the total weight of the rack and the batteries. Refer to "Floor Loading" on page 5-13.
- All terminal connections **shall** be tightened to manufacturers' specifications.

- A non-sparking circuit breaker of suitable size to handle maximum load and charging currents **shall** be installed in the ungrounded leg of the circuit to provide overcurrent protection. The ampacity of the circuit breaker **shall not** be greater than the ampacity rating of the circuit conductor. This device may also serve to disconnect the load during battery servicing.
- Circuit conductors, including jumpers between several cells, **shall** be jacketed copper of at least the minimum AWG size permitted for the maximum DC load. Conductor size may need to be larger than that specified to minimize voltage drop between the batteries and the equipment.
- DC conductor jacket colors shall be red (floating or ungrounded) and black (grounded). Red and black tape may be applied at each connection, splice or pull box if red and black conductors are not available. These requirements may vary by vendor product.
- Conductors **shall** be enclosed in PVC or metallic conduit or raceway for protection from physical damage and **shall not** be exposed except near terminations.
- Any additional disconnect switches **shall** have an ampacity rating equal to or greater than the circuit protection device.
- Battery terminals **shall** be protectively coated in accordance with manufacturer's specifications.
- Exposed battery terminals should be protected from accidentally contacting metal objects.
- Stationary lead acid batteries **shall** be equipped with an approved spill containment system to prevent damage caused by spilled battery electrolyte whenever electrolyte capacity is greater than 4.8 liters (1 gallon). A typical spill containment system is shown in Figure 8-14 on page 8-37. (NFPA 70, Article 480, BOCA 307.8.13, Universal Building Code Article 304.8.) The spill containment system **shall** comprise a passive and active neutralization system.

FIGURE 8-14 TYPICAL BATTERY SPILL CONTAINMENT SYSTEM

8.8.10 BATTERY MAINTENANCE DISCONNECT

At some time it will be necessary to perform off-line maintenance on the batteries. An individual disconnect **shall** be supplied for each string of batteries for isolating a string from the rest of the system to safely perform battery maintenance. The disconnect device **shall** be such as to prevent arcing upon circuit make/break, and prevent any exposed live conductors.

8.9 STANDBY GENERATOR SYSTEMS

NOTE: The expected need of having a site supplied with a standby generator should be balanced against the economy of including a generator at the site. It is most likely cost-prohibitive to provide standby generators for large systems utilizing many sites. Typically, only difficult to access or remote location sites are to be equipped with standby generator power. An "Appleton"-type power connector can be installed at sites not equipped with a generator. In these cases, a portable generator can be conveniently connected to the site if needed.

This section describes requirements for backup/standby generators. The purpose of a backup or standby generator is to supply reliable power to critical loads during times when commercial power has failed. It is very important that generators used for this purpose be capable of reliably handling the required loads for the desired time while maintaining proper voltage and frequency. Backup/standby generators are **not** required to be installed to the same standards as emergency generators. The standards included in this section do not apply to emergency generators or power systems. Emergency power systems are required to comply with NFPA 70, Article 700. Therefore, it is recommended to know and understand the difference between back-up/standby generator and emergency generator systems before procuring a generator equipment or installation work.

NOTE: There are certain locations where commercial power is not available and generators must be used for primary power. Primary power generators or generating systems **shall** be rated for continuous duty and **shall**, at a minimum, be installed to the standards covered in this section. All domestic installations **shall** meet National Electrical Code (NEC), National Fire Protection Association (NFPA) and any other local governing codes applicable to continuous duty, primary power generators. Installations performed in non-domestic locations **shall** meet all applicable national and local codes.

A generator system includes the generator, along with a cooling system, a fuel supply system, a transfer switch, and a control panel with required alarms. Liquid fueled generators may incorporate the fuel tank into one housing, such as a base mounted tank. The transfer switch and control panel may also be incorporated into one cabinet. The generator may be placed outside as a stand-alone piece of equipment or inside a building or structure. The location may depend on several factors that include generator size, fuel supply, noise restrictions and space availability. Note also that local codes can additionally dictate the fuel type allowed.

8.9.1 GENERATOR OUTPUT AND DERATING CONSIDERATIONS

To ensure that the backup generator can handle the power requirements of the equipment at the site, always consider the following factors when calculating generator output power requirements:

- Voltage, phase, and load requirements of the equipment to be supplied by the generator must be obtained, including unusual loads such as UPS power supplies and switched power supplies. The customer or an electrical engineer may specify these values.
- Consider site expansion. A 30% expansion factor is not unreasonable.
- Consider worse-case scenarios for generator load, such as all transmitters keyed simultaneously at a trunking site.
- Consider whether the generator load will be 3-phase or single-phase. Many generators are rated for operation with a 3-phase load and must be derated when working with a single-phase load. If the load is single phase, be certain that the generator is capable of supporting the maximum load while connected in a single-phase configuration. When balancing the single phase loads across three phases, always account for transmitter current.
- Consider physical requirements of the site. Generators may be derated based on operating altitude, type of fuel, and operating temperatures.
- The generator **shall not** be used under conditions that could exceed the manufacturer's specifications for the particular generator equipment.

8.9.2 GENERATOR PLACEMENT

All generators **shall** have an adequate supply of fresh air to ensure proper operation and extend life. Air is required for safe and efficient combustion as well as to cool the engine and generator. The type of engine cooling is determined by the capacity of the generator. Most generators above 7.5 kW utilize water-cooled engines; generators below 7.5 kW typically use air-cooled engines. The rate of airflow required for cooling is specified by the manufacturer. Manufacturer's guidelines **shall** be followed to ensure proper operation.

NOTE: The type of fuel used for a generator dictates the elevation of the fuel tank relative to the generator. A liquid-fuel generator (diesel or gasoline) will require that the fuel tank be upgrade from the generator fuel inlet such that the generator remains primed. Conversely, because gases rise, an LPG or natural-gas powered generator **shall** be placed upgrade from the fuel source outlet port.

8.9.2.1 GENERATORS LOCATED INDOORS

If the generator is to be located inside a separate structure or within the site building, the following requirements **shall** be met:

- Personnel safety and vulnerability of the generator to damage **shall** be considered, especially if the generator is to be installed without a protective housing. Moving engine parts and the exhaust system may be exposed, which could pose a hazard. Guards or shields **shall** be installed on exposed engine parts that could pose a safety hazard to personnel.
- The generator **shall** be located in an area accessible only by authorized personnel.
- Provide adequate spacing for service to the generator in accordance with NFPA 70 and state and local codes (or equivalent). Generally, a minimum spacing of 92 cm (3 ft.) on three sides is acceptable.
- Manufacturer's specifications **shall** be followed to ensure proper ventilation, fuel supply, and engine exhaust.
- Properly sized air intake and exhaust ports **shall** be installed and maintained. The exhaust air from the radiator area of the generator in most cases is ducted to the outside.
- A louver or shutter should be installed on the exterior of the duct to close off the duct when the generator is not running.
- A motorized louver or shutter should be installed on the air intake to close off the duct when not in use. The shutter should open automatically when the generator begins operating.
- (See Figure 8-18.) The concrete foundation for the generator should be separate from that of the general structure. An inset sub-foundation set within a well in the overall foundation will help isolate transmitted vibration and noise emanating from the generator.
- Ensure that there is an adequate fresh air supply. Should the fresh air supply not be adequate, air will be drawn through doors, or possibly through existing vent pipes, causing a down draft of these vents. This could draw undesirable or potentially harmful fumes or gases back into the room or building. This could be a major concern in manned buildings. Check local codes for recommendations and guidance in this area.
- Fuel supply lines **shall** be no smaller in diameter or of greater length than the minimum specified by the manufacturer. These lines should be routed and installed such that they are protected from potential damage.
- The engine exhaust system pipe and muffler **shall** be no smaller in diameter or of greater length than that specified by the manufacturer.
- Depending on the size of the generator, hearing protection and warning signs may be appropriate.

8.9.2.2 GENERATORS LOCATED OUTDOORS

If the generator is to be located outdoors, the following requirements **shall** be met:

- The generator **shall** be enclosed in a housing sufficiently rugged to protect against weather, animal/insect ingress, and tampering. This is especially important for the radiator and fuel tank.
- The generator **shall** be enclosed within a fenced area, with adequate distance between the fence and the equipment for servicing.
- A muffler **shall** be used to minimize noise. If the generator is installed near other buildings, a muffler suitable for use in residential areas **shall** be used.
- The engine exhaust **shall** be equipped with a rain cap.
- Locate the generator such that wind will not likely carry dust and moisture into the housing nor exhaust gases into the building.
- Locate the generator such that required ventilation may be achieved. Most generators exhaust air outward through the radiator.
- In colder climates other considerations apply. An engine block heater may be required to keep the engine oil usable.
- Grade relative to fuel source/fuel inlet **shall** be appropriately considered.

8.9.3 FUEL SUPPLY

Generators may be operated from diesel, liquid propane or gaseous (propane or natural gas) fuels. Domestically, state and local codes **shall** be observed since different areas of the country have unique requirements. Fueling requirements in non-domestic locations **shall** meet all applicable national and local codes.

When selecting a generator, determine the standard fuel source for the area and use it whenever possible to ensure that an adequate fuel supply is available. Where available, utility-provided natural gas provides the most reliable fuel source and releases the installation from concerns regarding fuel tanks.

In general, the following fueling considerations **shall** be observed:

- LPG is considered the best all-around backup generator fuel. If possible, an LPG-configured generator should be considered.
- Diesel and gaseous propane are not well-suited for cold climates. Special care needs to be taken if used.
- If natural gas is used, the generator output power will typically be reduced by 20%, as compared to gasoline. Generator output needs to be derated accordingly in these cases.
- Liquid fuel storage tanks **shall** be equipped with secondary containment capable of retaining 110% (or greater) of the maximum volume of fuel stored.
- The storage tank secondary containment **shall** be designed such that storm water and debris cannot collect inside it.
- All fuel lines or other system components that extend beyond the storage tank secondary containment area **shall** be designed with secondary containment.

- Local Environmental Protection Agency (EPA) rules **shall** be adhered to following a fuel spill. All fuel spills **shall** be cleaned up.
- In areas where the noise levels exceed 85 dBA, hearing protection **shall** be provided.
- Fuel storage tanks are required for all fuels except natural gas, which is provided by a utility. (However, a storage tank in conjunction with utility-provided natural gas provides additional backup in the case of gas main breakage.) Manufacturer specifications as to size and length of fuel supply lines as well as lift **shall** be followed.
- Fuel storage tanks located outside of a structure should be protected from damage and tampering, and **shall** be enclosed within a fenced area. In many areas local codes require a double wall construction for the tank or a catch basin to prevent fuel from contaminating the site. Minimum recommended distance between the storage tank and fence is 1.22 m (4 ft.); minimum recommended distance between the tank and site building is 3.05 m (10 ft.).
- Fuel storage tanks **shall** be secured to concrete pads using captive hardware.
- LPG fuel tanks **shall** utilize a fuel vent pressure relief valve. The relief valve vent **shall** be directed away from the tank, sources of ignition, and flammable material.
- Fuel lines **shall** be protected within the fuel storage area as well as along the route to the generator. Location and installation of the fuel tank and fuel lines **shall** meet all applicable environmental, building, and fire safety codes.
- All generator installations **shall** be equipped with secondary containment capable of retaining 110% of the volume of the largest tank within the containment structure, if the tanks system is a single-wall system. Alternatively, if the tank system is a double-walled system, the system **shall** be designed with interstitial monitoring devices that is capable of detecting a leak in the primary or secondary containment system unless tertiary containment is provided (for example, a convault or equivalent). Special tanks (double wall or fiberglass) and containment barriers are strongly recommended. Earthquake prone areas may require special fuel line considerations. Local codes and manufacturer's recommendations **shall** be followed.
- In potential flood zones, above ground fuel tanks should be secured with a safety cable around the tank attached to an anchoring device in the soil. This helps prevent the tank from breaking loose and floating away during a flood condition.
- Diesel is no longer allowed for new generator systems on US Federal lands due to ground contamination concerns.
- Natural gas-powered installations require a reservoir tank in addition to the supply line. If the supply line is severed, then the generator immediately stops.
- Gasoline is a poor fuel for remote generators, with a limited storage life and highly flammable properties. Gasoline generators also have difficulty with remote starting.

- Diesel requires regular anti-bacterial treatment and water drainage. Diesel must be replaced with fresh fuel periodically.
- Critical placement and orientation of the tank pressure relief valve is required. This is required, in the case of a fire, to prevent an over-pressure gas release cloud from feeding its own fire.

8.9.4 TRANSFER SWITCH

A transfer switch (Figure 8-15) **shall** be installed to perform the switching between commercial power and standby power. This switch is generally collocated with the site electrical service panel. In general, the following considerations need to be observed:

- The switch **shall** have an ampere rating equal to or greater than the ampere rating of the circuits to be transferred.
- The transfer switch is generally located inside a building; however, if the transfer switch is enclosed in an approved watertight housing it may be located outside.
- Many areas require a disconnect switch in the feeder cabling between the generator and the transfer switch. This facilitates generator servicing and provides an additional safety device to prevent AC power backfeed into the commercial service.
- For domestic sites, installation of the transfer switch **shall** follow the manufacturer's recommended installation guidelines as well as meet all applicable NFPA 70, national, state and local codes. Installations performed in non-domestic locations **shall** meet manufacturer's recommended installation guidelines, as well as all applicable national and local codes.
- Surge suppression **shall** be installed. See Chapter 9, "Transient Voltage Surge Suppression," for additional information.

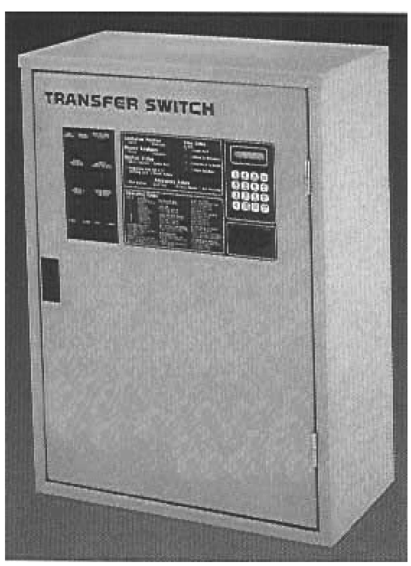


FIGURE 8-15 TYPICAL TRANSFER SWITCH

8.9.5 ELECTRICAL WIRING CONSIDERATIONS

When designing the interconnection wiring between the generator, transfer switch, and site AC mains, the following considerations **shall** be observed:

- There **shall** be two sets of circuit conductors run between the transfer switch and the generator. One set **shall** be for low voltage control/alarm circuits and the second set for the electrical service. Each set **shall** be installed within its own dedicated conduit/raceway.
- The control/alarm circuits **shall** never be installed within the same conduit or raceway as the electrical service.
- Conduits/raceways **shall** be sized and routed per the NFPA 70 code (or equivalent in non-domestic installations) and any other applicable national or local codes.
- A dedicated protected electrical circuit **shall** be provided at the generator for engine/battery heaters and service equipment. If located outside, this circuit **shall** have ground fault protection.

8.9.6 INSTALLATION PLAN

Standby generator system installations **shall** be carefully planned and properly installed to ensure proper operation for extended periods. All requirements for the proper location of the generator, properly sized and positioned vents for the required airflow, fuel storage or supply, exhaust system placement and electrical connections **shall** be reviewed by a qualified engineer or inspector to ensure compliance with applicable NFPA 70, national, state and local codes. In general, the following considerations need to be observed:

- Care **shall** be taken to ensure that exhaust gas discharged from the exhaust system **shall** disperse into the open atmosphere and will not be blown or drawn into the building interior. Proper precautions **shall** be taken when generators are installed within or in close proximity to occupied structures.
- Foundation size **shall** be determined based on the geographic area where the system is being installed.
- Door sizes, as existing in the finished structure, **shall** be considered to allow removal/replacement of the largest generator subassembly from within the structure.
- Rain hoods over intake and exhausting vents **shall** be designed to accommodate local extreme environments. Where the potential of high snowfall or drifting is possible, the vent hood **shall** be placed at an appropriate level and directed away from the elements.

NOTE: On radiator cooled generators, cooling air inlet **shall** be at least 1½ times larger than radiator duct receptacle area. Flow of cooling air and heated air should be controlled by automatically operated louvers.

- Earthquake prone areas (Moment Magnitude rating 3 or greater) may require special design and installation features, especially in the area of fuel lines, fuel storage, exhaust system and muffler supports. Appropriate geological information should be consulted regarding seismic considerations.
- For indoor installations, ensure that maximum floor loading will not be exceeded. Shock mounts are recommended and may be required on some installations to minimize vibration transfer.
- Batteries not required for operation of the generator **shall not** be located within a room containing a generator unless the room is properly ventilated.
- Manufacturer's guidelines and specifications to ensure proper air exchange for the generator room **shall** be followed.

8.9.7 ALARMS, METERS AND GAUGES

NOTE: Consideration **shall** be given to assure that remote alarm reporting systems are independent of the power systems they monitor. The reporting system **shall** be such that if the phone line breaks, the primary power source fails, or the common battery bank depletes, then alarms will still be transported.

All generators **shall** be equipped with an engine high temperature alarm/shutdown and low oil pressure alarm/shutdown.

All generators **shall** be equipped with an oil pressure gauge.

Frequency, Voltage and Amp meters are also recommended and should be installed either at the generator control panel or at the transfer switch. Figure 8-16 shows a typical generator control/instrument panel.

FIGURE 8-16 TYPICAL GENERATOR CONTROL/INSTRUMENT PANEL

Additional meter, gauge, remote alarm, engine and battery heater options and needs **shall** be considered. These alarms, if monitored, can provide an early warning to impending problems, thereby reducing cost and down time significantly.

8.9.8 GENERATOR INSTALLATION GROUNDING

All generators, fuel storage tanks above or at grade level, and fences discussed within this chapter **shall** be grounded as described below.

8.9.8.1 INDOOR GENERATOR GROUNDING

Generator systems located indoors **shall** be bonded to the internal grounding system as follows:

- Using the intended chassis grounding connection on the generator, the generator **shall** be bonded to the internal Master Ground Bus Bar or internal perimeter grounding bus in accordance with methods specified in Chapter 7, “Internal Grounding.”
- A transfer switch (if not part of the generator unit) **shall** be bonded to the interior Master Ground Bus Bar in accordance with methods specified in Chapter 7, “Internal Grounding.”

8.9.8.2 OUTDOOR GENERATOR GROUNDING

Generator systems located outdoors **shall** be bonded to the external grounding system as follows:

- Using the intended chassis grounding connection on the generator, the generator **shall** be bonded to the external site Ground Ring in accordance with methods specified in Chapter 6, "External Grounding."
- If a metallic fuel tank is utilized, the fuel tank **shall** be bonded to the external site Ground Ring in accordance with methods specified in Chapter 6, "External Grounding."
- Metallic fencing surrounding the generator installation **shall** be bonded to the external site Ground Ring in accordance with methods specified in Chapter 6, "External Grounding."
- A transfer switch (if not part of the generator unit) is typically installed in the site building or shelter and collocated with the site electrical service panel. In this case, the transfer switch **shall** be bonded to the interior Master Ground Bus Bar in accordance with methods specified in Chapter 7, "Internal Grounding."

Figure 8-17 shows typical generator chassis grounding. Note the ground wire from the generator chassis to the ground system. Also note proper attachment of the ground conductor to the conduit containing the ground conductor.

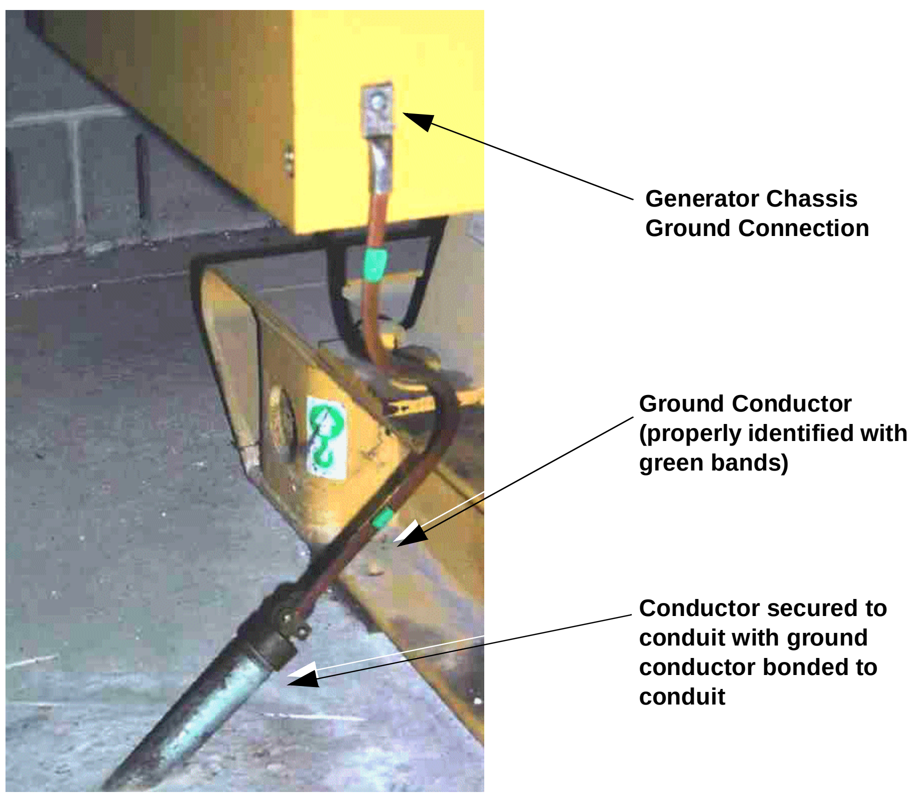


FIGURE 8-17 TYPICAL GENERATOR GROUNDING

8.9.9 GENERATOR INSTALLATION

The generator system **shall** be installed using all manufacturer's recommended installation practices. Figure 8-18 shows a typical installation. In general, observe the following considerations:

- In outdoor installations all foundations **shall** be of proper size to support the load (check local codes for special considerations).
- The generator, fuel tank(s), transfer switch/control panel and all associated components **shall** be securely fastened to the intended foundations.
- Fuel lines **shall** be adequately secured, protected and free of leaks.
- All parts of the system **shall** be installed in such a manner that it **shall** be easily serviceable without undue safety risk while the equipment is operational.
- Installations in earthquake prone areas (Moment Magnitude rating 3 or greater) may require additional fuel, exhaust system and muffler supports. Manufacturer recommendations and local codes **shall** be followed in these areas.
- In earthquake prone areas (Moment Magnitude rating 3 or greater), it is recommended that standby generators be installed on vibration isolators, with flexible cables used for electrical and grounding, and flexible tubing be provided for fuel systems.

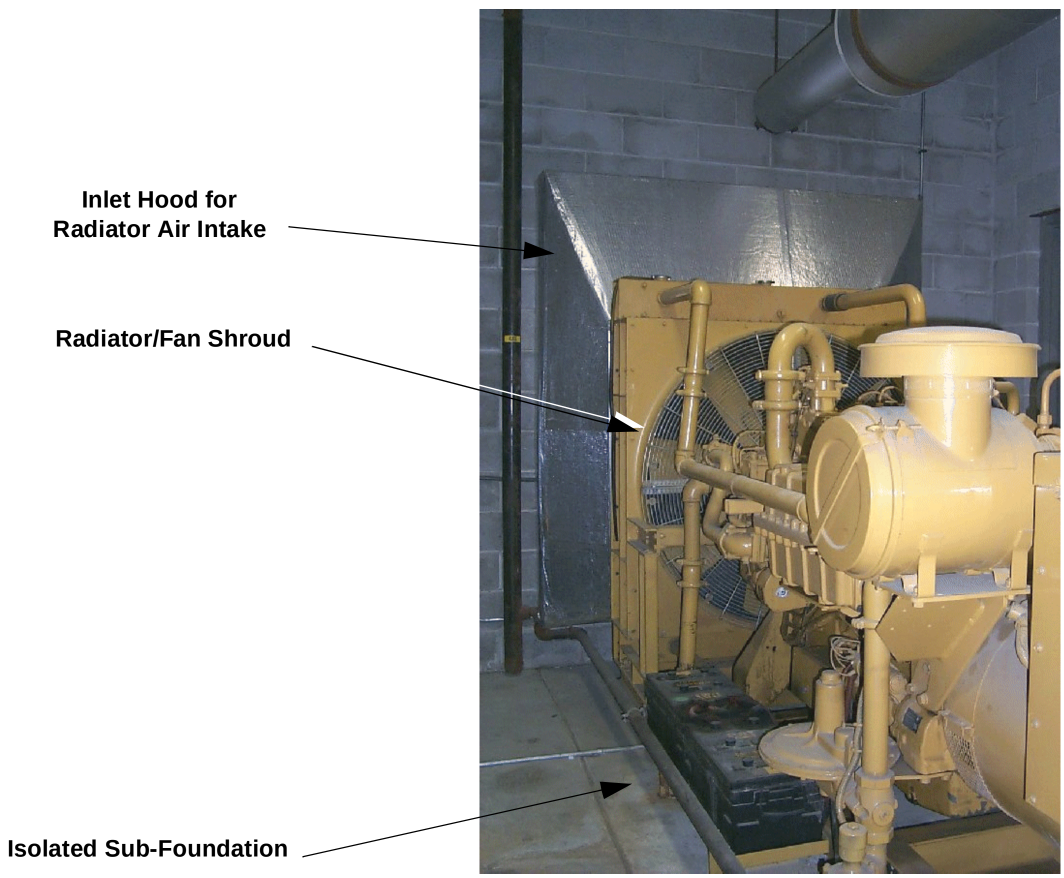


FIGURE 8-18 COMPLETED INSTALLATION OF TYPICAL GENERATOR SYSTEM

8.9.10 GENERATOR START UP

Most generators ship without oil and coolant. Many times fuel lines are not connected. An authorized manufacturer's service representative should be used to review the installation, prepare and start the generator. Observe the following considerations:

- All fluid levels **shall** be checked to ensure adequate supply prior to actual startup.
- The generator **shall** be checked for proper voltage and frequency while operating with and without load. These **shall** be within manufacturer's specifications or no greater than a 3% variation from rated voltages and 5% overall variation from specified frequency.
- Setting of all controls within the transfer switch/control panel **shall** be verified and checked to ensure proper load pickup, transfer, re-transfer and shut down.
- The charge rate of the battery charger should be checked.
- The exercise clock should be set and proper operation should be verified. The exercise clock **shall** be set to exercise the generator at a minimum of 30 minutes every 7 days. It is strongly recommended to exercise the generator under full load.
- All alarm connections **shall** be verified and functions tested.
- The fuel system and exhaust system **shall** be checked to ensure there are no leaks.
- Check to ensure that all safety shields and covers are in place.
- If a UPS system is employed in this configuration, tests should be conducted to ensure the UPS functions properly when being fed by the generator. If a problem occurs, frequency and voltage tolerances may need to be reviewed.

8.9.11 GENERATOR SAFETY

In general, the following safety considerations need to be observed:

- All moving parts **shall** be enclosed or protected.
- Safety shields and covers **shall** be in place except as necessary for service.
- Hot surfaces such as engine exhaust pipes and mufflers **shall** be protected to ensure that there is no accidental contact by foreign material or persons.
- "No Smoking," "Caution: Hearing Protection Required," and "automatic equipment may self-start" signs **shall** be posted within a generator room or adjacent to a generator which is located in a room with other equipment.
- Points where exhaust system components pass through walls **shall** have approved feed through thimbles installed.
- Fuel lines **shall** be protected from accidental damage.
- Electrical circuits **shall not** be exposed.
- Ensure that exhaust gases disperse and are not drawn back into the interior of the building.
- All manufacturer's safety guidelines **shall** be followed during installation and operation.
- Ensure that generators installed in earthquake prone areas meet all safety requirements for an installation in that area.

CHAPTER 9

TRANSIENT VOLTAGE SURGE SUPPRESSION

This chapter discusses the following topics:

9.1 INTRODUCTION

The installation of Transient Voltage Surge Suppression (TVSS) devices is a requirement for all communication sites and is essential for all facilities where communication-related electronics and electrical equipment is in use. Surges and transient power anomalies are potentially destructive electrical disturbances, the most damaging being over-voltage occurrences and short duration over-voltage events. Sometimes referred to as "spikes", high-energy transient power anomalies can arise from inductive load switching or other events within the power system or capacitive and inductive coupling from environmental events such as nearby lightning activity. Environmental and inductive power anomalies are wideband occurrences with a frequency range from close to DC to well into the RF high frequency spectrum. It is critical that each point-of-entry (AC, telephone, LAN, signal/control and RF) into the equipment area be protected against these anomalies. This protection is essential to reduce the risk of personal injury, physical equipment damage, and loss of operations (equipment down time). Although lightning can cause the most visible damage, it is not the predominant cause of transient voltages.

Transient voltage sources include, but are not limited to the following:

- Power company switching
- Generator transfer
- Shared commercial feeders with poor line regulation
- Load switching
- Fault currents
- HVAC units
- Heating elements
- Power tools
- Electric motors
- Fluorescent lights
- Elevators
- Switching of inductive loads
- Lightning activity

There are four major site entrances for surges that require individual attention in order to effectively protect a site and reduce the probability of damage.

- AC Power
  - Main service
  - External branch circuits or feeders
  - Generator
- Telephone/Data
  - Data circuits
  - LAN
  - Control
  - Security and card access
  - CCTV
- RF Cabling
  - Antenna transmit and receive lines
  - Cable TV service
- Tower Lighting Systems

Effective grounding or earthing alone will not protect a communications facility from damage due to surges, transients, and lightning. However, an effective combination of facility grounding, equipment bonding, and properly installed Surge Protection Devices (SPDs) on all circuit conductors entering the equipment area can significantly help maximize total site protection.

NOTE: The term 'SPD' is used interchangeably with TVSS. IEEE C62.41 and UL defines TVSS as an SPD.

Figure 9-1 on page 9-4 shows the minimum SPD installation complement for a typical communications facility.

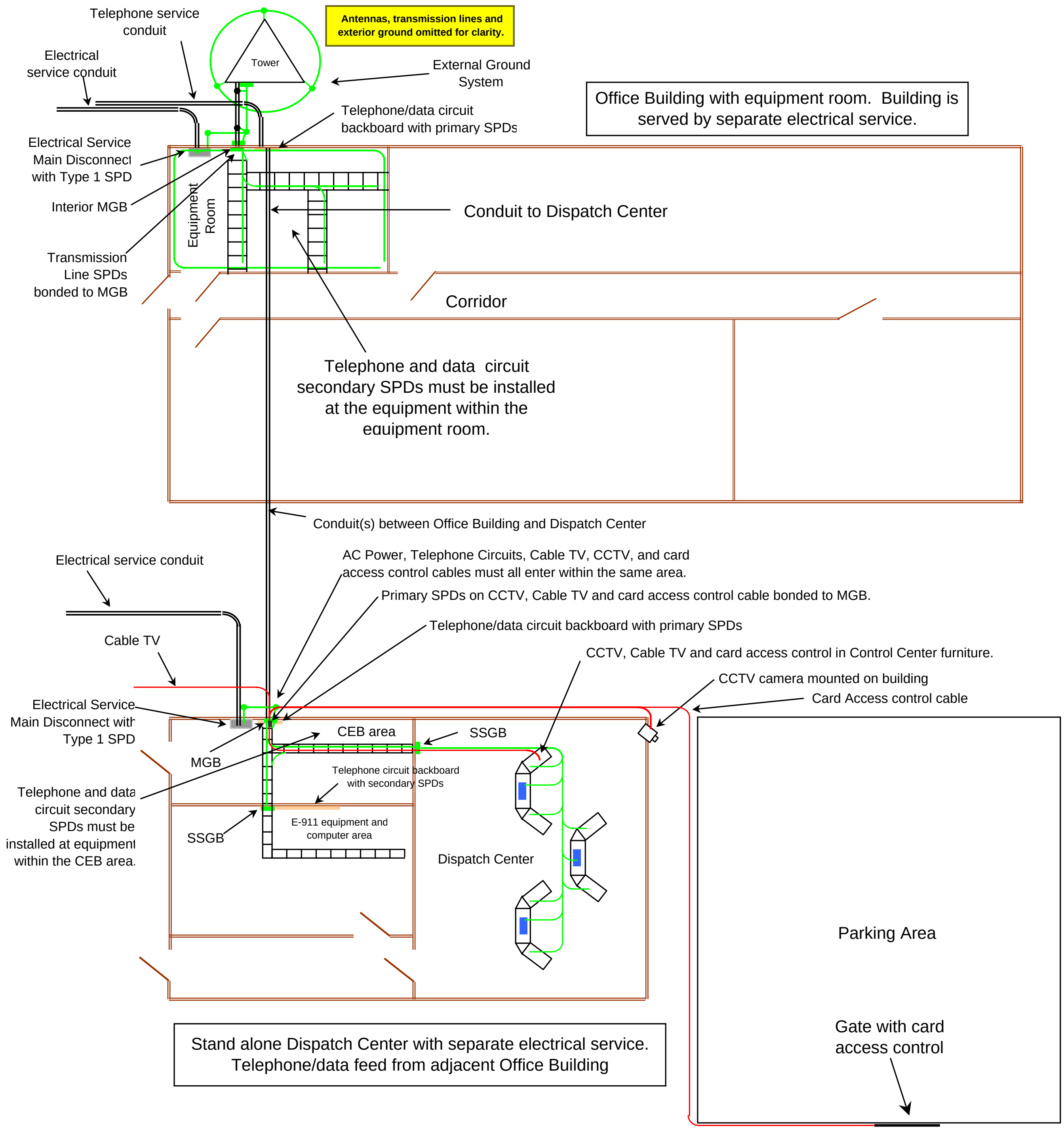


FIGURE 9-1 MINIMUM REQUIRED SPD FOR TYPICAL INSTALLATION

The requirements presented in this chapter will provide a suitable level of protection for communications equipment and sites in most areas. Areas subject to more severe lightning activity will require additional SPD design considerations which are beyond the scope of this chapter.

The ultimate goal of Transient Voltage Surge Suppression is to keep communications sites and systems operating reliably. Failure of a single SPD at a communications site would leave the site vulnerable to further damage. To maintain a backup level of protection, it may be necessary to install a redundant SPD. Another important design philosophy is that the AC power SPDs **shall not** cause interruptions to the site power when it operates. Therefore, to reduce this probability, all Type 1, 1A and 2 AC power SPDs **shall** be designed for and installed as parallel devices. A suitable disconnecting means **shall** be provided to permit servicing. Type 3 devices could be considered a series connected device as this is placed between the receptacle outlet and the load. In the Type 3 devices the surge protection medium **shall** be parallel connected between the phase conductor and the neutral conductor in a manner that will not interrupt power to the load should the surge suppression device fail. Alarms to report a device failure are recommended.

9.2 TECHNOLOGIES AVAILABLE

There are several major types of SPD technologies available today. The most common and most reliable are the Metal Oxide Varistor (MOV) and the Silicon Avalanche Diode (SAD) devices. These devices are ideal for protection of power and telephone or data circuits because of their fast response time and high energy handling capability. There are other components such as gas discharge tubes, spark gaps, surge relays, capacitors, inductors, and selenium devices that, although somewhat effective in specific applications, are not acceptable as power, telephone or data circuit SPDs at communications facilities as the typical response time is too slow.

It may be necessary to use more then one type of component in a protective device to obtain the best possible combination of SPD characteristics. The most common combination forming a “hybrid circuit” incorporates a high current, slower-acting component with a faster acting, but lower-power rated component. For AC power, this is typically a coordinated MOV and SAD combination.

WARNING

Gas Discharge Tubes shall not be used as AC power line surge suppression devices.

9.3 SUPPRESSION MODE DEFINITIONS

Normal Mode is defined as voltage appearing between line and neutral (L-N) and line to line (L-L) conductors.

Common Mode refers to voltages appearing between line or neutral conductors and ground (L-G or N-G).

WARNING

Common Mode AC power surge suppression devices shall not be utilized. These devices may fail in a short circuit condition. Should this occur, the AC power neutral conductor becomes bonded to the ground or equipment grounding conductor causing undesired currents in the ground or equipment grounding conductor(s). This may constitute a personnel safety hazard and could constitute an NFPA 70 violation by creating a neutral-ground bond at a location other than at the main service disconnect. (Common Mode surge suppression devices may be used on telephone or data circuits.)

WARNING

All AC power SPDs used within the United States shall be UL listed or recognized. Devices may conform to the international CE certification mark.

NOTE: There may be specific nondomestic applications where common mode protection may be advantageous although not recommended by Motorola. Installation of a transformer creating a separately derived electrical system is recommended for these applications. The SPD manufacturer should be contacted regarding these applications.

9.4 AC POWER SPD REQUIREMENTS

SPDs are required on all power feeders to and from communications facilities. All devices **shall** be installed per the manufacturers installation instructions. The facility grounding and bonding systems **shall** be properly implemented to help ensure that the electrical service, all surge suppression devices, and the communication system components within the equipment area are at the same ground potential. This is **critically important** to help ensure maximum safety of personnel and maximum effectiveness of the SPDs.

The SPDs **shall** be installed within the equipment shelter, room or area to achieve maximum effectiveness. Installation at locations away from the equipment area **shall not** be performed, as it reduces the effectiveness of the SPD.

9.4.1 AC SPD REQUIREMENTS BASED ON FACILITY DESCRIPTION

Table 9-1 on page 9-10 specifies the minimum AC power SPD requirements for various communications facilities. (The voltage and phase requirements are site specific and depend on the electrical service characteristics for the specific location.)

9.4.1.1 DETERMINING REQUIRED SPD COMPLEMENT

Use Table 9-1 to determine the SPD complement best suited for a particular application as follows:

1. In the **Service Type** column, note the type of electrical layout that best describes the site, facility or equipment location.
2. Review the **Interconnect Diagram** (**A** through **M**; Figures 9-2 through 9-14) associated with the **Service Type** to ensure the electrical service and distribution arrangement selected best matches the site, shelter or equipment area. (Figures 9-2 through 9-14 are on pages 9-13 through 9-25, respectively.)
3. Order and install the Type SPD(s) correspondingly listed for the selected service and distribution system.

   EXAMPLE: Assuming a stand-alone shelter as follows:

   - Without a generator
   - Main disconnect and all disconnects located within the shelter

   SPD requirements are determined as shown below.

1. **In Table 9-1, find the Service Type description that best matches site.**

2. **Compare site to corresponding Figure shown. Verify that site matches electrical service and distribution arrangement shown.**

3. **Note the required location and SPD type for the Service Type.**

Service Type	Interconnect Diagram (Fig. No.)	Main Disconnect	Main Panelboard or Feeder Side of ATS	Utility Panelboard	Utility Panelboard in Other Bldg./ Shelter
Stand-alone Building/shelter without Generator					
Main disconnect and all panelboards located within the same shelter, room or equipment area	**A (Figure 9-2)**			Type 1[1]	

In this example, a shelter with main disconnect and panelboard all located within shelter fits the description shown above and additionally matches Figure A. As such, the SPD type and location is correspondingly shown above.

For a given application, the SPDs **shall** be installed at the panelboard correspondingly specified in Table 9-1 and the associated figure.

A Type 1A SPD may be substituted for a Type 1 in areas where the level of exposure to power anomalies is high. (This would typically be within industrial or highly commercial complexes, hilltop locations or locations where there is a high incidence of lightning activity.

Installation of a Type 3 device is also recommended for high exposure locations when the branch circuit is greater than 3 m (10 ft.) of conductor length or 1.5 m (5 ft.) of circuit length from the panelboard where a Type 1 or 1A device is installed.

9.4.1.2 INSTALLATION WITH MAIN DISCONNECT AWAY FROM AREA

For installations where the main disconnecting means is located away from the shelter, room or equipment area (Diagrams **E** through **J**; Figures 9-6 through 9-11 on pages 9-17 through 9-22, respectively), a separately derived electrical system is required within the shelter, room or equipment area to provide maximum protection from transients or other power line anomalies. (Exceptions to this requirement are allowed for systems where all communications equipment is DC powered from a battery bank and where there is no RF equipment on site with external antennas and transmission lines. Examples to this exception could be cellular and iDEN sites, non RF prime sites and some dispatch centers.)

A separately derived electrical system can be achieved by installation of a step down or isolation transformer, or by the installation of a suitable UPS that qualifies as a separately derived electrical system. Similarly, when a power feed is provided to another building, shelter or equipment area (Diagrams **K** through **M**; Figures 9-12 through 9-14 on pages 9-23 through 9-25, respectively), a separately derived electrical system should be installed (**shall** be used for critical loads) within that shelter, building or equipment area to minimize potential damage resulting from power line anomalies generated by loads or lightning activity within that shelter, building or equipment area.

9.4.1.3 INSTALLATION WITH EQUIPMENT INSTALLED IN POLE OR PAD MOUNTED CABINETS

For installations where the equipment is installed within pole or pad mounted cabinets (Diagrams **N** through **P**; Figures 9-15 through 9-17 on pages 9-26 through 9-28), SPDs are required as specified in Table 9-1. Where a pole or pad mounted cabinet is installed and the electrical feeder originates from within another building or shelter (Diagram **Q**; Figure 9-18 on page 9-29), a Type 3 SPD is required to be installed on all equipment within the cabinet. In installations of this type it may be desirable to install additional SPDs at the branch circuit panelboard. Where the level of exposure is high a Type 2 SPD as a minimum is recommended. See Table 9-1 and footnotes for further information.

NOTE: Single conversion (forward transfer mode) UPS systems do not provide transient voltage surge suppression. Double conversion (reverse transfer mode or rectifier-inverter) UPS systems offer surge suppression to source induced transients. No surge suppression is afforded for load induced transients on either type.

TABLE 9-1 REQUIRED TVSS PROTECTION FOR VARIOUS SERVICE TYPES

Service Type	Interconnect Diagram (Fig. No.)	Main Disconnect	Main Panelboard or Feeder Side of ATS	Utility Panelboard	Utility Panelboard in Other Bldg./ Shelter	Equipment (If > 3 m (10 ft.) from panelboard)
Stand-alone Building/shelter without Generator						
Main service disconnect and all panelboards located within the same shelter, room or equipment area	**A (Figure 9-2)**			Type 1[1]		Type 3
Main service disconnect located outside the equipment area (greater than 3 m (10 ft.)):						
• At fence or property line utilizing a separately derived system supplying equipment area	**B (Figure 9-3)**			Type 1[1]		Type 3
• Within other building or structure utilizing a separately derived system supplying equipment area	**C (Figure 9-4)**			Type1[1]		Type 3
Stand-alone Building/shelter with Generator						
Main service disconnect and all panelboards located within the same shelter, room or equipment area	**D (Figure 9-5)**	Type 2		Type 1[1]		Type 3
Main service disconnect located outside the equipment area (greater than 3 m (10 ft.)):						
• At fence or property line utilizing a separately derived system supplying equipment area	**E (Figure 9-6)**		Type 2	Type 1[1]		Type 3
• Within other building or structure utilizing a separately derived system supplying equipment area	**F (Figure 9-7)**		Type 2	Type 1[1]		Type 3

TABLE 9-1 REQUIRED TVSS PROTECTION FOR VARIOUS SERVICE TYPES (CONTINUED)

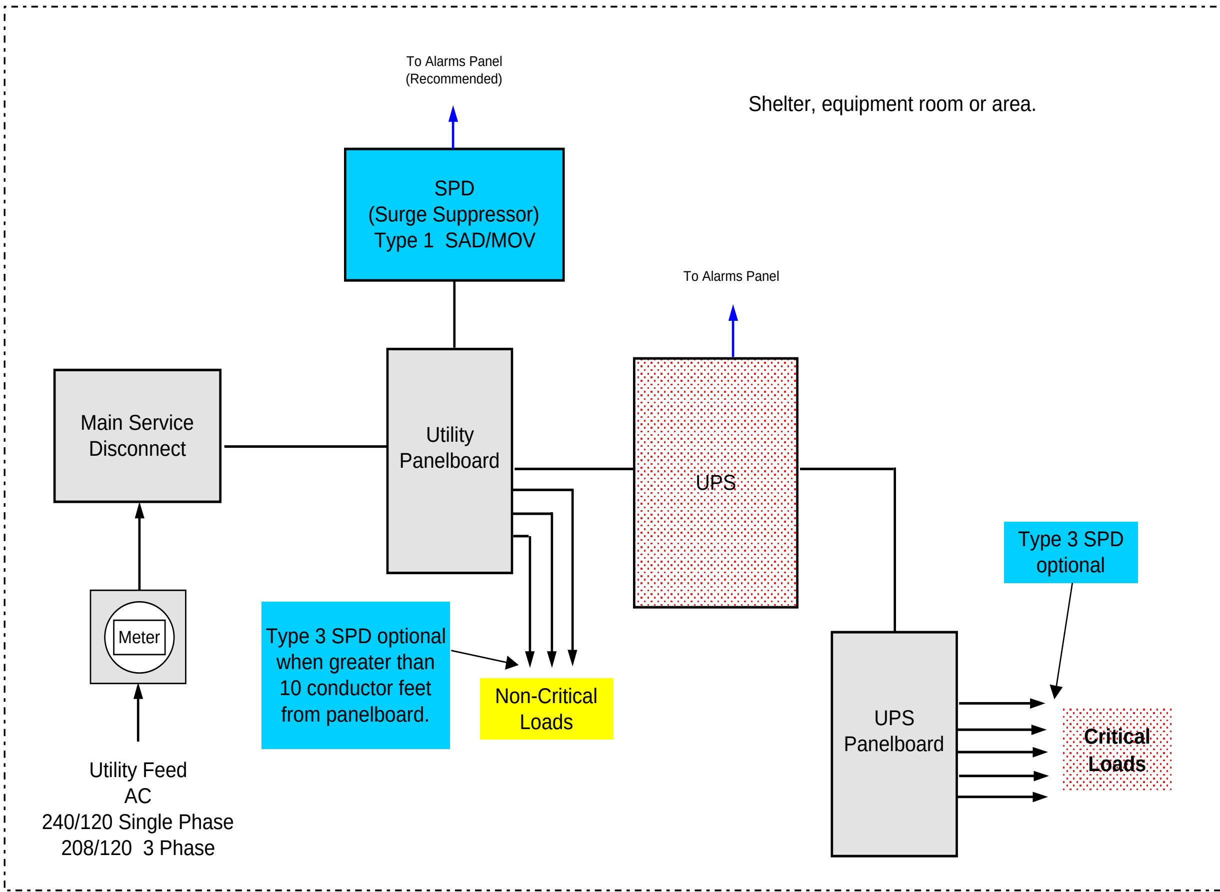
Service Type	Interconnect Diagram (Fig. No.)	Main Disconnect	Main Panelboard or Feeder Side of ATS	Utility Panelboard	Utility Panelboard in Other Bldg./ Shelter	Equipment (If > 3 m (10 ft.) from panelboard)
Equipment Area Located within a Larger Structure without Generator						
Main service disconnect located in another part of same structure utilizing a separately derived system supplying equipment area	**G (Figure 9-8)**			Type 1[1]		Type 3
Main service disconnect located within another structure utilizing a separately derived system supplying equipment area	**H (Figure 9-9)**			Type 1[1]		Type 3
Equipment Area Located within a Larger Structure with Generator						
Main service disconnect located in another part of same structure utilizing a separately derived system supplying equipment area	**I (Figure 9-10)**		Type 2	Type 1[1]		Type 3
Main service disconnect located within another structure utilizing a separately derived system supplying equipment area	**J (Figure 9-11)**		Type 2	Type 1[1]		Type 3
Feeder From Same Service Feeds Another Building or Shelter with Equipment on Same Service in Both Buildings or Shelters						
Feeder (not backed up by Generator)	**K (Figure 9-12)**			Type 1[1]	Type 1[1]	Type 3
Generator backed feeder	**L (Figure 9-13)**		Type 2	Type 1[1]	Type 1[1]	Type 3
Generator and UPS backed feeder	**M (Figure 9-14)**		Type 2	Type 1[1]	Type 1	Type 3

TABLE 9-1 REQUIRED TVSS PROTECTION FOR VARIOUS SERVICE TYPES (CONTINUED)

Service Type	Interconnect Diagram (Fig. No.)	Main Disconnect	Main Panelboard or Feeder Side of ATS	Utility Panelboard	Utility Panelboard in Other Bldg./ Shelter	Equipment (If > 3 m (10 ft.) from panelboard)
Pole or Pad Mount Cabinets with Independent Dedicated Service						
Complete System without Generator	**N (Figure 9-15)**			Type 1[1]		Type 3
Complete System with Generator	**O (Figure 9-16)**	Type 2		Type 1[1]		Type 3
Stand Alone Equipment (Single Repeater, Base Station, Receiver or Control Station)	**P (Figure 9-17)**			Type 2[2]		Type 3[3]
Branch Circuits						
Stand Alone Equipment (Single Repeater, Base Station, Receiver or Control Station)	**Q (Figure 9-18)**			Type 2[4]		Type 3[3]

1. A Type 1A SPD may be substituted. This substitution is highly recommended in areas where the exposure level is high.
2. Installation of Type 1, 1A, or 2 SPD is optional. This is recommended where the level of exposure is high.
3. A Type 3 device is required for these installations unless a Type 1 or Type 1A SPD is installed on the Utility Panelboard.
4. As an option, a Type 1, 1A or Type 2 SPD may be installed at the branch circuit panelboard for additional protection. Installation of a Type 2 (minimum) is recommended where the level of exposure is high.

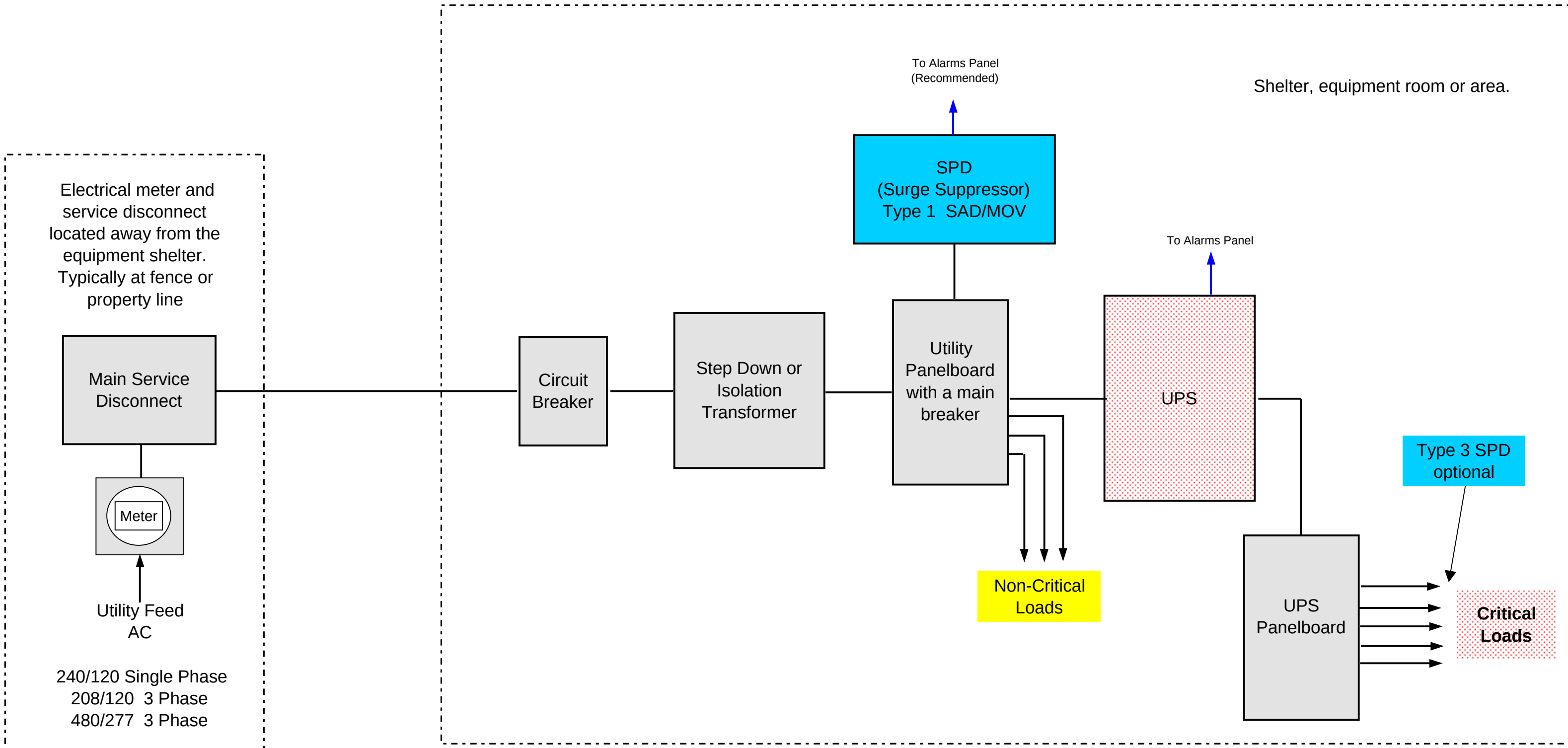
Type 3 devices may incorporate a telephone or data circuit secondary protection device within the same housing. Type 3 multiple receptacle outlet strip devices **shall** be securely fastened to a supporting structure.



NOTES:
1. The main service disconnect may be an integral part of the Utility Panelboard.
2. The main service disconnect and Utility Panelboard are collocated within the equipment area.
3. The Type 1 SPD shall be installed per the manufacturer's installation instructions.
4. All conductors between the SPD and the associated disconnecting device (60 Amp Circuit Breaker typical) shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
5. The SPD disconnecting device should be installed in the top most space available within the panelboard.
6. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
7. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

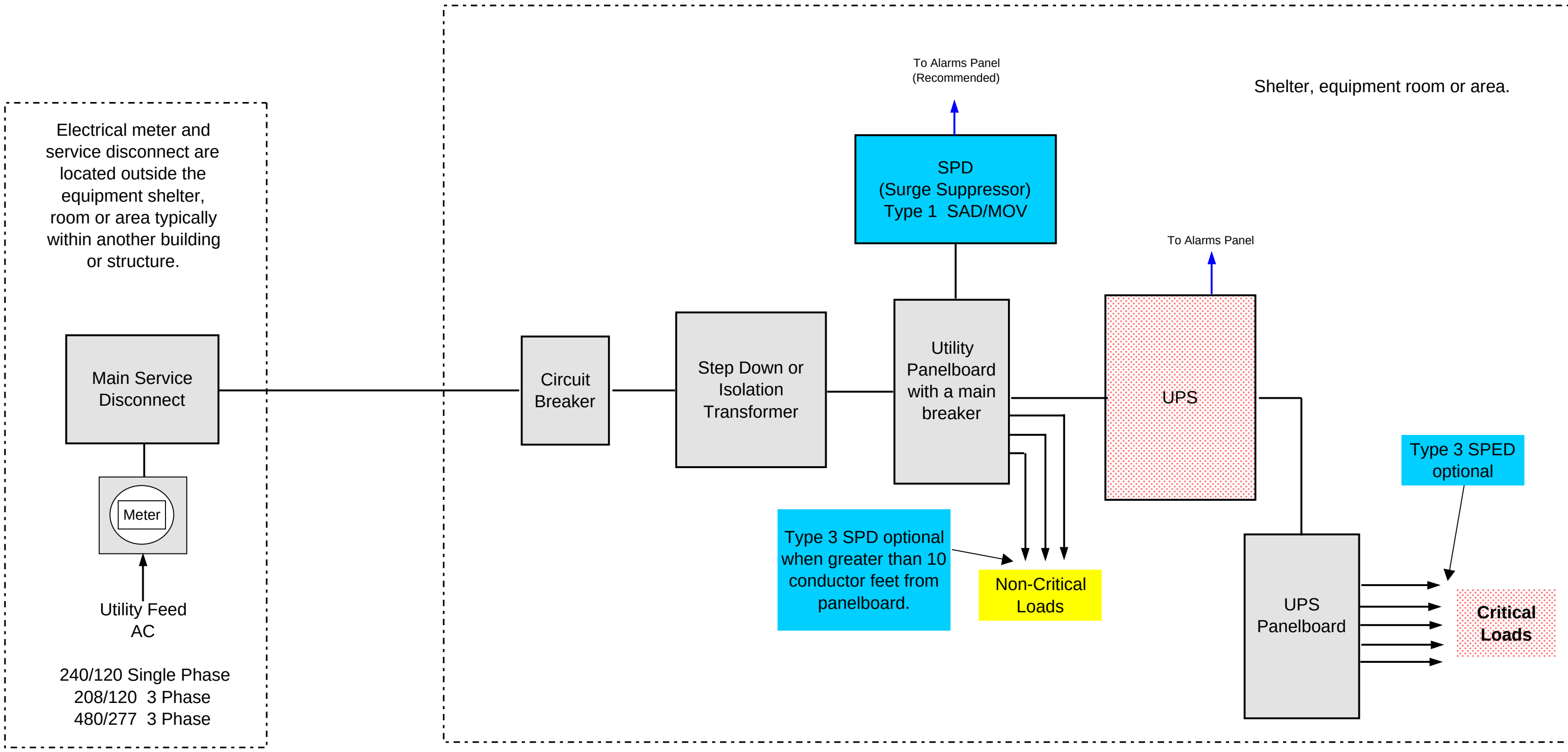
FIGURE 9-2 SPD INTERCONNECT BLOCK DIAGRAM 'A'

Figure 9-3 SPD Interconnect Block Diagram 'B'



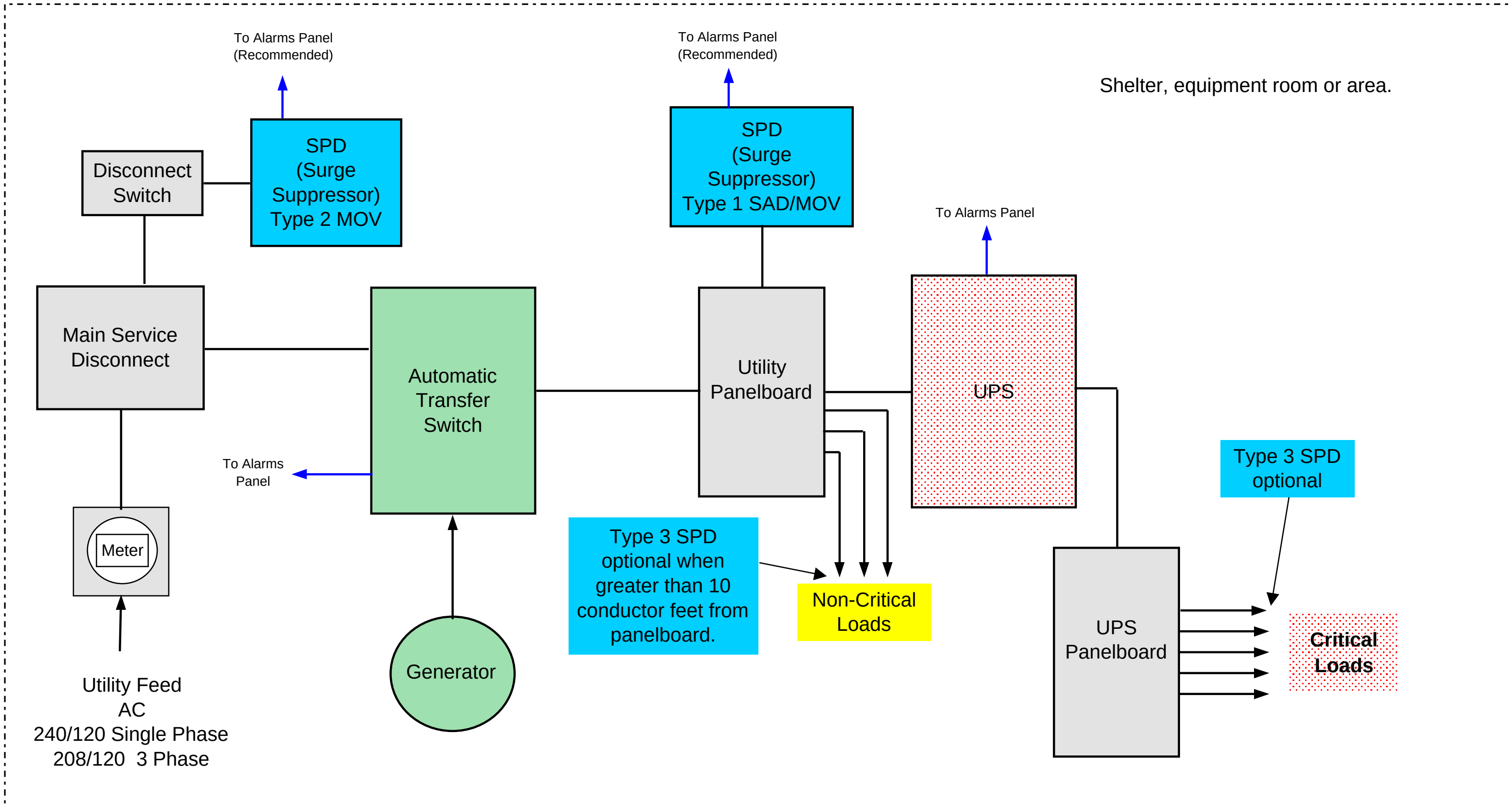
NOTES:
1. The main service disconnect is located outside the equipment shelter, room or area, typically at the fence or property line.
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system at the same point.
4. The Utility Panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 SPD shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPD and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting device should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

FIGURE 9-4 SPD INTERCONNECT BLOCK DIAGRAM 'C'



NOTES:
1. The main service disconnect is located outside the equipment shelter, room or area, typically within another building or structure.
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system at the same point.
4. The Utility Panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 SPD shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPD and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting device should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

FIGURE 9-5 SPD INTERCONNECT BLOCK DIAGRAM 'D'



NOTES:
1. All electrical panelboards shown are collocated within the shelter, room or equipment area.
2. The SPDs shall be installed per the manufacturer's installation instructions.
3. All conductors between the SPD and the associated disconnecting devices shall be as short as possible and routed together with a minimal number of bends or angles.
4. The SPD disconnecting device in the Utility Panelboard should be installed in the top most space available.
5. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
6. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

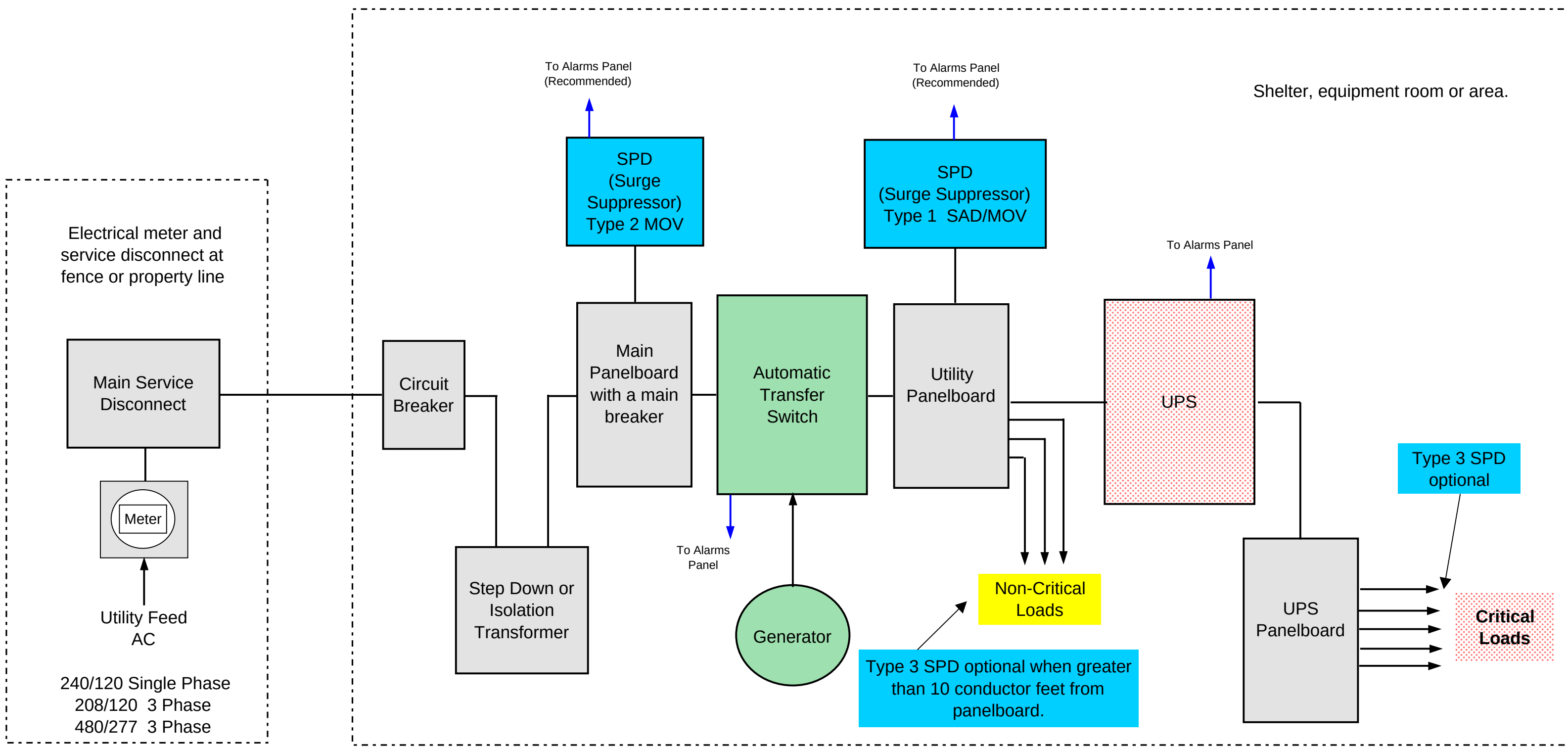


FIGURE 9-6 SPD INTERCONNECT BLOCK DIAGRAM 'E'

NOTES:

1. The main service disconnect is located outside the equipment shelter, room or area, typically at the fence or property line..
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system.
4. The Main panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 and Type 2 SPDs shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting devices should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load are recommended at locations with high lightning activity.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended at locations with high lightning activity.

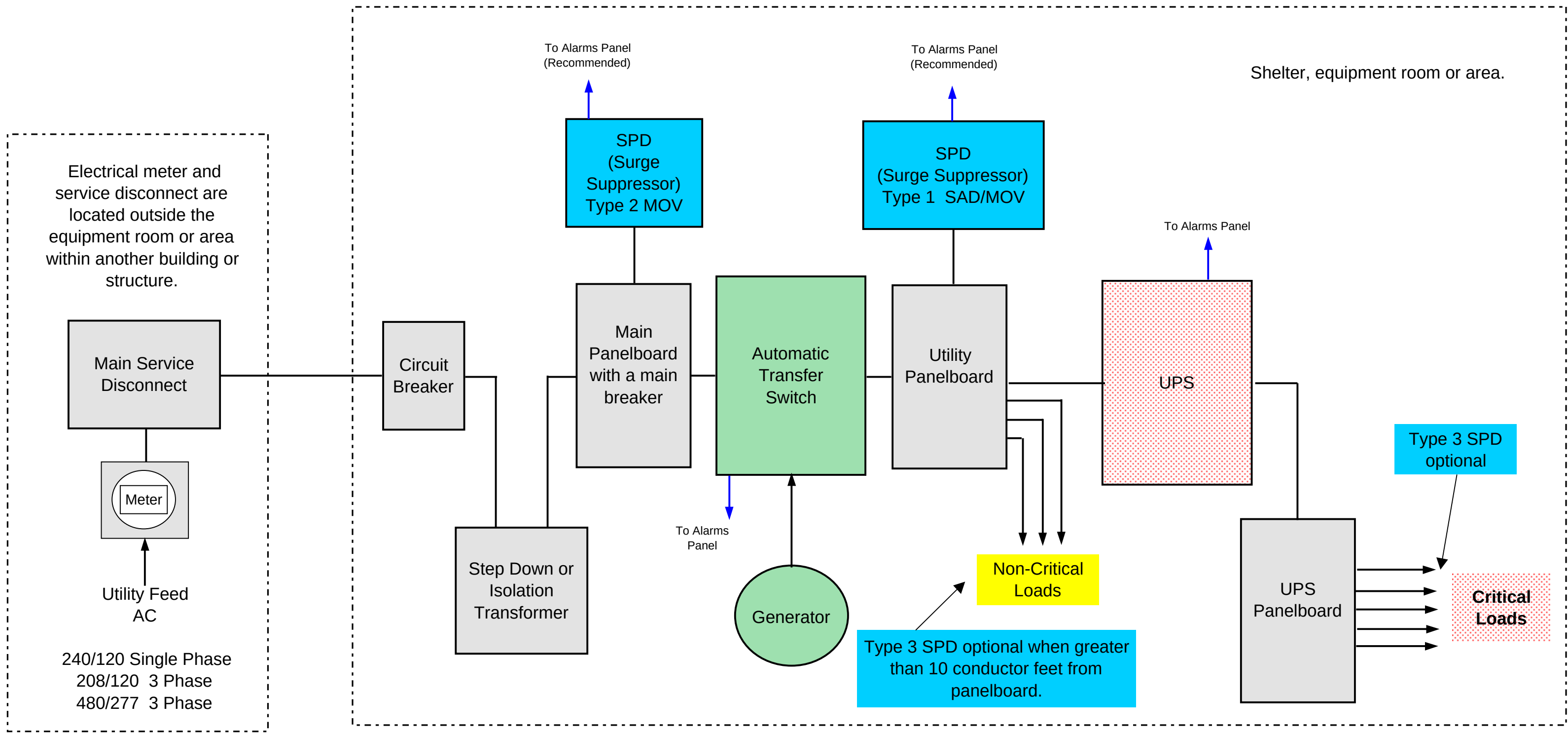


FIGURE 9-7 SPD INTERCONNECT BLOCK DIAGRAM 'F'

NOTES:

1. The main service disconnect is located outside the equipment shelter, room or area, typically within another building or structure.
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system.
4. The Main panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 and Type 2 SPDs shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting devices should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

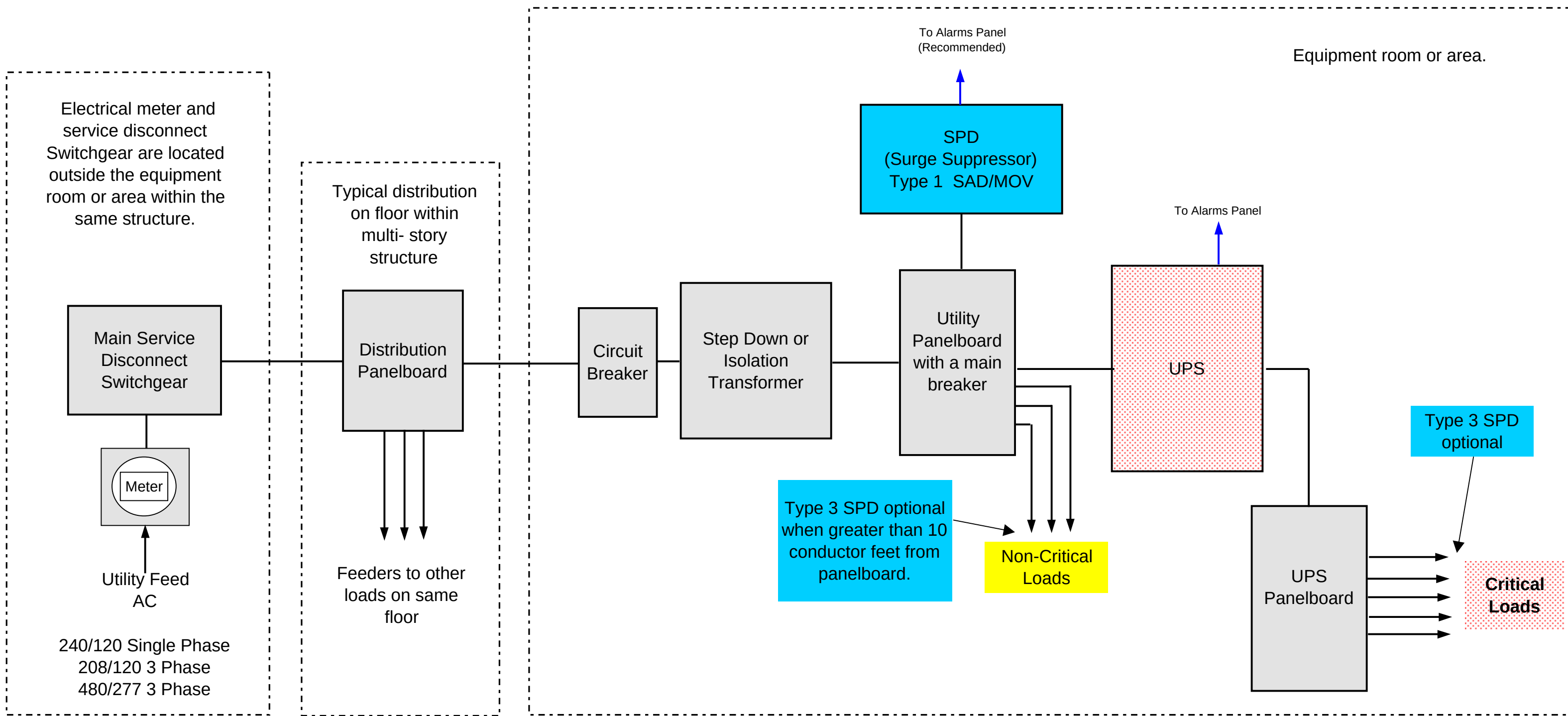


FIGURE 9-8 SPD INTERCONNECT BLOCK DIAGRAM 'G'

NOTES:
1. The main service disconnect is located outside the equipment room or area within the same structure. Additional distribution panelboards may be located within the structure, typically one per floor.
2. The service to the equipment room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system at the same point.
4. The Utility panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 SPD shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPD and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting device should be installed in the topmost space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

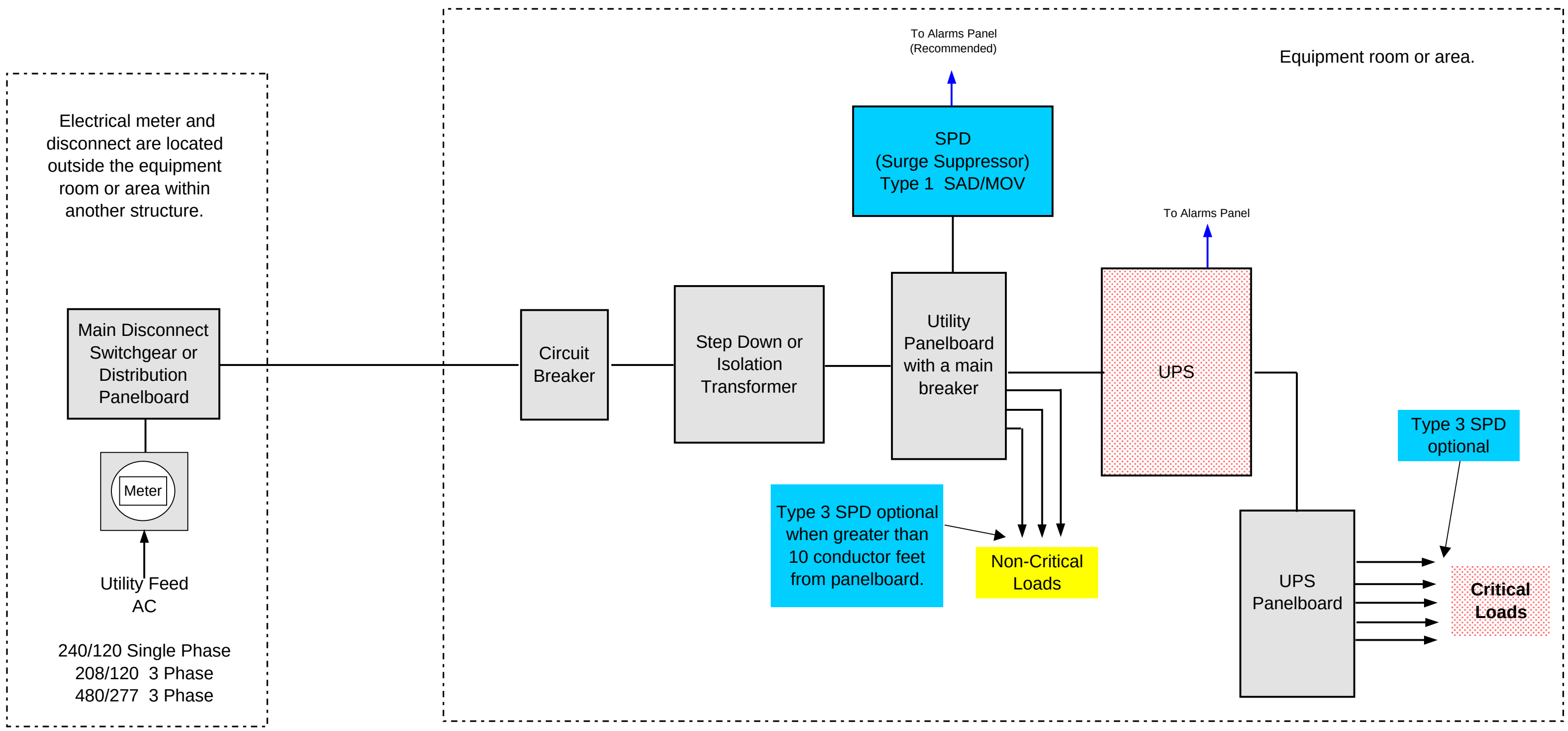


Figure 9-9 SPD Interconnect Block Diagram 'H'

NOTES:
1. The main service disconnect is located outside the equipment room or area within another structure.
2. The service to the equipment room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system at the same point.
4. The Utility panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 SPD shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPD and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting device should be installed in the topmost space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

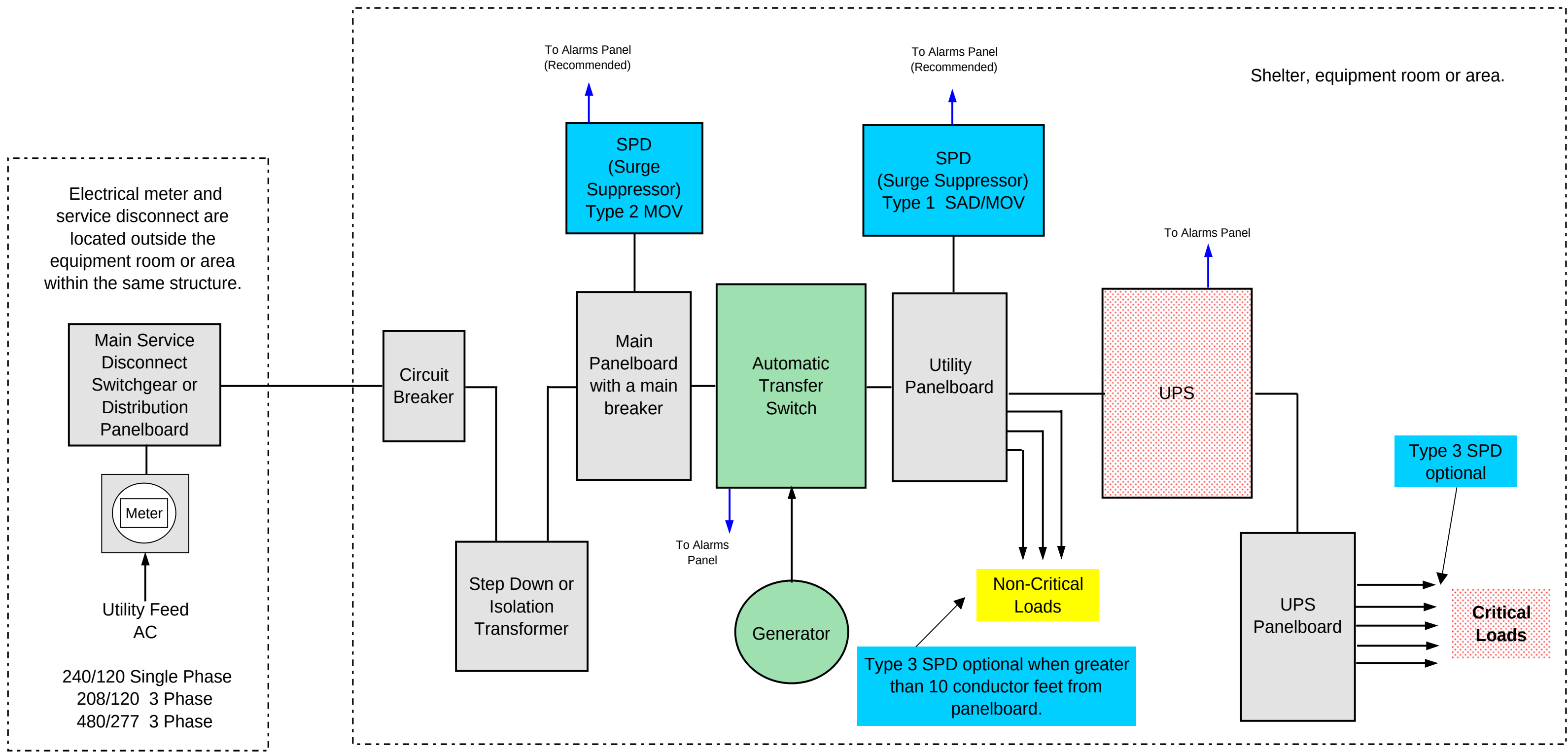


FIGURE 9-10 SPD INTERCONNECT BLOCK DIAGRAM 'I'

NOTES:

1. The main service disconnect is located outside the equipment shelter, room or area, typically within the same building or structure. Additional distribution panelboards may be located within the structure, but are not shown.
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system.
4. The Main panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 and Type 2 SPDs shall be installed per the manufacturer's installation instructions.
6. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting devices should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

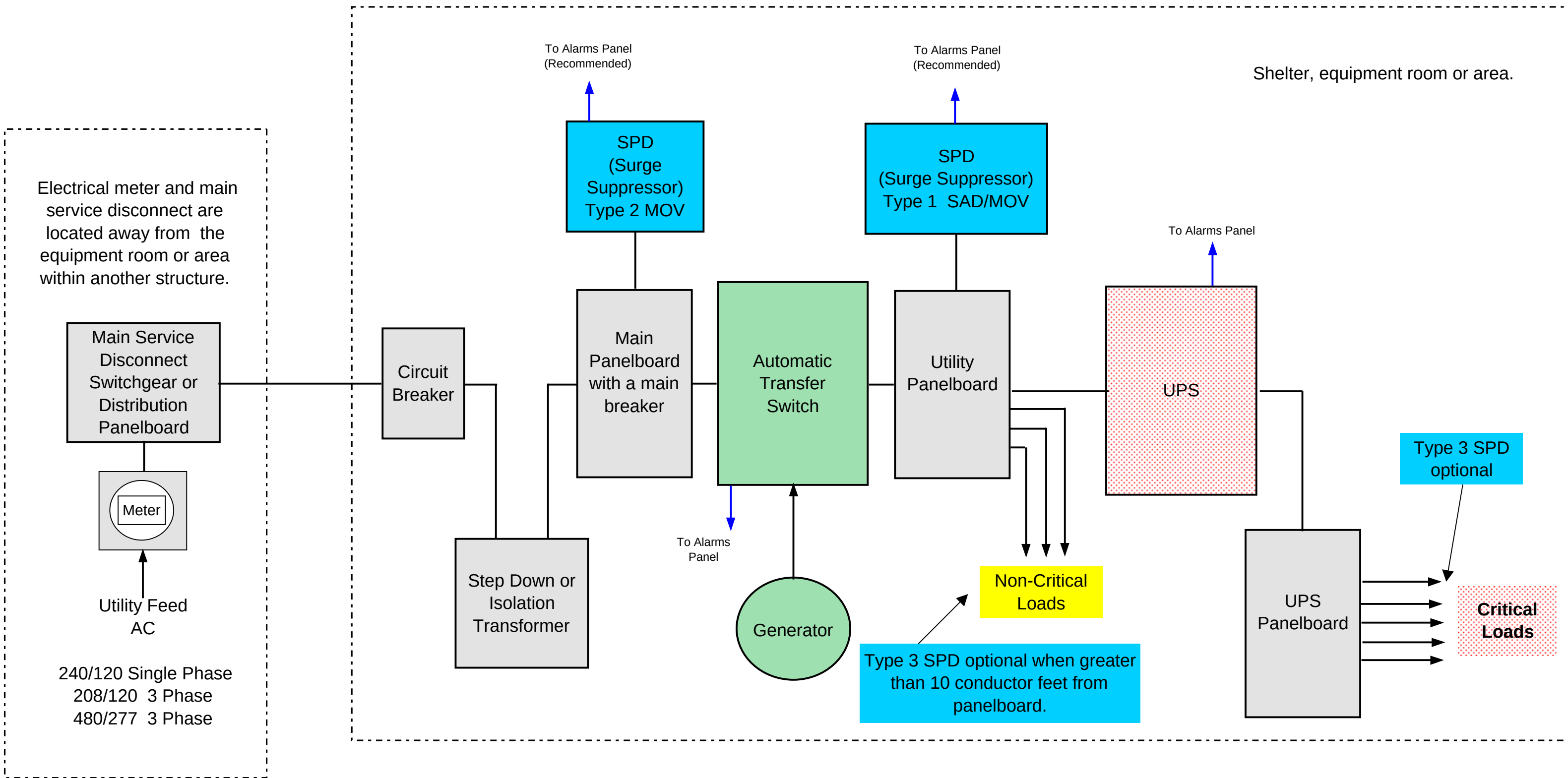


Figure 9-11 SPD Interconnect Block Diagram 'J'

NOTES:

1. The main service disconnect is located away from the equipment shelter, room or area, typically within another building or structure.
2. The service to the equipment shelter, room or area is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. The step-down or isolation transformer creates a separately derived system where the neutral and ground conductors are bonded together within the transformer and bonded to the equipment room MGB. The main disconnect ground and the MGB shall be bonded to the site grounding electrode system.
4. The Main panelboard shall use a main disconnecting device to serve the equipment area.
5. The Type 1 and Type 2 SPDs shall be installed per the manufacturers installation instructions.
6. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting devices should be installed in the top most space available in the Utility Panelboard.
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

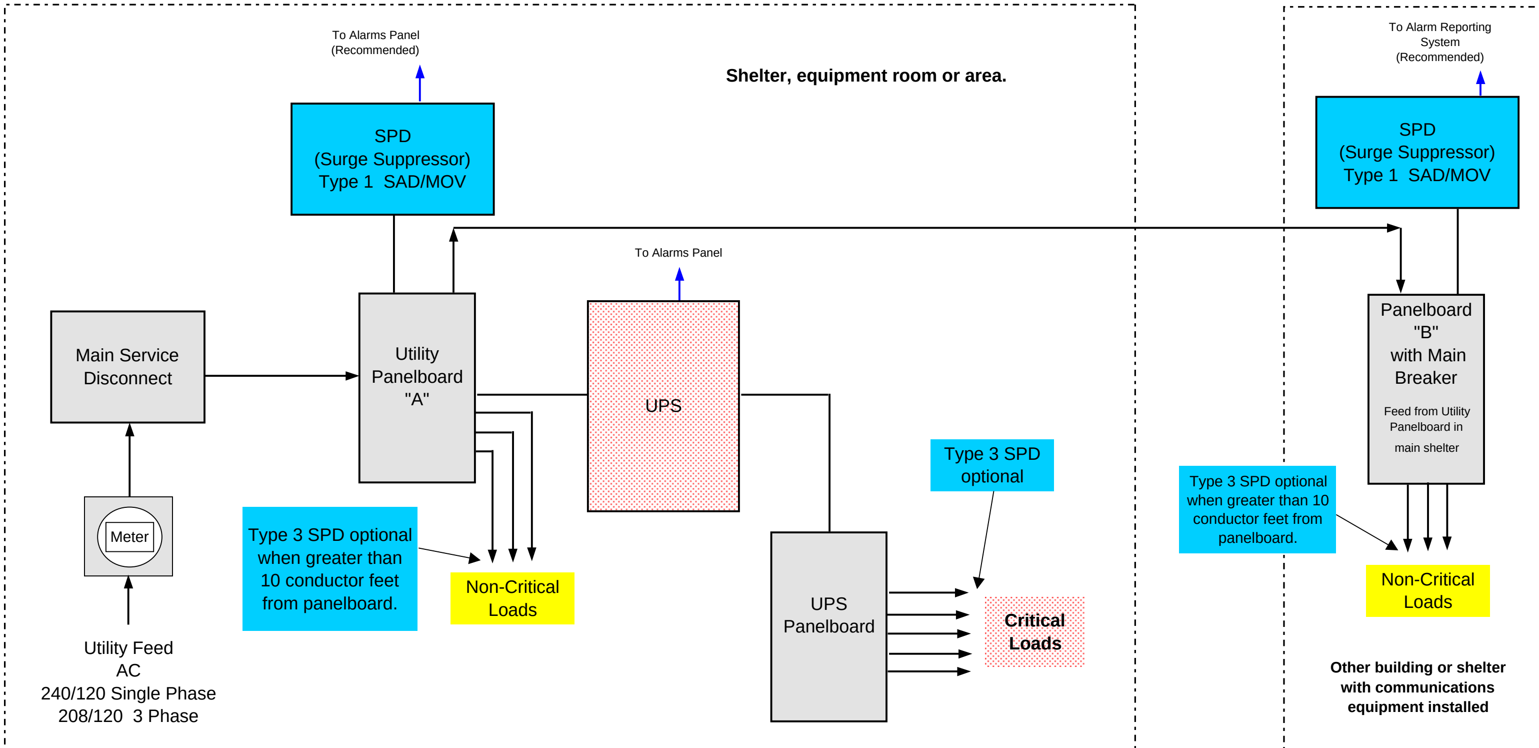
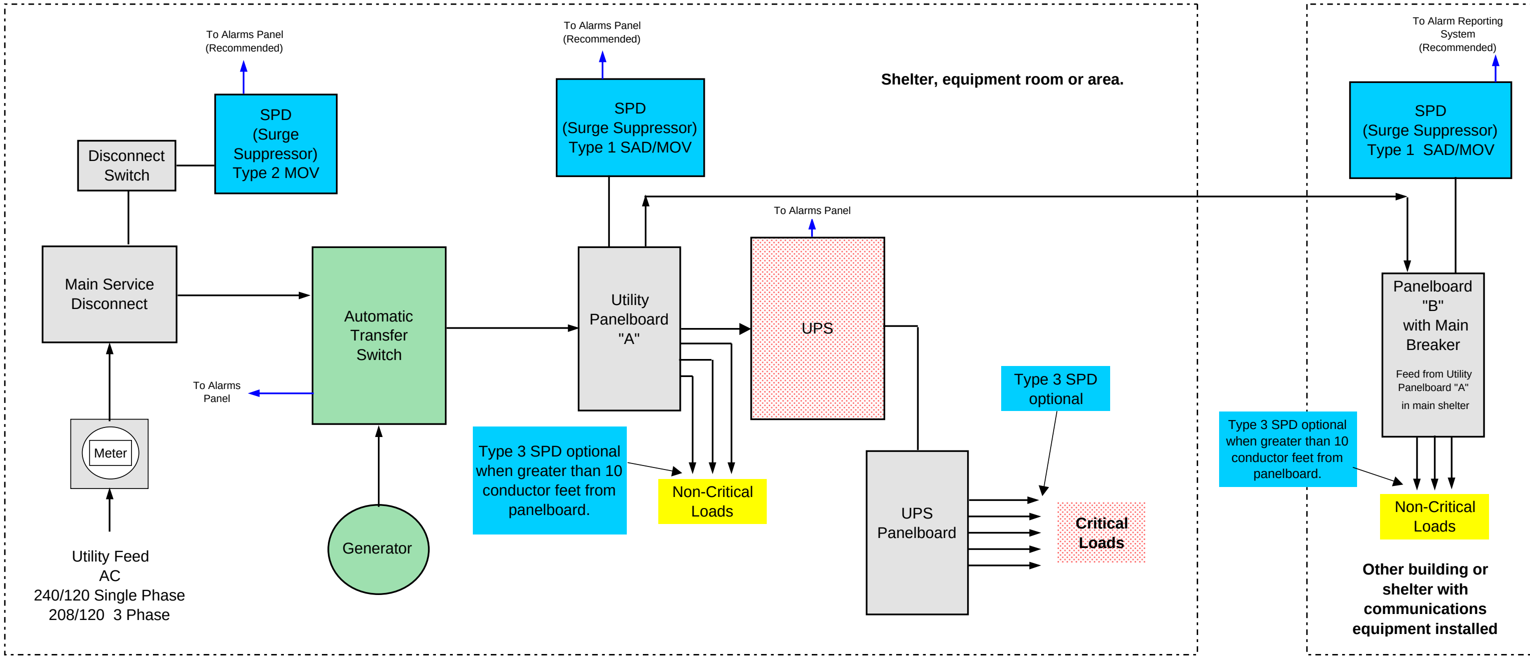


FIGURE 9-12 SPD INTERCONNECT BLOCK DIAGRAM 'K'

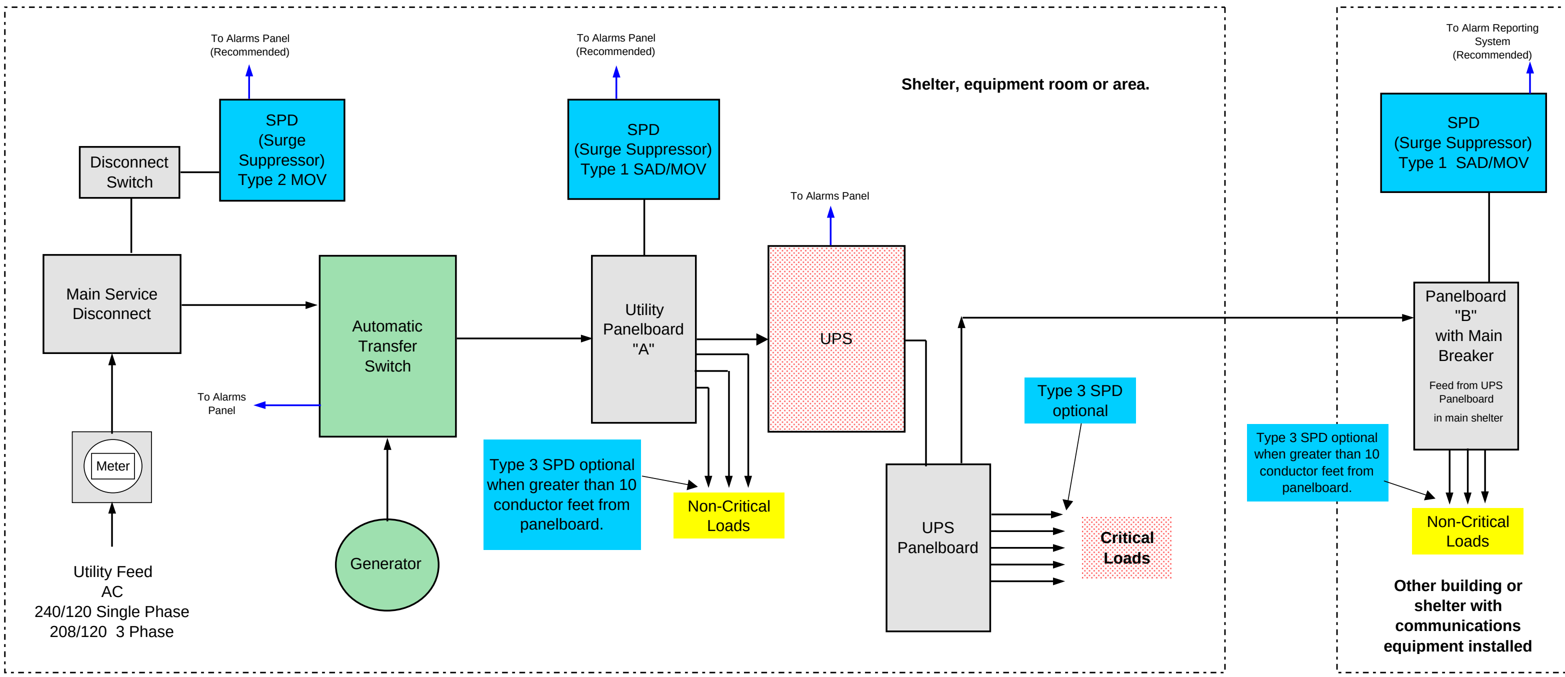
NOTES:
1. The main service disconnect may be an integral part of the Utility Panelboard.
2. The feeder to the adjacent shelter is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
3. No critical loads should be placed within the adjacent shelter or building unless a separately derived system is installed within the adjacent shelter. This could be in the form of a transformer or a suitable UPS system.
4. The main service disconnect and utility panelboard "A" are collocated within the equipment area. Panelboard "B" is located within another adjacent shelter or building.
5. The SPDs shall be installed per the manufacturers installation instructions.
6. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
7. The SPD disconnecting device should be installed in the top-most space available within panelboards "A" and "B."
8. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
9. Installation of Type 3 SPDs on each non-critical load that is located greater than 3m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

FIGURE 9-13 SPD INTERCONNECT BLOCK DIAGRAM 'L'



NOTES:

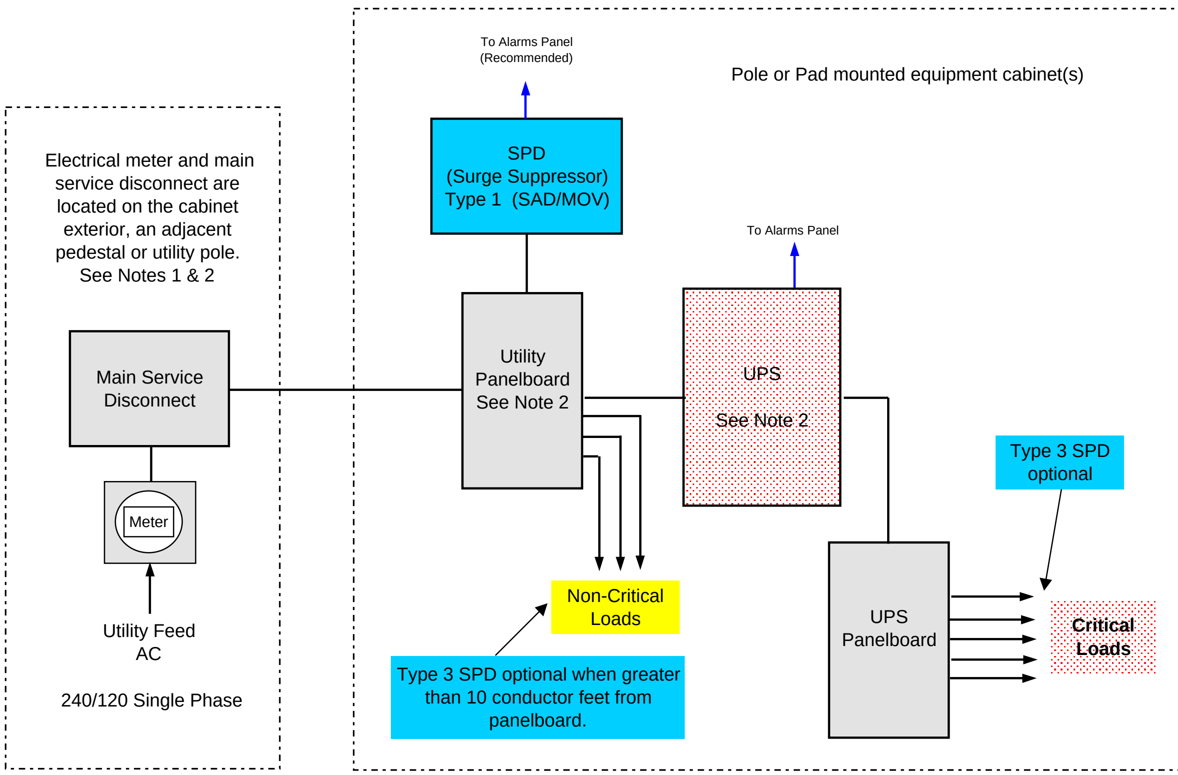
1. The feeder to the adjacent shelter is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
2. No critical loads should be placed within the adjacent shelter or building unless a separately derived system is installed within the adjacent shelter. This could be in the form of a transformer or a suitable UPS system.
3. The main service disconnect, Automatic Transfer Switch and utility panelboard "A" are collocated within the equipment area. Panelboard "B" is located within another adjacent shelter or building.
4. The SPDs shall be installed per the manufacturers installation instructions.
5. All conductors between the SPD and the associated disconnecting devices shall be as short as possible and routed together with a minimal number of bends or angles.
6. The SPD disconnecting devices should be installed in the top most space available in Panelboards "A" & "B".
7. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
8. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.



NOTES:

1. The feeder to the adjacent shelter is 3 conductors with ground for single phase or 4 conductors with ground for 3 phase.
2. No critical loads should be placed within the adjacent shelter or building unless a separately derived system is installed within the adjacent shelter. This could be in the form of a transformer or suitable UPS system.
2. The main service disconnect, Automatic Transfer Switch and utility panelboard "A" are collocated within the equipment area. Panelboard "B" is located within another adjacent shelter or building.
3. The SPDs shall be installed per the manufacturer's installation instructions.
4. All conductors between the SPD and the associated disconnecting devices shall be as short as possible and routed together with a minimal number of bends or angles.
5. The SPD disconnecting devices should be installed in the top most space available in Panelboards "A" & "B".
6. Installation of Type 3 SPDs on each critical load is recommended where the level of exposure is high.
7. Installation of Type 3 SPDs on each non-critical load that is located greater than 3 m (10 ft.) of conductor length from the panelboard is recommended where the level of exposure is high.

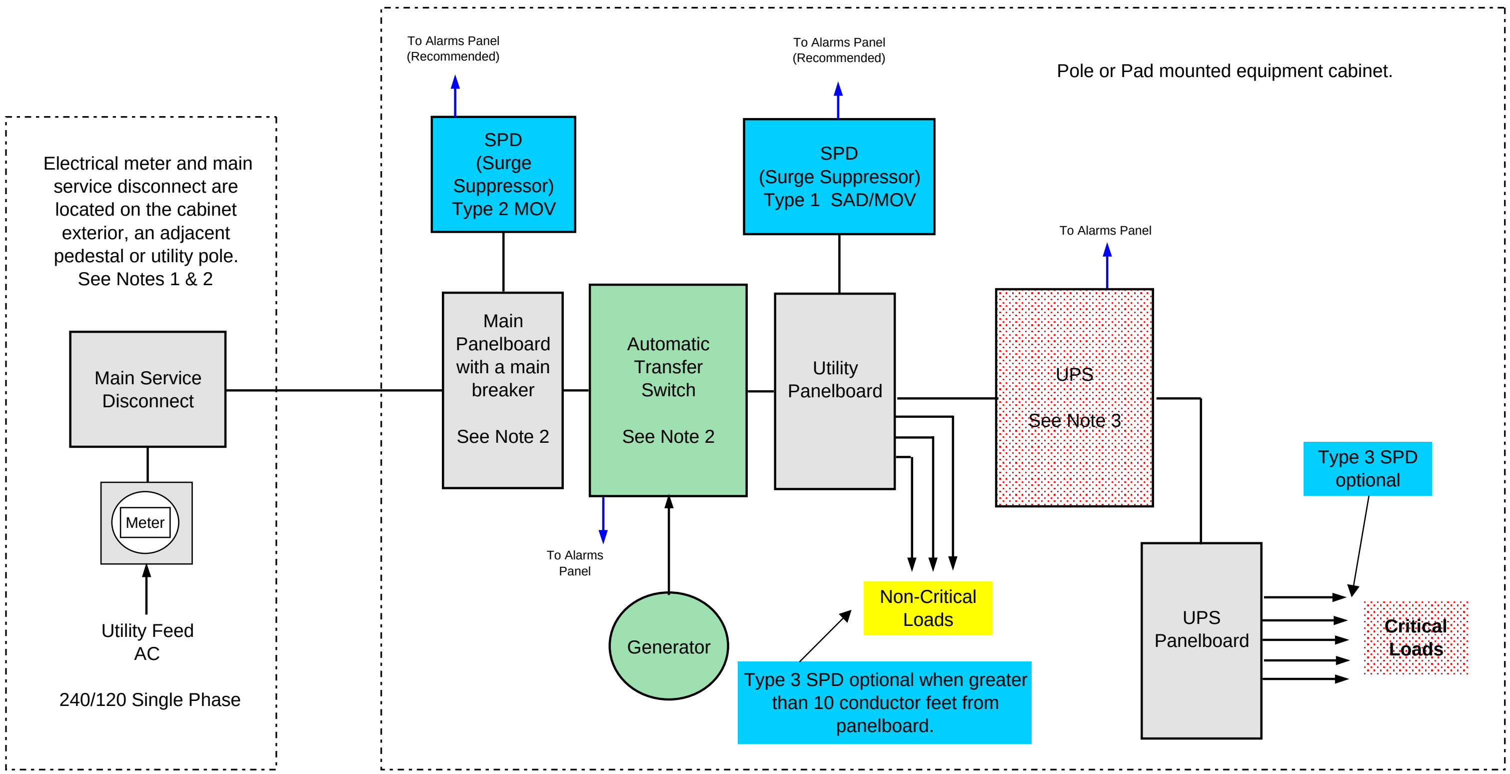
FIGURE 9-14 SPD INTERCONNECT BLOCK DIAGRAM 'M'



NOTES:
1. The main service disconnect may be located outside the pole or pad mounted equipment cabinet, typically on the cabinet exterior, an adjacent pedestal or utility pole.
2. The main service disconnect may be an integral part of the Utility Panelboard.
3. The UPS may not be present in which case all loads will be fed from the Utility Panelboard
4. The Type 1 or Type 1A SPD shall be installed per the manufacturer's installation instructions.
5. All conductors between the SPD and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
6. The SPD disconnecting device should be installed in the top most space available in the Utility Panelboard.
7. Installation of Type 3 SPDs on critical and non critical loads, although optional, is recommended where the level of exposure is high.

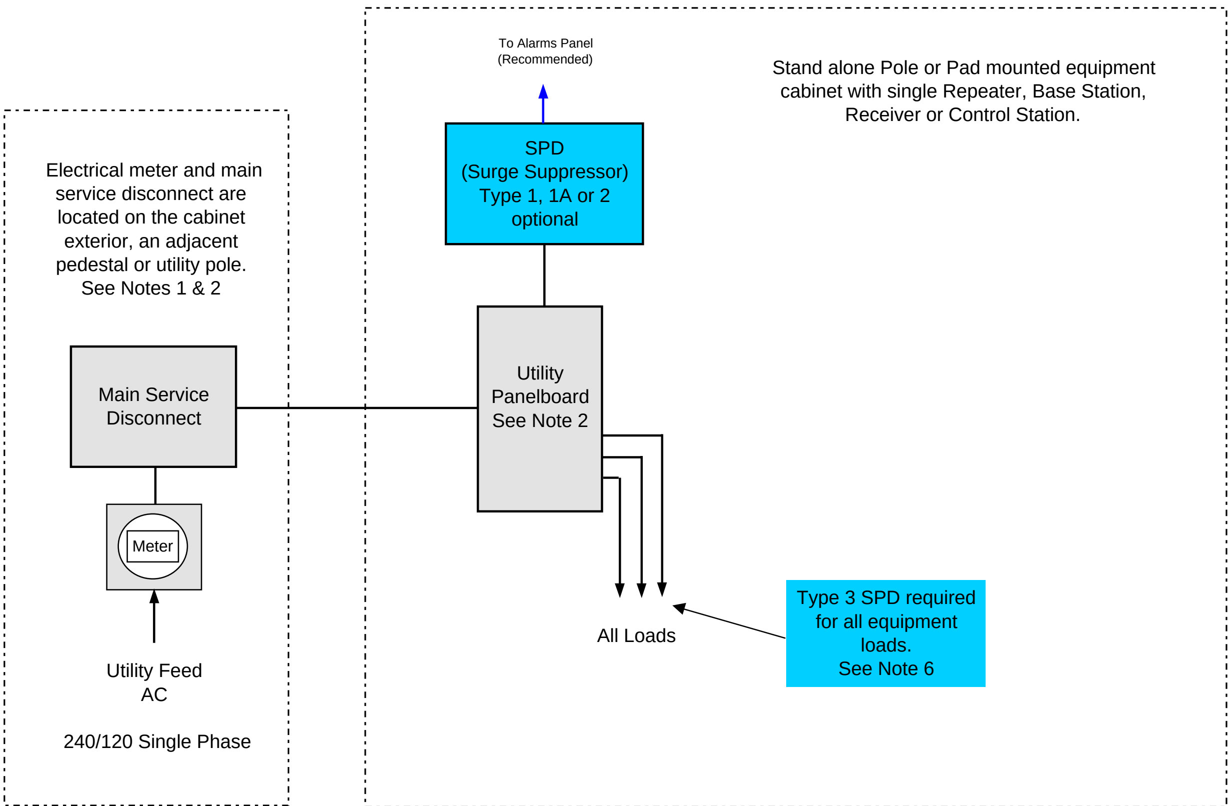
FIGURE 9-15 SPD INTERCONNECT BLOCK DIAGRAM 'N'

FIGURE 9-16 SPD INTERCONNECT BLOCK DIAGRAM 'O'



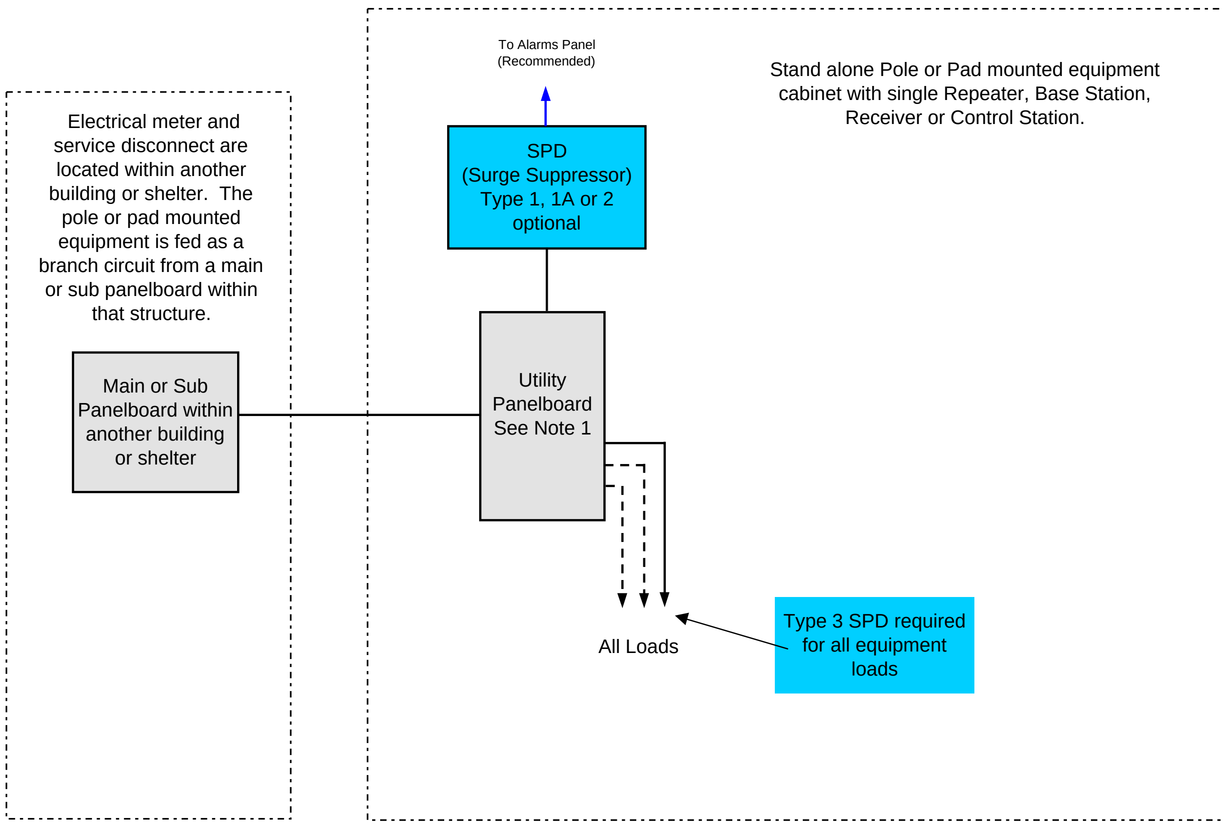
NOTES:

1. The main service disconnect may be located outside the pole or pad mounted equipment cabinet, typically on the cabinet exterior, an adjacent pedestal or utility pole. This may also be incorporated within the main panelboard.
2. The main panelboard, Type 2 SPD and Automatic Transfer Switch may be located outside the cabinet(s). (If located outside the cabinet these shall be in weatherproof enclosures.)
3. The UPS may not be present in which case all loads will be fed from the Utility Panelboard.
4. The Type 1 and Type 2 SPDs shall be installed per the manufacturer's installation instructions.
5. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
6. The SPD disconnecting devices should be installed in the top most space available in the Panelboards.
7. Installation of Type 3 SPDs on critical and non critical loads, although optional, is recommended where the level of exposure is high.



NOTES: 1. The main service disconnect may be located outside the equipment pole or pad mounted cabinet, typically on the cabinet exterior, an adjacent pedestal or utility pole.
2. The Main service disconnect may be a part of the Utility Panelboard.
3. When installed the Type 1, 1A or Type 2 SPD shall be installed per the manufacturer's installation instructions.
4. All conductors between the SPD and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
5. The SPD disconnecting devices should be installed in the top most space available in the Utility Panelboard.
6. Installation of Type 3 SPDs on each load is required unless a Type 1 or 1A SPD is installed on the Utility Panelboard.

Figure 9-17 SPD Interconnect Block Diagram 'P'



NOTES:
1. A disconnecting device is required within the pole or pad mounted cabinet. This may be a single disconnect if no Type 1, 1A or Type 2 SPD is installed and there is only one load.
2. When installed the Type 1, 1A or Type 2 SPDs shall be installed per the manufacturer's installation instructions.
3. All conductors between the SPDs and the associated disconnecting device shall be as short as possible and routed together with a minimal number of bends or angles of less than 90 degrees.
4. The SPD disconnecting devices should be installed in the top most space available in the Utility Panelboard.
6. Installation of Type 3 SPDs on each load is required unless a Type 1 or 1A SPD is installed on the Utility Panelboarc

FIGURE 9-18 SPD INTERCONNECT BLOCK DIAGRAM 'Q'

9.4.2 SPD Types

SPDs used for AC power protection referenced in this section are defined as Type 1, Type 1A, Type 2 or Type 3 and are defined below. SPDs may also be installed within a panelboard as an integral part of the panelboard. Devices installed directly across the bus conductors within a panelboard will generally provide a lower let-through voltage because the length of the conductors to the device are very short compared with a stand alone device. Although infrequent in occurrence, SPDs installed within the panelboard may result in a site power failure should there be a catastrophic failure of the devices.

WARNING

Maintenance of SPDs installed within a panelboard requires panelboard cover removal, which constitutes an electrocution hazard. As such, only a qualified and licensed electrician shall perform cover removal and maintenance.

Table 9-2 on page 9-35 lists required specifications for various SPDs.

9.4.2.1 Type 1 Panel Type Surge Suppression Device

Type 1 SPD provides suitable protection for the average facility. General requirements are as follows:

- The device **shall** consist of primary modules using SAD technology and secondary modules using MOV technology.
- A SAD and MOV module **shall** be installed from each phase conductor to the neutral conductor (L-N, Normal Mode).
- Module or devices of any type **shall not** be connected between any phase conductor and the equipment grounding conductor or ground (L-G, Common Mode).
- The primary modules **shall** consist of a SAD module providing 250 Joules per phase, per polarity, minimum energy absorption.
- The secondary module **shall** consist of a Metal Oxide Varistor (MOV) module, with 5000 Joules per phase of energy absorption. This module **shall** be equal to, and have the same specifications and performance characteristics, as modules utilized in the 1A and 2 devices.
- The minimum pulse life or durability requirements and the voltage protection level **shall** be as specified in Table 9-2 for the respective Maximum Continuous Operating Voltage (MCOV) listed.
- SPD **shall** be properly selected based on the operating voltage and number of phases of the circuits to be protected.
- Each module or subassembly **shall** be modular in design to allow for easy field replacement.
- Module components **shall not** be encapsulated.

- Each module **shall** have indicator lamps visible from the front of the device showing that the module has power applied and that the protection integrity has not been compromised.
- The SPD **shall** include a set of form "C" dry contacts for remote alarm reporting capability. This set of contacts **shall** operate when there is an input power failure or the integrity of any module has been compromised. This contact set **shall** be isolated from the AC power circuitry to safeguard the alarm circuit or reporting device should there be a catastrophic event.
- Installation of Type 3 SPDs on each critical load is recommended in locations highly vulnerable to transient surges or lightning activity. Refer to "Type 3 Individual Equipment SPDs" on page 9-33 for application information.
- The device **shall** be UL 1449, 2nd Edition (or later revision) listed or recognized. Devices may also conform to the international CE certification mark.

9.4.2.2 TYPE 1A PANEL TYPE SURGE SUPPRESSION DEVICE

Type 1A SPD provides suitable protection for facilities located where the level of exposure is high. General requirements are as follows:

- The device **shall** consist of primary modules using SAD technology and secondary modules using MOV technology.
- A SAD and MOV module **shall** be installed from each phase conductor to the neutral conductor (L-N, Normal Mode).
- Module or devices of any type **shall not** be connected between any phase conductor and the equipment grounding conductor or ground (L-G, Common Mode).
- The primary modules **shall** consist of a SAD module providing 500 Joules per phase, per polarity, minimum energy absorption.
- The secondary module **shall** consist of a Metal Oxide Varistor (MOV) module, with 5000 Joules per phase of energy absorption. This module **shall** be equal to, and have the same specifications and performance characteristics, as modules utilized in the Type 1 and Type 2 devices.
- The minimum pulse life or durability requirements and the voltage protection level **shall** be as specified in Table 9-2 for the respective Maximum Continuous Operating Voltage (MCOV) listed.
- SPD **shall** be properly selected based on the operating voltage and number of phases of the circuits to be protected.
- Each module or subassembly **shall** be modular in design to allow for easy field replacement.
- Module components **shall not** be encapsulated.
- Each module **shall** have indicator lamps visible from the front of the device showing that the module has power applied and that the protection integrity has not been compromised.

- The SPD **shall** include a set of form "C" dry contacts for remote alarm reporting capability. This set of contacts **shall** operate when there is an input power failure or the integrity of any module has been compromised. This contact set **shall** be isolated from the AC power circuitry to safeguard the alarm circuit or reporting device should there be a catastrophic event.
- Installation of Type 3 SPDs on each critical load is recommended in locations highly vulnerable to transient surges or lightning activity. Refer to "Type 3 Individual Equipment SPDs" on page 9-33 for application information.
- The device **shall** be UL 1449, 2nd Edition (or later revision) listed or recognized. Devices may also conform to the international CE certification mark.

9.4.2.3 TYPE 2 PANEL TYPE SURGE SUPPRESSION DEVICE

Type 2 SPD provides limited protection for specific applications. (See Table 9-1 on page 9-10 for specific applications.)

General requirements are as follows:

- The device **shall** consist of modules utilizing MOV technology installed from each phase conductor to the neutral conductor (L-N, Normal Mode).
- Module or devices of any type **shall not** be connected between any phase conductor and the equipment grounding conductor or ground (L-G, Common Mode).
- The SPDs **shall** consist of Metal Oxide Varistor (MOV) modules, with 5000 Joules per phase of energy absorption. This module **shall** be equal to, and have the same specifications and performance characteristics, as the MOV modules utilized in the Type 1 and 1A devices.
- The minimum pulse life or durability requirements and the voltage protection level **shall** be as specified in Table 9-2 for the respective Maximum Continuous Operating Voltage (MCOV) listed.
- SPD **shall** be properly selected based on the operating voltage and number of phases of the circuits to be protected.
- Each module or subassembly **shall** be modular in design to allow for easy field replacement.
- Module components **shall not** be encapsulated.
- Each module **shall** have indicator lamps visible from the front of the device showing that the module has power applied and that the protection integrity has not been compromised.
- The SPD **shall** include a set of form "C" dry contacts for remote alarm reporting capability. This set of contacts **shall** operate when there is an input power failure or the integrity of any module has been compromised. This contact set **shall** be isolated from the AC power circuitry to safeguard the alarm circuit or reporting device should there be a catastrophic event.
- Installation of Type 3 SPDs on each critical load is recommended in locations highly vulnerable to transient surges or lightning activity. Refer to "Type 3 Individual Equipment SPDs" on page 9-33 for application information.
- The device **shall** be UL 1449, 2nd Edition (or later revision) listed or recognized. Devices may also conform to the international CE certification mark.

9.4.2.4 TYPE 3 INDIVIDUAL EQUIPMENT SPDS

Individual equipment SPDs are available in many varieties. These may be wire-in receptacle outlet replacement types, plug-in adapters, or receptacle outlet panels or strips. General requirements are as follows:

- All individual equipment devices **shall** provide a minimum of 25 Joules of SAD Normal Mode (L-N) circuit protection.
- Common Mode (L-G) circuit protection **shall not** be permitted.
- Components within the device **shall not** be encapsulated.
- Individual devices with the plug manufactured as a combined part of the device **shall** be designed to be plugged into a single simplex receptacle outlet and **shall** incorporate a single simplex receptacle outlet for the load connection. Individual plug-in units with a duplex receptacle outlet **shall not** be used.
- Multi-receptacle outlet strip devices may incorporate multiple receptacle outlets and may also incorporate telephone or data circuit secondary protection devices within the same housing.
- Multi-receptacle outlet strip devices **shall** incorporate an independent ground point on the exterior of the device. This attachment point or stud **shall** be suitable for attachment of a lug sized for a 16 mm^2 csa (#6 AWG) conductor.
- Multi-receptacle device housings **shall** be metallic and **shall** be provided with mounting ears, tabs or brackets. Devices may be suitable for standard EIA 19 in. rack mounting.
- Each device **shall** have an indicator lamp visible from the front of the device showing that the module has power applied and that the protection integrity has not been compromised. Alarm relay contacts to remotely report device failure may be offered but are not required.
- The minimum pulse life or durability requirements and the voltage protection level **shall** be as specified in Table 9-2 for the respective Maximum Continuous Operating Voltage (MCOV) listed.

- Installation of Type 3 SPDs on each critical load is recommended in locations highly vulnerable to transient surges or lightning activity when the critical load is located greater than 3 m (10 ft.) of conductor length from the Type 1 SPD. Where the load is located between 3 to 15.3 m (10 to 50 ft.) of conductor length from a Type 1 device a Type 3 device is optional. Where the load is located greater than 15.3 m (50 ft.) of conductor length (7.6 m (25 ft.) of circuit length) from the Type 1 device, a Type 3 device is highly recommended. (See below.)

Conductor Length *		
0 - 3 m (0 - 10 ft.)	**3 - 15.2 m (10 - 50 ft.)**	**> 15.2 m (>50 ft.)**
Type 1 Required	**Type 1 Required Type 3 Optional**	**Type 1 Required Type 3 Highly recommended****

*** Lengths shown denote CONDUCTOR length. The CIRCUIT distance is ½ of conductor length shown.**
****In applications for standalone pole- or pad-mounted cabinets, where an SPD or a Type 2 SPD is not installed on the Utility Panelboard, Type 3 devices shall be installed on all loads.**

- The device **shall** be UL 1449, 2nd Edition (or later revision) listed or recognized. Devices may also conform to the international CE certification mark.
- Each multiple receptacle outlet strip type device incorporating telephone or data circuit protection **shall** be UL 1459 and UL 497A listed or recognized. Devices may conform to the international CE certification mark.

TABLE 9-2 SPD SPECIFICATIONS

Type SPD	Service Configuration	Nominal Svc. Voltage VAC (L-N)	MCOV VAC (L-N) Maximum	*Test/ Category	Voltage Protection Level (L-N) Maximum	Technology SAD/MOV (Joules)	Alarm Visual/Remote
Type-1							
Stand Alone Site	240/120 1ϕ 3-Wire	120-127	150	C1	330	250 / 5000	Yes / Yes
(Refer to Diagrams A	208/120 3ϕ 4-Wire	120-127	150	C1	330	250 / 5000	Yes / Yes
thru O)	415/240 3ϕ 4-Wire	240	275	C1	600	250 / 5000	Yes / Yes
	380/220 3ϕ 4-Wire	220	275	C1	600	250 / 5000	Yes / Yes
	480/277 3ϕ 4-Wire	277	320	C1	700	250 / 5000	Yes / Yes
	240 1ϕ 2-Wire	240	275	C1	600	250 / 5000	Yes / Yes
						250 / 5000	
Branch Service	240/120 1ϕ 3-Wire	120-127	150	C1	330	250 / 5000	Yes / Yes
(Refer to Diagrams K	208/120 3 ϕ 4-Wire	120-127	150	C1	330	250 / 5000	Yes / Yes
thru O)	415/240 3ϕ 4-Wire	240	275	C1	600	250 / 5000	Yes / Yes
	380/220 3ϕ 4-Wire	220	275	C1	600	250 / 5000	Yes / Yes
	480/277 3ϕ 4-Wire	277	320	C1	700	250 / 5000	Yes / Yes
	240 1ϕ 2-Wire	240	275	C1	600	250 / 5000	Yes / Yes
Type-1A 'High Exposure'							
Stand Alone Site							
(Refer to Diagrams A	240/120 1ϕ 3-Wire	120-127	150	C3	330	500 / 5000	Yes / Yes
thru O)	208/120 3ϕ 4-Wire	120-127	150	C3	330	500 / 5000	Yes / Yes
	415/240 3ϕ 3-Wire	240	275	C3	600	500 / 5000	Yes / Yes
	380/220 3ϕ 4-Wire	220	275	C3	600	500 / 5000	Yes / Yes
	480/277 3ϕ 4-Wire	277	320	C3	700	500 / 5000	Yes / Yes
	240 1ϕ 2-Wire	240	275	C3	600	500 / 5000	Yes / Yes
						500 / 5000	
Branch Service	240/120 1ϕ 3-Wire	120-127	150	C3	330	500 / 5000	Yes / Yes
(Refer to Diagrams K	208/120 3ϕ 4-Wire	120-127	150	C3	330	500 / 5000	Yes / Yes
thru O)	415/240 3ϕ 4-Wire	240	275	C3	600	500 / 5000	Yes / Yes
	380/220 3ϕ 4-Wire	220	275	C3	600	500 / 5000	Yes / Yes
	480/277 3ϕ 4-Wire	277	320	C3	700	500 / 5000	Yes / Yes
	240 1ϕ 2-Wire	240	275	C3	600	500 / 5000	Yes / Yes
Type-2							
(Refer to Diagrams	240/120 1ϕ 3-Wire	120-127	150	C1	400	--- / 5000	Yes / Yes
D thru F,	208/120 3ϕ 4-Wire	120-127	150	C1	400	--- / 5000	Yes / Yes
I, J, L, M, O thru Q)	415/240 3ϕ 4-Wire	240	275	C1	700	--- / 5000	Yes / Yes
	380/220 3ϕ 4-Wire	220	275	C1	700	--- / 5000	Yes / Yes
	480/277 3ϕ 4-Wire	277	320	C1	800	--- / 5000	Yes / Yes
	240 1ϕ 2-Wire	220	275	C1	700	--- / 5000	Yes / Yes
Type-3	120 1ϕ 2-Wire	120-127	140	A3	250	25 / ---	Yes / No

NOTES:

* **Location/Category** as defined by IEEE C62.41-1991 test methods: SPDs used at these locations **shall** meet the following parameters:
  - Tested to IEEE C62.45 waveforms, 1.2/50 open circuit voltage and 8/20 short circuit current. Location: C1: 6kVp / 3kA; C3: Combined 6kVp / 3kA and 20kVp / 10kA; A3: 200A - 100 kHz (see "AC Power Line SPD Test Certification Requirements" on page 9-47 for detailed testing descriptions and certification information).
  - The Voltage Protection Level equals the let-through voltage when the device is tested to the Test/Category C1. The tests **shall** be conducted with the device (EUT) connected as defined in Sub-Section 34.2 through 34.4 of UL 1449, 2nd Edition.

Durability Cycle Requirements: Type 1, 1A, 2 and 3 SPDs **shall** be tested to a minimum number of surges as described below. (See "AC Power Line SPD Test Certification Requirements" on page 9-47 for testing details.)
- Type-1: C1: 200 Minimum (+ and -) Alternating at 6kVp / 3 kA
- Type-1A: C3: 10 Minimum (+ and -) Alternating at 20kVp / 10 kA, 180 Minimum (+ and -) Alternating at 6kVp / 3 kA followed by 10 Minimum (+ and -) Alternating at 20kVp / 10 kA
- Type-2: C1: 200 Minimum (+ and -) Alternating at 6kVp / 3 kA
- Type-3: A3: 200 Minimum (+ and -) Alternating at 200 A per 62.41-1991

9.4.3 INSTALLATION REQUIREMENTS

All SPDs **shall** be installed per the manufacturers installation instructions and in accordance with all applicable codes. Type 1, 1A, and Type 2 devices **shall** be securely attached to the mounting surface and **shall not** depend on the interconnecting raceway for support.

9.4.3.1 LOCATION

When selecting the location, consideration must be given to conductor routing, length and required number of bends in each conductor. The SPD **shall** be installed as close as possible to the associated main disconnect or panelboard, and in a location that permits the shortest and most direct electrical connection. The most suitable location is immediately adjacent to the associated panelboard keeping the conductor length as short as possible. To accommodate this specification some manufacturers have developed specific models for installation directly above, below, or to the right or left of the associated panelboard.

9.4.3.2 INTERCONNECTING RACEWAY OR CONDUIT

The raceway or conduit between the panelboard (or disconnecting means) and the SPD **shall** be sized for the size and number of conductors to be routed through it. A non metallic conduit (such as PVC) or raceway is recommended. The length **shall** be as short as possible. This raceway **shall** be routed as direct as possible between the SPD, the disconnecting means (if a separate enclosure is used), and the associated panelboard. The raceway or conduit **shall not** be used as a support for the device.

9.4.3.3 CIRCUIT BREAKER OR DISCONNECTING MEANS

The manufacturer's installation instructions typically indicate that the SPD should be wired through a 60-Ampere (or larger) circuit breaker or a fuse device. This serves a double purpose in preventing a total site power outage in the event that the SPD self-sacrifices during a catastrophic lightning event, and allows a disconnecting means for servicing the SPD without disturbing site power. If the SPD utilizes self-contained over current protection, only a means to disconnect for servicing is required. Consideration **shall** be given to ensure that the proper type circuit breaker or disconnecting device is used. Molded case switches that offer over current protection **shall not** be used as a disconnecting device. Circuit breakers suitable for motor starting loads or loads with a high inrush current are most suitable.

9.4.3.4 CONDUCTOR SIZE, LENGTH AND ROUTING

Conductor size, total circuit length, and routing are critical to proper SPD performance. The conductor **shall** be of the minimum size recommended by the manufacturer, however, **shall not** be smaller than 16 mm^2 csa (#6 AWG). Larger conductor sizes are most desirable. A maximum conductor length of 61 cm (2 ft.) is most desirable. The conductors **shall** be routed together and **shall** be free of sharp bends or angles of less than 90 degrees.

9.4.3.5 PERFORMANCE EVALUATION

SPDs **shall** be evaluated using the specific criteria outlined in "AC Power Line SPD Test Certification Requirements" on page 9-47, and **shall** meet the requirements established in this section and Table 9-2 on page 9-35. Devices that do not meet this minimum criteria **shall not** be furnished, installed, or recommended for installation.

9.5 TELEPHONE/CONTROL/DATA NETWORK CIRCUIT SPDS

All copper circuit conductors entering any communications site, shelter, room equipment area or pole/pad mounted cabinet **shall** be protected with suitable SPDs. NFPA 70 requires that telephone, communications or data type circuit conductors be properly surge protected with a primary SPD as close as practicable to the point of entry into the structure or building. Some applications may require fused or resetable fuse type primary protection devices. SPDs equipped with jacks or cords and plugs **shall** have all through conductors protected. Conductors that are not extended through the device **shall** be bonded to the ground connection point. The protected (equipment) and unprotected (line or CO) terminations **shall** be clearly marked. A grounding conductor or a ground connection post or terminal **shall** be provided. Devices that have the grounding conductor incorporated by the manufacturer as an integral part of the device **shall** utilize an 8 mm^2 csa (#12 AWG), green jacketed, stranded copper conductor for a single line (2 pr, 4 conductor) device or a 16 mm^2 csa (#6 AWG), green jacketed, stranded copper conductor for a multi-line device. The conductor provided as an integral part of the device by the manufacturer **shall** be a minimum of 1.22 m (4 ft.) in length to accommodate various installation requirements. When installed, this conductor **shall** be cut to the length required to permit attachment to the ground bus or equipment grounding conductor and **shall** be as short as possible to help ensure maximum protection. The ground connection post or terminal **shall** be suitable for connection of an 8 mm^2 csa (#12 AWG) conductor for a single line device or a 16 mm^2 csa (#6 AWG) conductor for a multi-line device. All ground conductors **shall** be mechanically attached to the device circuit board and **shall not** be dependent on solder for connection integrity. The voltage limiting devices **shall** be connected between the line conductors and ground.

Primary and secondary SPD operating voltages are application dependent and **shall** be properly chosen. Coordination between the Primary and Secondary devices **shall** be considered to ensure the most effective level of surge protection. High speed data circuits require SPDs designed for these applications.

The metallic sheath of any telephone, control or data network cable **shall** be grounded as close as practicable to the point of entrance to any structure or in accordance with industry standards, and as specified in Chapter 7, "Internal Grounding." The goal is to keep high voltages from entering the building and damaging wire insulation or putting personnel safety in jeopardy.

9.5.1 PRIMARY PROTECTION

The primary SPD installation **shall** comply with all applicable codes. The devices **shall** be UL Listed or recognized, or conform to the international CE certification mark. The SPD **shall** be installed at the entrance point into any building and within close proximity to the electrical service entrance and the master ground bus bar. The SPD **shall** also be installed on remote cable runs between buildings to help ensure that high energy is not allowed to penetrate the building interior. In some applications a fused type primary SPD may be required (NFPA 70). To reduce the need for fuse replacement, devices that incorporate resetable fuse technology are recommended. Primary SPDs are available from most telephone product distributors and are typically supplied during installation by the telephone circuit supplier. The purpose of primary protection is to help ensure personnel safety and help protect internal cables from extremely high voltage. The primary SPD **shall** be grounded in accordance with NFPA 70 or other codes, industry standards, and as outlined in Chapter 7, "Internal Grounding." The ground conductor **shall** be as short as possible, **shall** be routed as directly as possible to the ground bus or MGB, and **shall** be as free of bends as is possible.

9.5.2 SECONDARY PROTECTION

Secondary SPDs (preferably including silicon avalanche diode technology) **shall** be installed. The SPDs **shall** be installed as close to the equipment being protected as possible. This includes (but is not limited to) the circuits associated with the base stations, repeaters, remotes, modems, consoles and channel banks that extend from the shelter, room or equipment area. This also includes any circuit staying within the same building, but extending outside the immediate equipment room or area. Secondary SPDs **shall** be UL 497A listed or recognized. The device may also conform to the international CE certification mark. Secondary protection may be included as an integral part of a Type 3 multiple receptacle outlet strip.

NOTE: The installation of a secondary SPD does not negate the need for a primary device where copper circuit conductors enter the building, shelter or equipment area.

The purpose of secondary SPDs is to limit transient over voltages to as close to the prescribed operating level of the protected equipment as is possible. The SPD also serves as a barrier against transient anomalies that may be induced between the cable entrance point and the equipment, and in cable runs within the building or shelter interior. The secondary SPD ground conductor **shall** be bonded to the equipment grounding conductor or ground bus conductor as outlined in Chapter 7, "Internal Grounding." This conductor **shall** be as short as possible, free of sharp bends, and **shall** be routed as directly to the equipment grounding conductor or ground bus as is possible.

The operating voltage and SPD configuration is application dependent. The lowest suitable voltage should be chosen to ensure the most effective level of surge suppression.

CAUTION

SPDs using SAD technology may develop an artificial diode bias when subjected to strong RF fields that may be experienced at AM, FM or TV broadcast sites. This bias may cause data circuit errors.

9.5.3 FIBER OPTIC CABLES

An intrinsic benefit of fiberglass (fiber optic) telephone lines is that they offer excellent isolation from line-induced lightning strikes, RF, and electrical noise coupling. The "fiber" telephone/data line is far from perfect as it can melt when subjected to high energy strikes or fire. No primary SPD is required for fiber circuits entering a building, shelter or equipment area; however, any metallic shield, jacket or drain conductor **shall** be bonded to the MGB. A secondary SPD may be installed on the equipment end of copper circuit conductors originating at a fiber optic interface in areas where the level of lightning exposure is high.

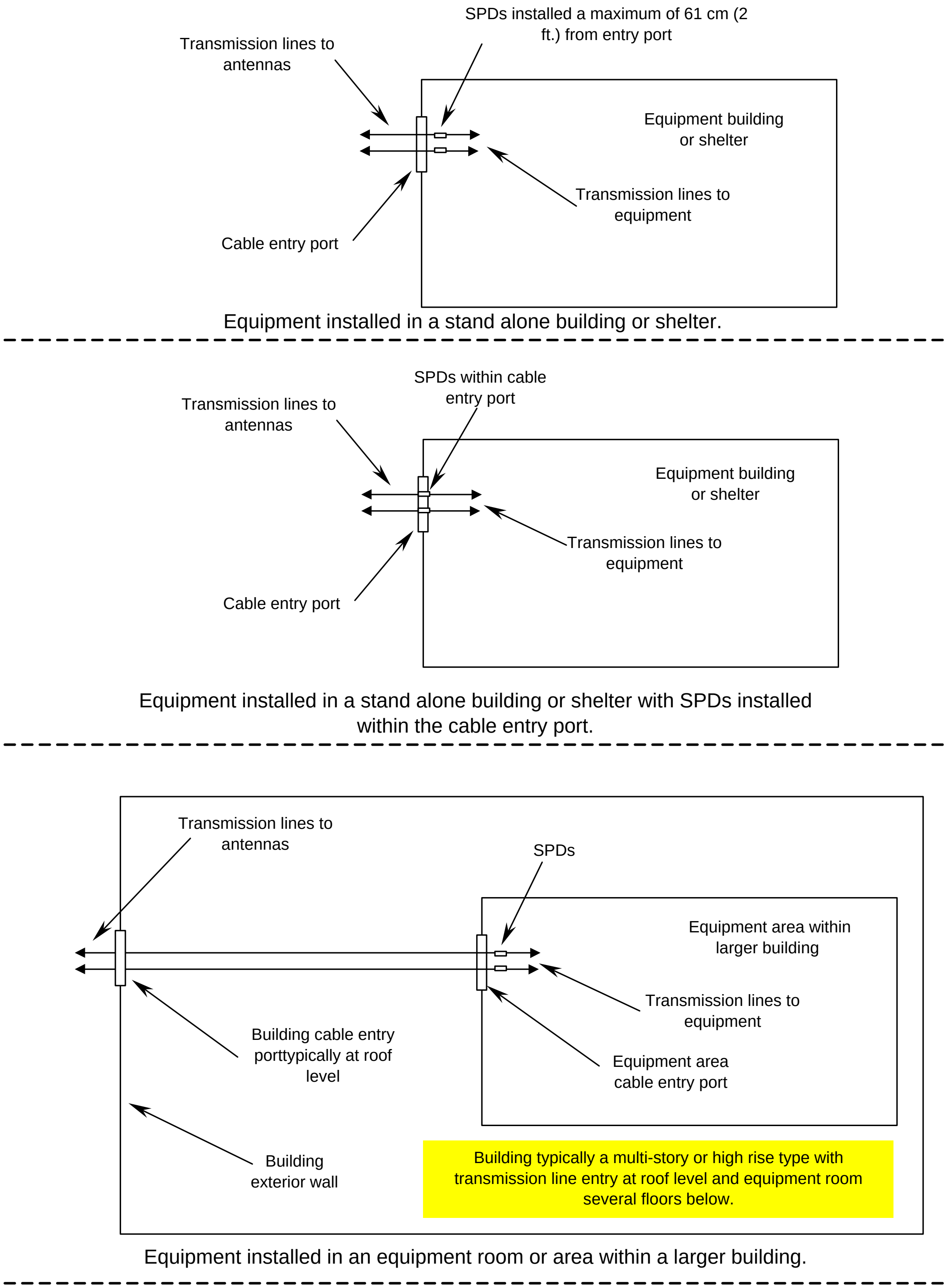
Suitable surge suppression devices offering primary and secondary protection are available from several surge suppression device manufacturers. Devices **shall** be selected based on the specific application and requirements specified above.

9.6 RF COMPONENTS PROTECTION

RF transmission lines from the antenna structure to the shelter or building **shall** be grounded as described in Chapter 6, "External Grounding." Upon entering the shelter or building, **all** RF transmission lines (including sample port (test) and unused spares) **shall** route through coaxial RF-type SPDs. The coaxial RF devices **shall** be bonded to the single point ground window as described in Chapter 7, "Internal Grounding." The SPD **shall** be located within the shelter, room or equipment area and **shall** be a maximum distance of 61 cm (2 ft.) from the transmission line entrance point into the shelter, room or equipment area as shown in Figure 9-19 on page 9-41. Some RF surge protection products can be installed at or within the entry port; this is the most desirable location to install coaxial cable SPDs if the entry port is located in the wall of the shelter, equipment room or area. If the equipment room or area is located within a larger building (such as a high rise structure), the SPDs **shall** be installed as specified above; not at the entry point into the building. In this application the transmission lines **shall** be grounded at the point where they enter the building; however, SPDs are not required to be installed at the building entry point.

Coaxial RF type SPDs come in several varieties, with the gas tube/reactive network types and the shorted stub types being most popular. The gas tube, when combined with a reactive bandshape network becomes an effective lightning protector for transmitters, receivers, CCTV, tower top amplifiers, and GPS active antenna systems. The gas tube, though "old technology" serves well for RF equipment coaxial circuit protection in that it has only two distinct states (ON and OFF). When not energized, the coaxial RF circuit protector presents a very high impedance, which is virtually lossless in terms of RF devices. When energized, the device presents a low-impedance short for the duration of the lightning strike, then returns to the open circuit state. At worst, the gas tube may explode during a lightning strike, but the radio equipment may likely have been saved from damage, and should continue to operate without degradation. While a silicon avalanche diode would appear to be the best surge suppression device, it is not suitable for use in RF circuits because it is a non-linear device. Non-linear devices produce intermodulation at radio frequencies.

Shorted inductor (or shorted stub) lightning surge protection devices can appear electrically as an open circuit or a short circuit, depending on the applied radio frequency and physical dimensions of the transmission line inductor or stub. Within the designed frequency band, the shorted inductor or stub appears as an infinite impedance, producing very little passive insertion loss. Shorted inductors are indeed "shorted" at DC and frequencies outside the designed passband. This makes for a very effective lightning energy shunt at all frequencies outside the designed passband.



NOTE: Ground and electrical details not shown.

FIGURE 9-19 TRANSMISSION LINE SPD INSTALLATION LOCATIONS

Shortcomings of the shorted inductor lightning protector which must be considered are that it will pass on-frequency lightning energy and that it must be made of compatible, non-ferrous materials or it also becomes an excellent intermodulation generator. The shorted inductor will not allow DC to pass, therefore it is not suited in CCTV, tower top amplifier, and GPS receiver applications where DC bias is multiplexed on RF transmission line. There are shorted stub inductor lightning protectors on the market which place a neon tube device in series with the tuned circuit to provide DC isolation. While this solves the DC voltage problem for tower top amplifier and GPS applications, it significantly limits current-handling capacity of the protection device and does not reduce the let through voltage to the level required for equipment survivability; such device **shall not** be used.

The shorted stub inductor device is frequency-sensitive, therefore it must be selected for the specific frequency band in use. Different bands multiplexed on the same transmission line will not work with band-limiting devices such as the shorted stub inductor. The shorted stub inductor device is mechanically large compared to other gas protector/reactive filter lightning surge protector devices in common use. There could quickly develop an installation space problem if a number of transmission lines are protected by individual shorted stub inductor devices at the common facility cable entrance port. The shorted inductor type device differs somewhat from the shorted stub inductor type device in that the shorted inductor type device incorporates a helical wound shorted inductor. These devices typically exhibit an open DC circuit through the device and have a much larger bandpass than a shorted stub inductor device.

All coaxial RF surge suppression devices **shall** exhibit an open DC circuit through the device (unprotected port center pin to protected port center pin), except those specifically designed to pass DC for CCTV, tower top amplifiers and GPS installations as described in this section and "GPS Receiver Protection" on page 9-44. The input and output ports **shall not** be directly connected and may have a capacitive or reactive network installed within the device to permit the RF energy to pass. The unprotected port and the protected port **shall** be clearly marked on the device.

A coaxial RF SPD will typically have a turn-on current threshold of approximately 1200 VDC in 7 nsec, exhibiting a VSWR of less than or equal to 1.1:1 or better over the frequency range, and an insertion loss of less than or equal to 0.1 dB over the frequency range. This device also is specified to handle a surge current of 20kA ANSI C62.1 8/20 waveform of 138 Joules.

The shorted inductor type protector can be expected to provide an impulse discharge current of 40 kA, with an insertion loss of 0.05 dB, and a 1.1 VSWR over the frequency range. As this is a permanently DC shorted device, it can respond almost immediately to lightning strikes (less than 4 µsec).

Selection of the proper SPD for RF transmission lines will depend on the specific application.

Some tower top amplifier configurations incorporate a control and alarm cable in addition to the RF transmission line and sample port (test) cable. This control and alarm cable is typically a multi-conductor cable connecting the tower top amplifier unit collocated with the receive antenna to the control chassis collocated with the receiver multicoupler. This cable is typically installed and routed with the receive antenna transmission line. Any shield within this cable **shall** be bonded to the MGB.

All conductors of this cable **shall** be protected by installation of a suitable SPD within a maximum of 61 cm (2 ft.) of the point of entry into the shelter, room or equipment area. The ground terminal of the SPD **shall** be bonded to the MGB with a 16 mm^2 csa (#6 AWG) or larger, green jacketed, stranded copper conductor.

The specifications for this SPD will be dependent on the design parameters of the tower top amplifier system, including the operating voltage and number of conductors within the control or alarm cable. The proper SPD **shall** be selected for the specific application. The device selected should have a turn-on voltage that is nominally 20% higher than the maximum DC operating voltage; however, the turn-on voltage **shall** be low enough to provide suitable protection. The tower top amplifier system and SPD manufacturer should be consulted for guidance in selecting the proper SPD.

CCTV and Cable TV system cables entering a communications facility **shall** have SPDs installed. These cables, like RF transmission lines, should by design enter the shelter, room or equipment area at the same location as the RF transmission lines. When there are no RF transmission lines at the facility where these systems are installed (dispatch and command centers) the cables should enter as close as is practicable to the point where the power and telephone conductors enter the facility. The shield of these cables **shall** be bonded to the MGB. The SPD **shall** be installed within 61 cm (2 ft.) of the point of entry of the cable(s) into the shelter, room or equipment area. The ground terminal of the SPD **shall** be bonded to the MGB with a 16 mm^2 csa (#6 AWG) or larger, green jacketed, stranded copper conductor as described in Chapter 7, "Internal Grounding."

The proper SPD **shall** be selected based on the application. Some CCTV systems will provide DC power to the remote camera via the coaxial cable. The Cable TV service provider or the CCTV manufacturer, as well as the SPD manufacturer, should be consulted for guidance in selecting the proper SPD for the specific application.

9.7 GPS Receiver Protection

Global Positioning System (GPS) receivers are often a part of a modern communications system. GPS receivers are used for site timing and synchronization. Failure of a GPS receiver will usually render the radio system unusable. GPS receiver systems on telecommunications sites typically include a GPS receiver which is built-into the basic radio equipment, an amplified GPS antenna unit, and low-loss transmission line. The GPS antenna includes a GaAsFET device wideband RF amplifier. The RF amplifier is fed with low-voltage DC (around 15 VDC) through a multiplex arrangement using a single coaxial transmission line which also serves to couple the incoming GPS signal from the antenna to the receiver. A fused power supply within the radio equipment provides the RF amplifier operating voltage.

Damage to the GPS receiver can be induced directly from an antenna head strike, or through induced coupling from other transmission lines on the same antenna structure. There is little that can be done to effectively protect the GPS antenna unit itself from direct lightning strikes, other than to assure that it is **never** mounted at the highest point on the tower. The GPS system coaxial transmission line **shall** be installed and grounded in accordance with the practices described in Chapter 6, "External Grounding." A special GPS coaxial RF SPD **shall** be installed within 61 cm (2 ft.) of the cable entry port and bonded to the MGB as described in Chapter 7, "Internal Grounding." Also refer to "RF Components Protection" on page 9-39 and Figure 9-19.

The GPS compatible RF coaxial lightning protector is different from normal coaxial protectors in that it is designed to pass the DC bias through the coaxial line which is required to power the antenna-mounted amplifier. Before selecting a coaxial SPD, it should be verified that the GPS receiver can operate with an SPD in the coaxial line. In most installations the GPS receiver will require optimization to compensate for the delay caused by the SPD and the variations in the length of the transmission line (which is site specific). The GPS antenna transmission line **shall** be cut to the proper length as excess transmission line **shall not** be coiled either inside or outside the shelter, room or equipment area.

All coaxial RF surge suppression devices **shall** exhibit an open DC circuit through the device except those specifically designed to pass DC for CCTV, tower top amplifiers and GPS active antenna installations. These devices **shall** incorporate a circuit to pass the DC power while providing suitable surge protection for the DC circuit path. The input and output ports **shall not** be directly connected and may have a capacitive or reactive network installed within the device to permit the RF and DC energy to pass.

A DC injector/DC path coaxial hybrid RF SPD will typically have a turn-on voltage nominally 20% above the maximum DC operating voltage, with a turn-on time of 4 nsec for 2 kV/nsec. This protector will also offer a VSWR of less than or equal to 1.2:1 over the frequency range, and an insertion loss of less than or equal to 0.3 dB, handling a 20 kA, ANSI C62.1 8/20 waveform of 138 Joules.

The proper surge suppression device **shall** be selected for the specific application. Different active GPS receiver antennas will have different DC power supply voltages on the transmission line. The device selected should have a turn-on voltage that is nominally 20% higher than the maximum DC operating voltage; however, the turn-on voltage **shall** be low enough to provide suitable protection.

9.8 TOWER LIGHTING PROTECTION

All tower lighting system power, control and alarm conductors **shall** have SPDs installed at the point of entry into the building, shelter, room or equipment area. If the equipment room or area is located within a larger building and several feet away from the point where the conductors enter the building, the SPDs **shall** be installed within 61 cm (2 ft.) of the equipment room or area entry point or wall penetration.

AC power conductors **shall** have normal mode (L-N or L-L) surge suppression devices installed. Common mode (L-G) devices **shall not** be used on AC power circuits, although common mode devices will provide the most effective suppression on alarm and modem circuits and may be used on these circuits.

Tower lighting protection is typically overlooked in communications facility design. Tower lighting systems typically use either incandescent lamps, strobe lighting or both. These systems are typically powered from an AC circuit originating from the utility panelboard. Conductors connecting the lamps or lighting heads to a control unit at the tower base may be installed within conduit or be attached directly to the tower structure. Routing of flexible lighting power and controller cables is critically important.

CAUTION

Tower lighting cables shall not be bundled along with transmission lines or other conductors anywhere within cable ladders, or the building interior.

Tower lights or beacon power and control conductors can provide a path for conducting lightning energy into the shelter, building or equipment area. These conductors should be installed such that lightning energy **shall not** be routed through the building, shelter, room or equipment area where this energy may be inductively coupled into critical equipment interconnecting cables. For this reason an exterior location is preferable and highly recommended. Many manufacturers provide a weatherproof enclosure suitable for outdoor installation as a standard product. Others offer the weatherproof enclosure as an option, which can be easily ordered. The weatherproof tower light controller housing may be mounted to a tower leg, a pedestal alongside of the antenna structure or to the exterior surface of the shelter or building.

If the tower lighting controller is installed within the building, shelter, room or equipment area, it **shall** be located as close to the cable entrance port as practicable. All control unit metallic housings **shall** be bonded to the exterior ground system or the interior perimeter ground bus or MGB based on their location.

Strobe lighting systems may use voltages in excess of 600 VDC; therefore, installation of a surge suppressor on these power conductors to the strobe light heads is not reasonable and will not adequately reduce surge voltages that may enter the shelter. For this reason it is recommended that tower lighting controllers be located outside the shelter. Suppressing voltage transients on the AC power, alarm and modem conductors of control units located outside the shelter, building or equipment area can be effectively done by installation of a suitable SPD at the point of entry of the conductors into the shelter, building or equipment area. Tower light AC power, alarm and modem cables **shall** enter the shelter, building or equipment area within or adjacent to the antenna transmission line entry port location. The ground conductors of the SPDs **shall** be bonded to the MGB at this point.

Some tower lighting manufacturers offer an optional surge suppression device that may be installed within the tower lighting control unit. Although this device may be suitable for protecting the control unit circuitry, it does not provide adequate protection to inductively coupled energy that may enter the shelter, building or equipment area through the tower light power or control conductors.

Suitable surge suppression devices offering protection for AC power, control and modem circuits are available from several surge suppression device manufacturers. Devices **shall** be selected based on the specific application and requirements specified above.

9.9 BATTERY POWERED PROTECTION

As telecommunications systems and sites have changed, so have power requirements. Cellular, PCS, and iDEN systems typically operate from a battery plant. Motorola Communications Enterprise equipment is also available with a DC power capability. The battery plants are usually powered by AC battery charging systems. Cellular, PCS and iDEN Mobile Switching Offices (MSO) or Central Offices also operate from a large battery system. Most of these sites adopt the telephone/microwave systems convention of -48 VDC, but some applications can use ±24 VDC as well as 12 VDC.

A battery powered site offers a level of isolation from the AC power system affording some surge protection, voltage regulation, and electrical feed noise suppression to the equipment load. A battery system will attempt to maintain a normalized voltage, absorbing variations in voltage. This can be an effective method of surge suppression when the equipment is located within a **conductor length** of 6 m (20 ft.) from the battery plant; or a **circuit length** of 3 m (10 ft.) from the battery plant.

A DC SPD in the form of a SAD and MOV matrix device is recommended for installations where the equipment is separated from the battery plant by a **conductor length** exceeding 6 m (20 ft.); or a **circuit length** exceeding 3 m (10 ft.) from the battery plant. This protection is also recommended for installations in an area where the level of lightning exposure is high. The SPD voltage rating and polarity **shall** be coordinated with the circuit voltage and polarity of the battery plant.

To maximize the effectiveness, the SPD should be installed at the equipment to be protected. Additional devices are recommended for each DC equipment load at the site.

Suitable surge suppression devices are available from several surge suppression device manufacturers. Devices **shall** be selected based on the specific application and requirements specified above.

9.10 AC POWER LINE SPD TEST CERTIFICATION REQUIREMENTS

AC power line SPDs which are recommended, distributed or installed by Motorola **shall** meet the specifications requirements cited in "AC Power SPD Requirements" on page 9-7, and those specified in Table 9-2, "SPD Specifications" on page 9-35. Additionally, these devices **shall** have been certified as meeting the criteria cited in "Impulse Surge Durability Test Requirements" on page 9-48 below.

Manufacturers of AC power line surge suppression devices may have an independent laboratory test their products for compliance with the specifications cited in "AC Power SPD Requirements" on page 9-7, and Table 9-2, "SPD Specifications". These tests **shall** follow the procedure outlined in the "Impulse Surge Durability Test Requirements" below and **shall** be done at no cost to Motorola. The results of these tests **shall** be certified by the independent laboratory and **shall** be submitted to representatives of Motorola for review. Devices that have been tested following the procedure established below and found to be compliant with the specifications cited in "AC Power SPD Requirements" on page 9-7, and those specified in Table 9-2, "SPD Specifications" **shall** be considered to have met the device requirements established by Motorola.

Motorola **shall** be afforded the opportunity to have their representative or representatives present at the time of the testing to witness and verify the test data compiled by the independent laboratory. The manufacturer may request that the test results be considered proprietary and may request that the information not be disclosed by representatives of the independent laboratory or Motorola.

Motorola, at their option and expense, may purchase additional units from the manufacturers normal production and have these devices tested by an independent laboratory of their choice following the same test criteria. Should it be found that the units purchased fail to meet the requirements as defined in "AC Power SPD Requirements" on page 9-7, and Table 9-2, "SPD Specifications", the manufacturer **shall** be notified. Motorola may, at their option, discontinue recommending, distributing or installing the product at any time.

9.10.1 IMPULSE SURGE DURABILITY TEST REQUIREMENTS

9.10.1.1 GENERAL

This test is to stress the Type 1, 1A, 2 and Type 3 SPDs further than the UL 1449 2nd Edition "Duty Cycle" test. It will be a similar procedure as defined in 34.10 of UL 1449, 2nd Edition. Connections to the Equipment Under Test (EUT) **shall** be as defined in Sub-Section 34.2 through 34.4 of UL 1449, 2nd Edition.

9.10.1.2 TEST REQUIREMENTS

9.10.1.2.1

The surge generator **shall** be calibrated as specified in sub section 34.5 (UL 1449, 2nd Edition). For Types 1 and 2, the open circuit **shall** be 6 kVp and the short circuit current **shall** be 3 kA. For Type 1A, the open circuit **shall** be 20 kVp and the short circuit current **shall** be 10 kA. Tolerances and waveform **shall** be as described in 34.5 (UL 1449, 2nd Edition). This test is for Type 1, 1A and 2 SPDs only.

9.10.1.2.2

The test voltage and current **shall** be as follows:

1. For Types 1 and 2, the test voltage and current **shall** be 6 kVp at 3 kA, respectively.
2. For Type 1A, the test voltage and current **shall** be a combination of pulses at 6 kVp at 3 kA and 20 kVp at 10 kA. This test **shall** consist of 10 impulses at 20 kVp / 10 kA, followed by 180 impulses at 6 kVp / 3 kA, followed by 10 impulses at 20 kVp / 10 kA respectively per polarity. The total number of impulses being 400.
3. For Type 3, the test current and frequency **shall** be 200 A and 100 kHz. These values will be used to compare for pass or fail criteria during the post test.

9.10.1.2.3

The total number of impulse for each type of SPD (Type I, IA, 2 and 3) is four hundred (400). Two hundred (200) surges **shall** be positive at a phase angle of 90° (+0,-15°) and two hundred (200) surges **shall** be applied negative at a phase angle of 90° (+0,-15°).

9.10.1.2.4

The surges **shall** be conducted in succession, alternating polarity, with a maximum of 60 second period between each surge.

9.10.1.2.5

This is a “Type test” and only two (2) samples **shall** be required.

9.10.1.2.6

Type 3 SPDs **shall** be tested with 100 kHz ringwave as defined in C62.45- 1992 at 200 A. (Category A3 per C62.41-1991)

9.10.1.3 POST-TEST (PASS OR FAIL)

9.10.1.3.1

Following the test as defined above (paragraphs 9.10.1.2.1 through 9.10.1.2.6), the representative devices **shall** be allowed to cool to room temperature and then be subjected to the measurement of limiting voltage as specified in Sub-Section 34.9, but with the short circuit amount to be 3 kA for Type 1, 1A and 2. Type 3, 200A per 62.41-1991. The result measured limiting voltage **shall not** deviate more than 10% from the original values measured and **shall not** exceed the manufacturers marked suppressed voltage rating by 10%.

9.10.1.3.2

The same two representative devices **shall** be operated on the AC power line at nominal system voltage or the manufacturer's operating voltage rating, whichever is greater, for 7 hours or until thermal equilibrium.

9.10.1.3.3

The same two representative devices **shall** be subjected to, and comply with, the Leakage Current Test requirement, Of Dielectric Voltage Withstand Test requirements of Section 32 (UL 1449, 2nd Edition).

9.10.1.3.4

During and following the Measured Limiting Voltage test, the following conditions **shall not** result in:

1. Emissions of flame, molten metal, glowing or flaming particles through any openings (pre-existing or created as a result of the test) in the product.
2. Ignition of the enclosure.
3. Creation of any openings in the enclosure that results in accessibility of live parts, when judged in accordance with section 13 of UL 1449, 2nd Edition.
4. A supplementary protection device opening.

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CHAPTER 10

MINIMIZING SITE INTERFERENCE

This chapter provides information on preventing radio frequency (RF) interference at a communications site.

10.1 INTRODUCTION

Wireless communications equipment utilizes RF energy to carry information (voice or data) between two or more locations. Unlike mobile units that can be moved to an interference-free area, fixed sites must incorporate equipment and techniques to reduce the likelihood of interference.

This chapter describes the minimum filtering and techniques that should be applied at any fixed site to minimize interference. These techniques should be used by a site manager or carrier to define the minimum essential elements to achieve successful operation. Implementation of these requirements will provide an environment for both successful operation and future expansion.

Site studies are required to define additional filtering or isolation that may be required between the various transmitters and receivers at the site. The local Motorola Engineering team can provide support in this area by utilizing design evaluation techniques for things like Transmitter Noise (TN) and Receiver Desensitization (RD) to accurately determine any additional isolation or protection requirements.

The requirements defined in this chapter pertain to eliminating interference, and are separate from the RF Engineering design of the site.

10.2 INTERFERENCE PROTECTION RECOMMENDATIONS

The ability to successfully receive the desired radio signal at the fixed receiver is dependent upon providing the best possible radio frequency environment at the site. To accomplish this, the level of undesirable energy occurring on the received frequency must be minimized. In most cases, minimizing the level of undesirable energy emitted by the local transmitters and filtering out undesirable signals coming into the receiver eliminates received interference in the receiver environment. Interference is more likely to be a problem at sites with multiple antennas (dense sites, see Figure 10-1 for an example). If these measures have been taken and the receiver is still picking up noise, then noise sources in the surrounding environment must be identified and eliminated.

FIGURE 10-1 EXAMPLE OF DENSE SITE

A successful communication site should have standards that are applied to all users of the site and recommended to other communications sites in the general vicinity. Another site within a quarter mile radius may interfere with your site or may receive interference from your site unless protective equipment and techniques are used.

The techniques described in this section have a history of successful implementation, and are not specific to any particular radio or filter vendor. The protective equipment to be used is available from numerous vendors that have met Motorola's criteria for product performance, reliability, and support. Contact the local Motorola engineering team for additional details.

Transmitter noise, receiver desensitization and unwanted intermodulation caused by objects in the site environment are the most common causes of receiver interference. Requirements for preventing problems in each of these areas are described below.

10.2.1 MINIMUM TRANSMITTER PROTECTION REQUIREMENTS

A properly designed site will incorporate several techniques to reduce the likelihood of the transmitters causing interference to a receiver signal. Each transmitter should have an isolator, low pass filter and bandpass cavity setup. The number of isolators and bandpass cavities needed for a transmitter to achieve proper filtering is dependent upon the transmitter equipment and frequencies at the communication site and other transmission sites in the local area. If additional help is needed to determine these requirements, contact the local Motorola engineering team for additional support.

An isolator is used on a transmitter to reduce the amount of radio energy, which is coming back into the final amplifier stage from the antenna system. This action in turn reduces the undesirable signal levels of other radio signals coming back into the final amplifier stage and helps to prevent a mixing of two or more different frequencies within the non-linear device. The mixing process is called transmitter intermodulation and it can generate interfering frequencies for receivers. In some situations, the isolator can produce second harmonic spurious emissions, which are also harmful to receiver reception. To protect against this a low pass filter should used between isolator stage and the antenna system.

A bandpass cavity is a high Q resonant circuit, which is designed to pass a narrow band of frequencies with very little energy loss while attenuating all other non-resonant frequencies. Bandpass cavities should be installed between the transmitter and antenna system to reduce spurious signals and transmitter sideband noise that might otherwise be radiated from the transmitter and degrade the performance of nearby receivers. The use of a bandpass cavity will also reduce and minimize transmitter intermodulation since all off-frequency signals from other nearby transmitters will be attenuated as they pass through the cavity.

For successful operations and future expansion of the site, the following recommendations should be considered when installing transmitters within the following frequency bands. Refer to Figure 10-2 for proper configuration of the recommended filtering devices.

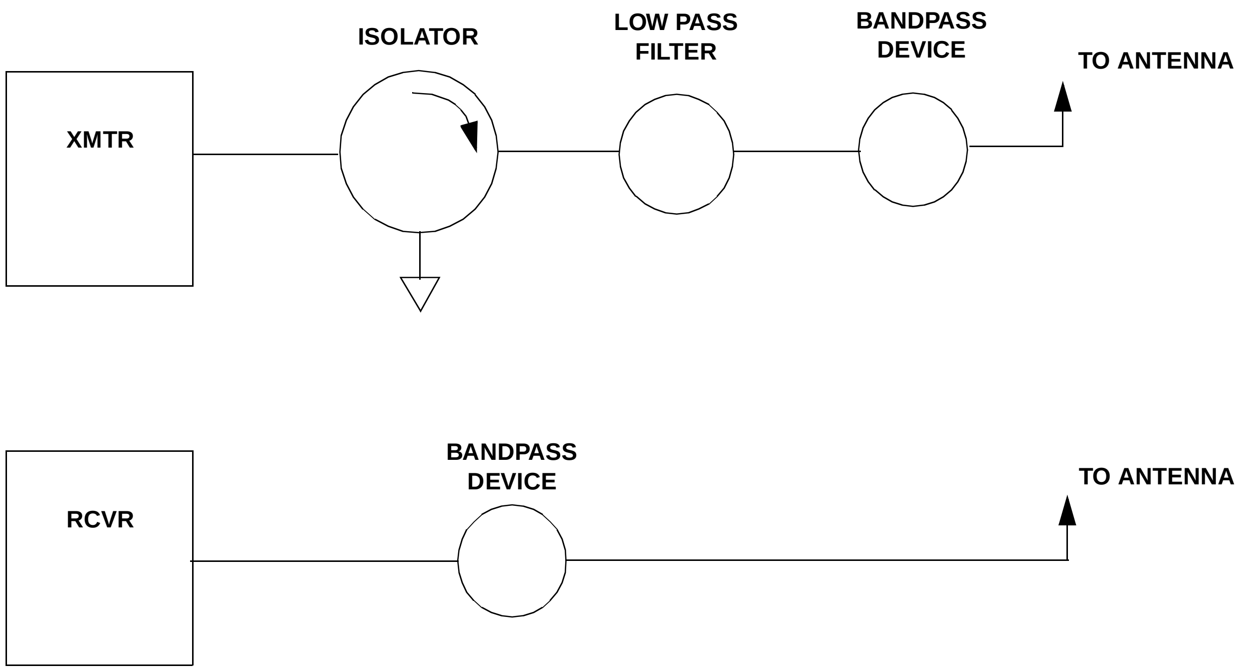

FIGURE 10-2 CONFIGURATION OF FILTERING DEVICES

25-54 MHz - Transmitters in this range **shall** have an isolator with a minimum of 20dB reverse isolation followed by a low pass filter and a bandpass cavity setup, which provides a minimum of 20dB of attenuation at 1 MHz from the transmit frequency.

66-88 MHz - Transmitters in this range **shall** have an isolator with a minimum of 25dB reverse isolation followed by a low pass filter and bandpass cavity setup, which provides a minimum of 20dB of attenuation at 1 MHz from the transmit frequency.

130-225 MHz - Transmitters in this range **shall** have a set of isolators with a minimum of 50dB reverse isolation followed by a low pass filter and a bandpass cavity setup, which provides a minimum of 25dB of attenuation at 1 MHz from the transmit frequency.

276-284 MHz - Transmitters in this range shall have a set of isolators with a minimum of 50dB reverse isolation followed by a low pass filter and a bandpass cavity setup, which provides a minimum of 25dB of attenuation at 1 MHz from the transmit frequency.

400-512 MHz - Transmitters in this range **shall** have a set of isolators with a minimum of 50dB reverse isolation followed by a low pass filter and a bandpass cavity setup, which provides a minimum of 15dB of attenuation at 1 MHz from the transmit frequency.

806-960 MHz - Transmitters in this range **shall** have a set of isolators with a minimum of 50dB reverse isolation followed by a low pass filter and a bandpass cavity setup, which provides a minimum of 15dB of attenuation at 1 MHz from the transmit frequency.

10.2.2 MINIMUM RECEIVER PROTECTION REQUIREMENT

A properly designed fixed site will require that each receiver input be connected to a crystal filter, window filter and/or bandpass cavity to minimize or eliminate receiver desensitization. These devices will create a narrow band window to allow only the desired receive signal to enter the receiver. If the interference is very close in frequency to the receiver frequency, a dual or triple bandpass cavity setup or notch filter may be required. This is normally a less costly and more permanent option to moving the receiver antenna to an alternate location. If additional support is necessary contact the local Motorola engineering team.

10.2.3 SITE ENVIRONMENTAL REQUIREMENTS

A properly designed communication site uses the following preventive measures to minimize and eliminate locations where radio signals can mix and create intermodulation frequencies or broadband noise.

- Rust - All materials must be free of rust.
- Braided wire **shall not** be used because it can corrode and cause intermodulation signals.
- Rigid metal connections - Metal to metal connections must be rigid.
- All loose metal should be removed from the site.
- Fencing - Chain link type fence material should be vinyl clad.
- Dissimilar metals - Connection of dissimilar metals should be done after review of the Galvanic table (Table 6-3 on page 6-59) for each metal. The connections must be rigid and tight.
- Transmission line – Unjacketed transmission line is prohibited.
- Cable ties – Bare metallic cable ties **shall not** be used.
- Power line insulators (glass type) – Cracked insulators are a very likely source of broadband noise. If broadband noise cannot be eliminated by implementing the above recommendations, contact the local utility company and ask them to perform a noise sweep of the general area.

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CHAPTER 11

EQUIPMENT INSTALLATION

This chapter includes the following topics:

11.1 INTRODUCTION

This chapter describes requirements and standard methods for communications equipment installation.

NOTE: The requirements described in this chapter **shall** be met before communications equipment is installed in site.

NOTE: This chapter assumes that all site and structure preparations have been performed (including battery systems, generators, line transient voltage suppression systems, tower systems, and site/structure grounding systems).

11.2 FACILITY READINESS

Following all construction work, both exterior and interior, the site and facility (structure or shelter) **shall** be in a suitable condition for installation of communication equipment. In general, the following considerations need to be observed:

- Interior of facility **shall** be free of excessive dust.
- Site exterior area **shall** have all refuse related to the installation tasks described in this manual removed before occupancy.

11.3 GENERAL CONSIDERATIONS FOR LAYOUT, WORK AREAS, AND SPACING

Consideration should be exercised when laying out a site to allow primarily for all code requirements for spacing, and then the most efficient use of space. Special attention **shall** be given to future expansion with regard to cable runway heights, electrical outlet placement, and equipment placement. Figure 11-1 shows proper equipment layout.

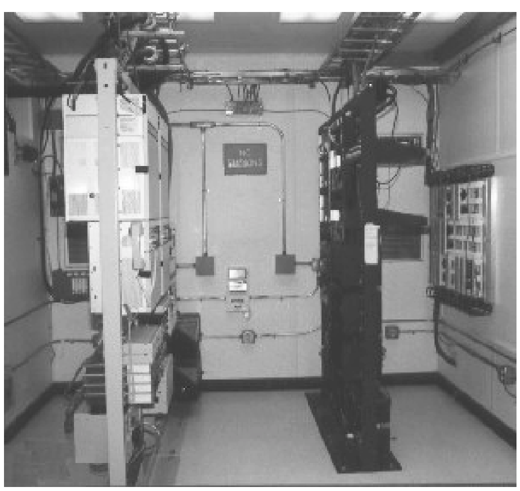


FIGURE 11-1 TYPICAL SITE INSTALLATION SHOWING PROPER EQUIPMENT LAYOUT

11.3.1 SPACING REQUIREMENTS

Proper spacing of equipment is essential for efficient use of the room area, ease of maintenance, and safety of personnel. The following specifications have been established to meet the National Fire Protection Associations (NFPA) Code, and the American Society of Heating, Refrigerating, and Air Conditioning Engineers (ASHRAE) standards. Any local regulations, as applicable, **shall** also be adhered to.

- To provide adequate working space, a 0.37 m^2 (576 sq in.) footprint (as measured from facing equipment surfaces) **shall** be used for combining equipment and upright base station equipment.

  NOTE: Local codes may require additional clearance than stated above. In such cases, the local code **shall** prevail.

- 91 cm (36 in.) front and side aisles **shall** be maintained around electrical panel boards (NFPA 70, Article 110-26).
- 91 to 122 cm (36 to 48 in.) front, side, and (where applicable) rear aisles are required for servicing interior mounted air conditioners (NFPA 70, Article 110-26, ASHRAE).
- 91 cm (36 in.) aisle **shall** be maintained in front of all telephone switching or demarc equipment.
- 91 cm (36 in.) aisle **shall** be maintained between at least one end of an equipment row and building wall or other obstruction; longer aisles may require additional access breaks. Larger aisles and additional access breaks in a row may be required as the row becomes longer, such that a fire in the aisle does not prevent egress. Comply with any codes regarding fire egress specifications.
- Ingress and egress to equipment rooms **shall** conform with NFPA 70, Article 110 and local building and fire codes.
- In US installations where a facility is to be normally occupied, American with Disabilities Act (ADA) **shall** be complied with. Some general requirements of ADA are 91.5 cm (36 in.) wide doors, ramps and safety rails, 91.5 cm (36 in.) turn-around clearance for wheelchairs, and specific placement of telephones, fire extinguishers, light switches, etc. Note that ADA compliance in architectural plans may be required in obtaining a construction permit in some localities.

11.4 SEISMIC CONSIDERATIONS

Site protection from earthquakes may be required in certain areas. Typically, this would be an area having historical data indicating a Moment Magnitude rating of 3 or 4. Note that areas other than historically prone areas may need consideration. Obviously, addressing such concerns results in increased costs of equipment installation.

A certified architect specializing in earthquake-resistant installation **shall** be consulted for seismic designs and recommendations in areas where the potential loss of the site may outweigh associated costs of earthquake-resistant design. In the United States, it is recommended to consult the US Geological Survey for more information regarding earthquake probability and historical data for various areas. In other areas, similar consultation should be done.

NOTE: US Geological Survey information can be accessed at
http://geohazards.cr.usgs.gov
Seismic maps are available at:
http://www.neic.cr.usgs.gov/

11.4.1 GENERAL RECOMMENDATIONS

Earthquake-resistant design should be contracted to a firm specializing in such work. However, the following general considerations need to be observed and factored into a seismic design program:

- Equipment **shall not** be secured to both the shelter walls and floors, since dissimilar movement between these surfaces is likely in an earthquake.
- Mounting should provide for some "sway" in the overall equipment mounting, thereby absorbing the energy of an earthquake. This is typically accomplished by rigid mounting of racked equipment or cabinets at the base, while semi-rigidly attaching the rack top using 3.2 mm (1/8 in.) diameter steel braided wire rope. Wire rope anchors are then secured to ceilings joists. The benefit of this type of installation is that racks are allowed to sway within limits but can't fall over.
- Cabinet designs with wide footprints can be used to help prevent cabinets from tipping over.
- Columns of cabinets stacked and bolted back-to-back present a very stable and wide footprint. The bottom cabinets **shall** still, however, be bolted to the floor for complete security.
- Some cabinets can be outfitted with outrigger-type support legs to prevent tip-over. These outriggers alone do not provide adequate earthquake protection, but are typically adequate if the cabinet is bolted to the floor.

NOTE: If a rack is seismic rated, any add-on aftermarket equipment or equipment that is not seismic rated will render the overall package as not being seismic tested and certified as a unit. Therefore, the unit would no longer be considered as seismic rated.

- When bolting down to computer floor, be sure to anchor all the way to the sub-floor.
- Columns of cabinets must be supported, though **not** rigidly. Rigid mounting will result in extreme vibration and resultant mechanical failure during an earthquake. Semi-rigid mounting is preferred. Semi-rigid bracing is defined as bracing which allows a measurable amount of movement.

- Some computer floors lose mechanical integrity if several panels are simultaneously removed. This could lead to equipment floor collapse during an earthquake. The flooring manufacturer **shall** be consulted for floor removal procedures.
- Equipment **shall** be stabilized by a top support. This is critical in preventing a column of equipment from toppling, causing injury to personnel. The footings of cabinet columns and racks **shall** be bolted to the floor as appropriate, using concrete anchors. Sometimes the cabinet columns are placed on C-channel tracks or wooden pedestals.
- Cables and transmission lines should not be installed rigidly, and without strain relief. Make broad service loops.
- Lighting fixtures should be prevented from swaying by addition of one or more guy wires. A fluorescent lighting fixture in particular, can be very dangerous if allowed to swing against a wall or equipment racks, shattering and spraying broken glass below. Fluorescent lighting fixtures **shall** have protective lenses or protective plastic sleeves which cover the fluorescent tube, preventing broken glass from falling on occupants.
- Storage cabinets **shall** be secured to the wall to prevent upset. Storage cabinets **shall** also have closable, secured doors to prevent contents from spilling during an earthquake.
- Ladders and other large objects **shall** be secured to a wall or removed from the equipment room when not in use. These items have been known to fall into "live" equipment during earthquakes.

11.5 EQUIPMENT MOUNTING PLUMB AND SQUARENESS

- Equipment **shall** be level and plumb. Equipment level **shall** be tested on a known flat surface in at least two directions to verify accuracy.
- Equipment **shall** be parallel or perpendicular to the surrounding walls and adjacent installed equipment.

11.6 EQUIPMENT ANCHORING

Anchoring is the mechanical fastening of the communications equipment to suitable locations using hardware acceptable for the application.

Although every installation is unique, certain methods for anchoring **shall** be adhered to for all installations. Typically, at least four anchor points **shall** be used on each item of equipment mounted to the floor. (The only exception is when the equipment manufacturer supplies other than four mounting points.)

> **NOTE:** Where seismic concerns exist (Moment Magnitude rating 3 or greater), refer to "Seismic Considerations" on page 11-3 for additional information and requirements.

11.6.1 MOUNTING ON CONCRETE FLOORS

11.6.1.1 GENERAL REQUIREMENTS

Equipment racks or cabinets should be positioned and anchored to the floor using preferred mounting methods. Figure 11-2 on page 11-8 shows proper concrete mounting techniques and materials. In general, observe the following considerations:

- An anchor specifically designed for concrete **shall** be used. The preferred method for anchoring racks, or other ancillary equipment to concrete floors is to use flush-mount expansion anchors properly sized for the application. Flush mount expansion anchors do not extend above the surface of the floor and provide an easy bolt down. They also provide the required pullout and shear strength. If at a later time equipment needs to be moved, flush mount expansion anchors do not get in the way.

> **NOTE:** Unless an isolating mounting scheme is used (refer to "Isolated Mounting" on page 11-9), ensure that no anchors come in contact with reinforcing rods or wire mesh buried in the concrete; the rack **shall** be electrically isolated from any other equipment or materials at the site.

- In applications where flush mount expansion anchors are not preferred or acceptable, then wedge-type stud anchors may be used.
- All concrete anchors **shall** be zinc plated carbon steel for standard applications, galvanized steel for mildly humid or corrosive environments, and yellow zinc or stainless steel for humid, highly corrosive, or acidic environments. Minimum bolt diameter **shall** be 10 mm (0.375 in.) with 12 mm (0.5 in.) preferred. Anchor embedment depth should be at least 76 mm (3 in.) to provide good tensile and shear strength. Follow manufacturer's instructions for depth reduction when rebar is encountered. A heavy duty washer should be part of the anchor assembly to ensure the equipment is secure.

11.6.1.2 SEISMIC ANCHORING

Seismic anchors are designed, tested, and specified for seismic zones 3 and 4. The use of seismic anchors enhance the stability of equipment due to the special characteristics specifically suited to the dynamic and cyclic loading effects experienced during earthquake events. As such, anchors **shall** be used that are manufactured to particular specifications that make them the most resistant to the effects of dynamic and cyclic loading effects. Selected anchors **shall** meet standards set forth in NEBS (Network Equipment Building Systems) TR-64 and ASTM (American Society For Testing and Materials) 488-90 for earthquake compliance. This testing evaluates anchors for bolt failure from shearing and from pullout or slippage. Compliance with these standards requires that the anchor not allow a standard top heavy 2.2 m (7 ft.) rack to have a deflection greater than 7.6 cm (3 in.) at the top of the frame. This compliance will also adhere to Bellcore Technical Specifications AU-434 for earthquake concrete expansion anchors.

Anchor selection criteria **shall** comply with all general requirements for standard concrete anchors plus meet the above seismic requirements. All seismic anchoring **shall** be enhanced with top cabinet or rack bracing.

NOTE: For seismic installation, concrete **shall** be a minimum of 206.73 MPa (3000 PSI or 2109.23 Tonnes/m^2) rating, at a minimum of 15.24 cm (6 in.) thickness (per Bellcore specification TR-64).

1. (See **Detail A**) Using appropriate pattern, drill 18 mm (11/16 in.) holes. Hole depth **shall** be 10.2 cm (4 in.) minimum below floor tile.
2. Vacuum excess drilling dust from holes.
3. (See **Detail B**) Insert anchors into hole until plate washer is flat against floor surface.
4. Tighten anchor nuts to a torque of 67.8 Nm (50 lb ft.).
5. Break nuts loose and remove rods using the 1/4-in drive top.
6. Place cabinet in mounting position.
7. Re-insert threaded rods with stack-up parts into holes. Hand-tighten nuts.
8. Using a wrench, tighten nuts until the tops of torque nuts twist off (between 1/4 and 1/2 turn).
9. If rebar is encountered with the standard anchor, remove the spacer (See **Detail C**). With spacer removed, reinstall the anchor. (Length of threaded rod can be altered, as required.)

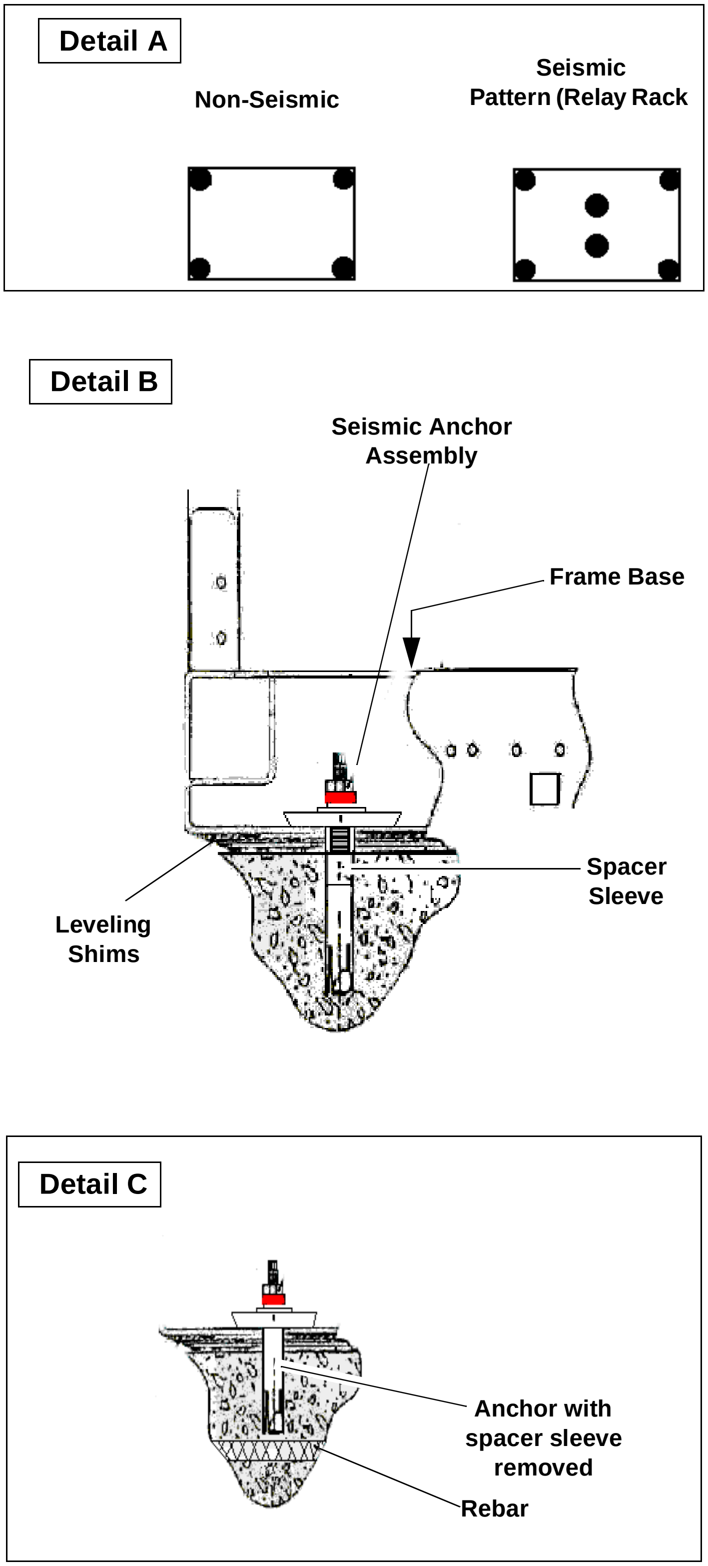


FIGURE 11-2 CONCRETE MOUNTING USING CONCRETE ANCHORS

11.6.1.3 ISOLATED MOUNTING

Isolated mounting is recommended to prevent a second path to ground through the concrete floor, and is required for the installation of certain equipment. In these cases, expansion anchors are inserted into the concrete floor. However, isolation of the equipment rack is ensured using an insulating plate and hardware as shown in Figure 11-3. If the installation is in an earthquake zone, additional anchors are used as shown in Figure 11-3.

NOTE: Motorola cellular base stations and central control equipment frames are always required to use, and are shipped with, isolating washer and bolt assemblies, and have separate insulating mounting plates. See Cellular document 68P09226A18, *Frame Mounting Guide*, for more information.

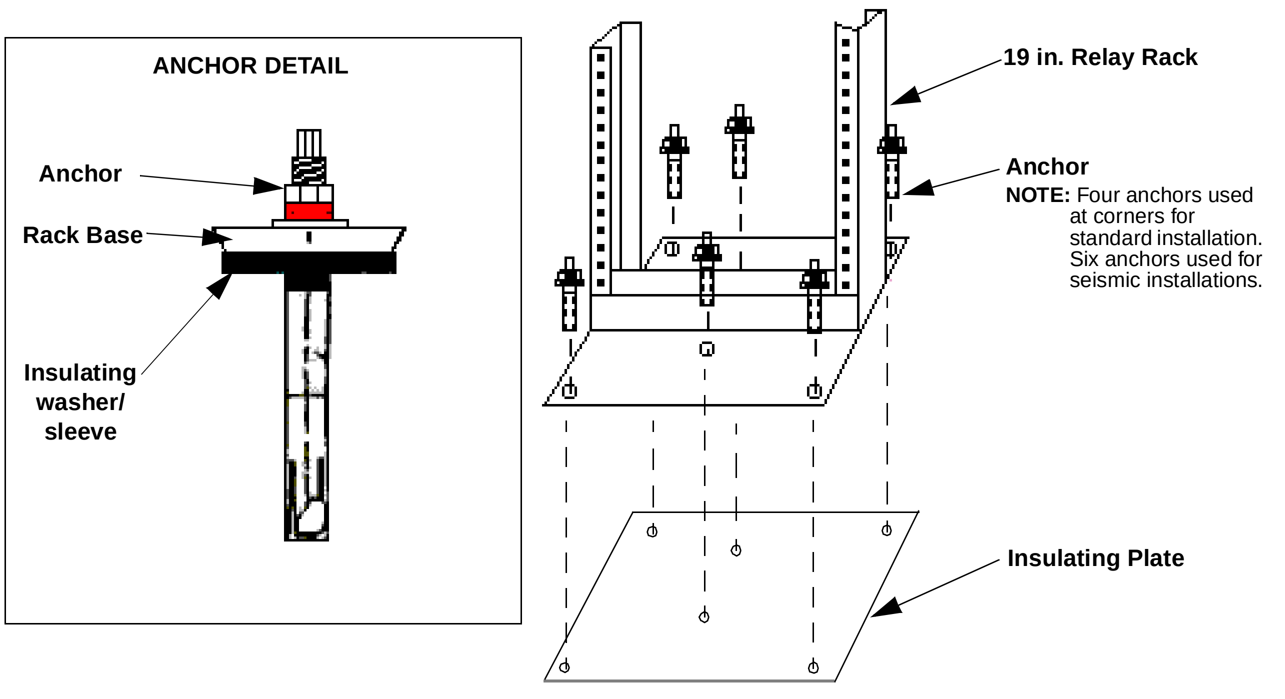


FIGURE 11-3 ISOLATED MOUNTING SYSTEM

11.6.2 MOUNTING ON WOOD OR FIBERGLASS FLOORS

Appropriately sized lag bolts **shall** be used for mounting on wood or fiberglass floors. If the underside is accessible and the floor stability is questionable, then thru-bolting may be desirable.

It is recommend to mount base stations and other non-racked ancillary equipment on a “C-channel” type of mounting track where possible. This provides for easy cleaning and some isolation in the case of standing water. Another benefit of installing non-rack mounted equipment off the floor, is that the weight is distributed across the floor. In these cases, C-channel type mounting provides multiple floor anchor points where the equipment provides only four to six anchor points.

When mounting racks to raised computer floors, 13 mm (0.5 in.) minimum diameter allthread rod and flush mount expansion anchors **shall** be used to anchor to the concrete sub-floor. When mounting consoles to a raised floor, 10 mm (0.375 in.) minimum allthread rod and hardware **shall** be used for anchoring. Mounting arrangement **shall** be in accordance with mounting kit manufacturer’s instructions.

11.6.3 ANCHORING EQUIPMENT TO RAISED FLOORS

11.6.3.1 OVERHEAD AND WALL MOUNTING

The anchoring of overhead and wall-mounted devices present a number of considerations. Placement is very important; if equipment is bolted to a wall that is on an aisle, the aisle may be unacceptably narrowed with the danger of injury to personnel. Also, the serviceability of the equipment being mounted to adjacent equipment may be inhibited.

Overhead applications generally include coax cabling, cable runways, and mounts for earthquake bracing. All overhead applications should keep in mind loading of overhead surfaces. Care must be exercised when deciding how much can be held up by the ceiling without some sort of building foundation support. In the case of earthquake bracing equipment (discussed in “Seismic Considerations” on page 11-3), cable runways can be secured overhead then affixed to the equipment racks providing acceptable foundation support.

When anchoring cable runways to ceilings or walls, the manufacturer-supplied support hardware **shall** be used.

Anchors used in overhead applications vary depending on the ceiling structure as follows:

- For concrete and wood ceilings, the same principles discussed in floor anchoring apply.
- For an exposed steel I-Beam ceiling, many cable runway manufacturers make beam clamps for C-channel or threaded drop rods.
- For corrugated steel ceilings, C-channel tracks can be affixed to the ceiling using properly sized lag bolts. The C-channel will span the corrugated steel and provide multiple anchor points.

For drywall or plasterboard ceilings, special considerations are required:

- If the drywall is on steel or wooden roof joists, locate and tap into the roof joists with lag bolts.
- C-channel mounting can be used.
- An alternative to C-channel mounting is using large toggle or molly wings with hex head tap bolts.

NOTE: Make certain joists are properly located before drilling into drywall.

11.7 EQUIPMENT INSTALLATION WITHIN RACKS OR CABINETS

Most communication equipment is mounted into standard 19-in EIA racks or enclosed cabinets. Follow the rack and/or equipment manufacturer's instructions when installing equipment into racks or cabinets.

- All supplied bracing hardware **shall** be properly utilized.
- Proper hardware **shall** be used to secure equipment.
- Convected heat transfer from one piece of equipment rack to another **shall** be considered. Heat baffles may be required.

WARNING

Do not mount heavy equipment at the top of the equipment rack or cabinet. It may cause the rack to become top-heavy and unstable.

11.8 EQUIPMENT CABLING

This section describes requirements for cabling within equipment cabinets and racks, and requirements for cable runs between equipment cabinets/racks. Cabling within racks and cabinets **shall** conform to the requirements of NFPA 70, Article 300, Article 800, Article 810, and Article 820. (See *ANSI/TIA/EIA-568(a)* and *569(a)* for additional information.)

11.8.1 CABLING REQUIREMENTS FOR EQUIPMENT IN RACKS AND CABINETS

All cables **shall** be installed and routed so that personal safety and equipment functionality is not compromised and that all equipment is accessible for servicing. The following requirements apply to cabling installed in racks or cabinets:

11.8.1.1 SECURING CABLES WITHIN RACKS OR CABINETS

- To help prevent damage or accidental disconnection, cables and conductors **shall** be secured at intervals of no more than 91 cm (3 ft.). Attachment **shall** be accomplished in a manner that does not restrict access to the equipment in the rack or cabinet.
- Insulated standoffs are recommended for use in racks or cabinets. The standoffs should be of sufficient length to maintain the proper cable separation.
- Nonmetallic cable ties **shall** be used to secure cables and conductors. Attachment **shall** be tight enough to secure cables without crushing them.
- Cables that span a gap greater than 61 cm (2 ft.) **shall** be supported.

11.8.1.2 ROUTING CABLES WITHIN RACKS AND CABINETS

- Gounding conductors within racks or cabinets **shall** be routed toward the RGB, MGB, SSGB, or ground bus conductor. Connections to the RGB or ground bus conductor **shall** always be made with the equipment grounding or tap conductors being routed toward the MGB, SSGB, or RGB. See Figure 7-26 on page 7-52 for an example.
- At points where grounding conductors must pass through a hole in a metallic surface and the hole is slightly larger than the conductor, the conductor **shall** be bonded to the metallic surface through which it passes. If the hole or opening is much larger than the conductor, and it is intended to accommodate several conductors, the conductor is not required to be bonded. See Figure 7-28 on page 7-53.
- Cables in racks or cabinets **shall** be sized to length, and **shall** be installed and routed neatly and in a professional manner.
- Excess cable **shall not** be coiled on top of cabinets or racks.
- AC power cords longer than necessary may be looped down and back up a rack or cabinet. Excess lengths of AC power cord **shall not** be coiled on top of racks or cabinets.

11.8.1.3 PROTECTING CABLES WITHIN RACKS AND CABINETS

- Grounding conductor tap joints **shall** be installed in order to prevent the conductor or connection device from coming in contact with metallic surfaces.
- Where cables or conductors are routed through holes in metallic surfaces or near sharp edges, the sharp surfaces **shall** be suitably protected with a grommet or similar material to help protect the cable or conductor from damage caused by sharp edges.

11.8.1.4 CABLE BENDING RADIUS WITHIN RACKS AND CABINETS

- Grounding conductors of all sizes **shall** maintain a minimum bending radius of 20 cm (8 in.). The angle of any bend **shall** be not less than 90°.
- The bending radius of CAT-5 cables **shall** be not less than 10 times the outside diameter of the cable. Follow the cable manufacturer's recommendations and see ANSI/TIA/EIA-568 and CSA-T529 for additional information.
- All other cables **shall not** have sharp bends which will damage or degrade the performance of the cable. The cable manufacturer's specifications **shall** be followed.

11.8.1.5 CABLE SEPARATION AND GROUPING WITHIN RACKS AND CABINETS

- Cabling in racks or cabinets **shall** be grouped according to function.
- Cable groups within racks and cabinets **shall** be separated by a minimum of 5.1 cm (2 in.) from other cable groups. Refer to *ANSI/TIA/EIA-568a* and *-569*; and *NFPA 70, Articles 800-52, 810-18, and 820-52* for more information.

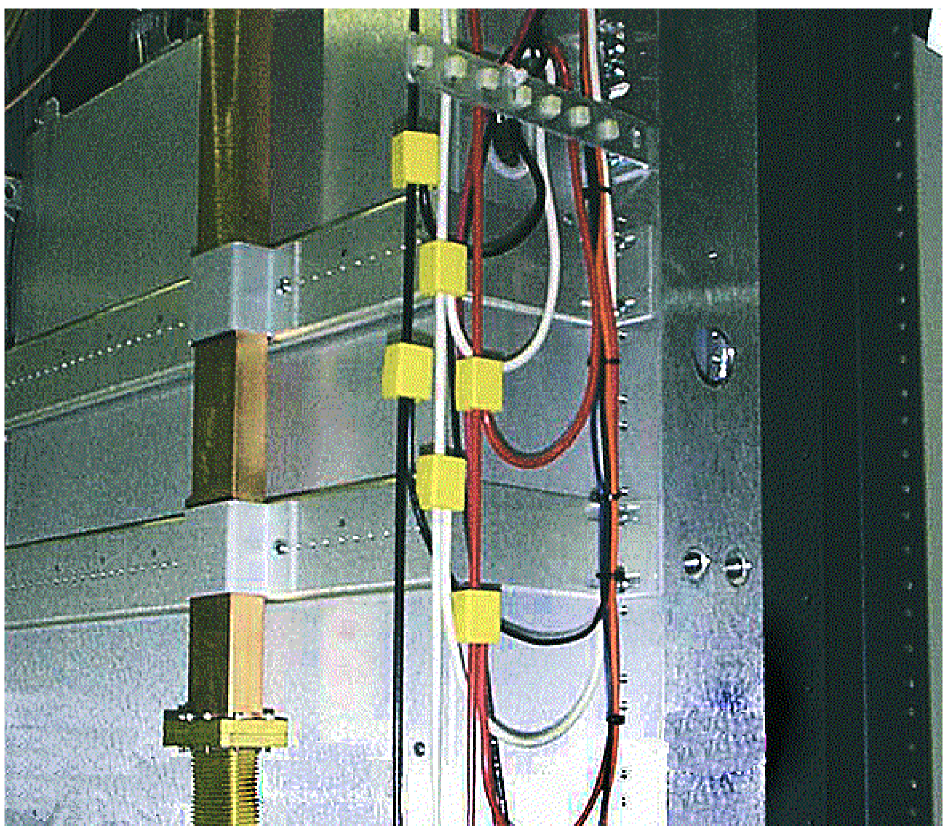


FIGURE 11-4 TYPICAL RACK CABLING

11.8.2 CABLING REQUIREMENTS FOR PLENUMS AND OTHER AIR-HANDLING SPACES

The following requirements specify installation practices that help, should a fire occur, minimize smoke and products of combustion from electrical wiring in areas that handle environmental air. These areas are typically referred to as plenums. A plenum is defined as a compartment or chamber to which one or more air ducts are connected and that forms part of the air distribution system. See *NFPA 70, Article 100* for more information.

WARNING

Electrical installations installed in hollow spaces, vertical shafts, and ventilation or air-handling ducts shall be installed in a manner such that the possible spread of fire or products of combustion will not be substantially increased. Openings around penetrations through fire resistance-rated walls, partitions, floors, or ceilings shall be firestopped using approved methods to maintain the fire resistance rating. Firestopping such penetrations may be accomplished by using specially manufactured fire seals or fire-barrier caulking. See NFPA 70, Article 300-21, Article 800-52 and ANSI/TIA/EIA-569-A for more information.

- No wiring system of any type **shall** be installed in ducts used to transport dust, loose stock, or flammable vapors. See *NFPA 70, Article 300-22(a)* for more information.
- No wiring system of any type **shall** be installed in any duct, or shaft containing only such ducts, used for vapor removal. See *NFPA 70, Article 300-22(a)* for more information.
- Wiring systems may be installed in ducts specifically constructed to transport environmental air only when such wiring consists exclusively of the following:
  - Type MI (mineral insulated) cable
  - Type MC (metal-clad) cable employing a smooth or corrugated impervious metal sheath without an overall nonmetallic covering
  - Type CMP (communications plenum cable), electrical metallic tubing, flexible metal tubing, intermediate metal conduit, or rigid metal conduit. Flexible metal conduit and liquid-tight flexible metal conduit **shall** only be permitted in lengths not exceeding 1.22 m (4 ft.), to connect physically adjustable equipment and devices permitted to be in the ducts. See *NFPA 70, Article 300-22(b)* and *Article 800-53(a)* for more information.
- Wiring installed in other spaces used for environmental air, such as the area above a suspended ceiling or as otherwise defined in NFPA 70, Article 300-22(c), **shall** be installed in accordance with NFPA 70, Article 300-22(c). Such wiring methods include using Type MI (mineral insulated) cable, Type MC (metal-clad) cable without an overall nonmetallic covering, Type AC (armored cable) cable, and Type CMP (Communications plenum cable). See NFPA 70, Article 300-22(c) and Article 800-53(a) for complete details.

- Communications cables installed in vertical runs spanning more than one floor, or cables installed in vertical runs in a shaft **shall** be Type CMR (Communications riser cable) or Type CMP. See *NFPA 70, Article 800-53(b)* for more information.
- Refer to *NFPA 70, Article 645* for details on Information Technology equipment room wiring.

11.8.3 CABLING REQUIREMENTS FOR CABLE RUNWAYS

11.8.3.1 CABLE INSTALLATION WITHIN CABLE RUNWAYS

- When installing cables into a cable runway system, cables **shall not** be pulled with such force that the conductor insulation or cable jacket integrity is destroyed or that the cable is deformed.
- Antenna and transmission lines minimum bending radii **shall** be considered when placing these cables within the cable runway. Follow manufacturers' specifications.
- Cables installed within a cable runway system **shall** be fastened securely to transverse members in other than horizontal runs.
- Cables installed within a cable runway system **shall** be separated by the following use categories:
    - DC power (when required)
    - Signal/control
    - Telephone cables
    - Antenna/transmission lines
    - Ground conductors
- The most desirable method to exit the cable runway is to drop out the bottom into a rack/cabinet or a vertical support such that physical separation is maintained.
- AC power cables **shall not** be run within a cable runway system unless they are enclosed within metallic conduit or raceway. (Note that raceways or conduit installed below or along side cable runways may not be supported by the cable runways themselves unless the cable runway system is designed to provide such support.)

11.8.3.2 CABLE SEPARATION AND GROUPING WITHIN CABLE RUNWAYS

- Cabling **shall** be separated from each other according to function (e.g., DC power, RF, ground, and data ground cables.) Similarly, cabling **shall** be grouped into similar functional groups (for example: RF cables in one group, DC power in another group).
- Cable groups **shall** be separated a minimum of 5.1 cm (2 in.) from other cable groups. (Refer to *ANSI/TIA/EIA-568-A* and *569-A; NFPA 70*, *Articles 800-52*, *810-18*, and *820-52* for more information.)

- AC power cables cannot be run in the same cable runway as CAT-5 or communications cables unless separated by a barrier as defined by NFPA 70. (Refer to “Computer Network Cabling” on page 11-19 for more information.

11.8.3.3 SECURING CABLES WITHIN CABLE RUNWAYS

- Cables and conductors **shall** be secured at intervals of no more than 91 cm (3 ft.).
- Nonmetallic cable ties **shall** be used to secure cables and conductors. Attachment **shall** be tight enough to secure cable, yet not crushing the cable.
- Cables running vertically on a cable ladder **shall** be secured at every rung.
- When cables span a gap (such as between a cable tray and a ladder) in excess of 61 cm (24 in.), the cables **shall** be supported.
- Certain telephony requirements may exist for cables to be laced. Refer to “Cabling in Telephone Wiring Environments” on page 11-30 for more information.
- Cable **shall** be sized to length, and not coiled on top of cabinets or cable runways.
- Communications cables **shall not** be attached by any means to the exterior of a conduit or other raceway as a means of support (NFPA 70, Articles 725-56 and 800-52).
- Communications cables **shall not** be laid directly on the tiles of a false ceiling (ANSI/TIA/EIA-569(a)).

11.8.4 AC POWER CABLING

WARNING

Facility AC wiring within junction boxes, receptacles, and switches shall be performed by a licensed and bonded electrical contractor. Personnel safety and liability hazards can result from AC wiring performed by installation personnel other than an electrical contractor.

When an open equipment rack is used, hardwiring of power is not always possible. Mounting a dedicated simplex receptacle or receptacle assembly on the rack may be the most convenient method of supplying power, especially if multiple pieces of equipment are mounted on the rack. This is also a convenient way to install personal protection type 3 SPD devices (such as Motorola PN RLN4924A) to the equipment.

These receptacle assemblies can be pre-manufactured and mounted to the top face of an equipment rack. Mounting can also use a fabricated power pole mounted between racks.

Equipment that contains its own AC power supply, is typically fitted with a standard grounded line cord. Where this equipment is used, the rack **shall** be equipped with an dedicated simplex receptacle or receptacle assembly. See “Receptacles” on page 8-12 for specific requirements.

Figure 11-5 shows a rack-mounted receptacle assembly as well as proper dress of line cords within an equipment rack.

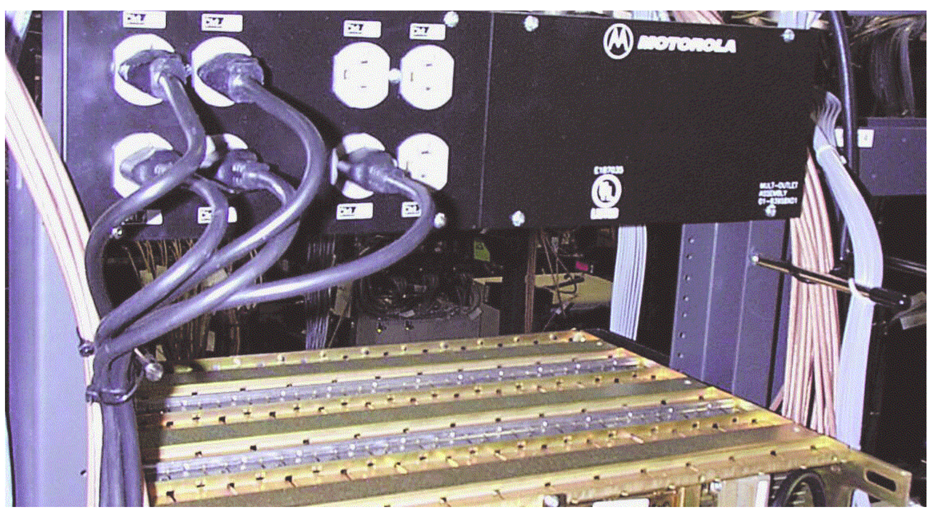


FIGURE 11-5 PROPER AC LINE CORD DRESS TO RACK-MOUNTED MULTIOUTLET PANEL

WARNING

Under no circumstances shall consumer-grade power outlet strips be used in any installation. Extension cords of any type shall not be used for connecting line power to communications equipment.

11.8.5 DC POWER CABLING

In telecommunications environments, common DC systems are as follows:

- +12 volt systems
- +24 volt systems
- -24 volt systems
- -48 volt systems

Traditional wireline telephone offices most often use -48V, sometimes called -BATT voltage, whereas many cellular, PCS, and other radio systems use +24 to 27 V. There are also instances of -24V systems. In U. S. installations, the most common practice is to use red cabling for the sourcing, fused, ungrounded, “hot” terminal. Black cabling is used for the return, unfused, grounded, terminal. (European installation practice uses blue insulation for the “hot” lead.) Chapter 8, “Power Sources,”discusses power cabling sizing and other installation concerns. The manual for the equipment being installed will also have specifications stating the cabling size required.

11.8.6 CONTROL AND DATA CABLING

Due to the low levels and broad frequency ranges associated with these cable, this cabling **shall** be separated a minimum of 5 cm (2 in.) from AC or DC power cabling. Also, these cables should never be run with ground cables since energy can be induced, especially during lightning strikes.

Figure 11-6 shows proper dress of control cabling within an equipment rack. Note that adequate loops are provided to relieve stress on connectors and facilitate easy removal, while minimizing unnecessary clutter. Any cable excess **shall** be coiled away from equipment connecting points.

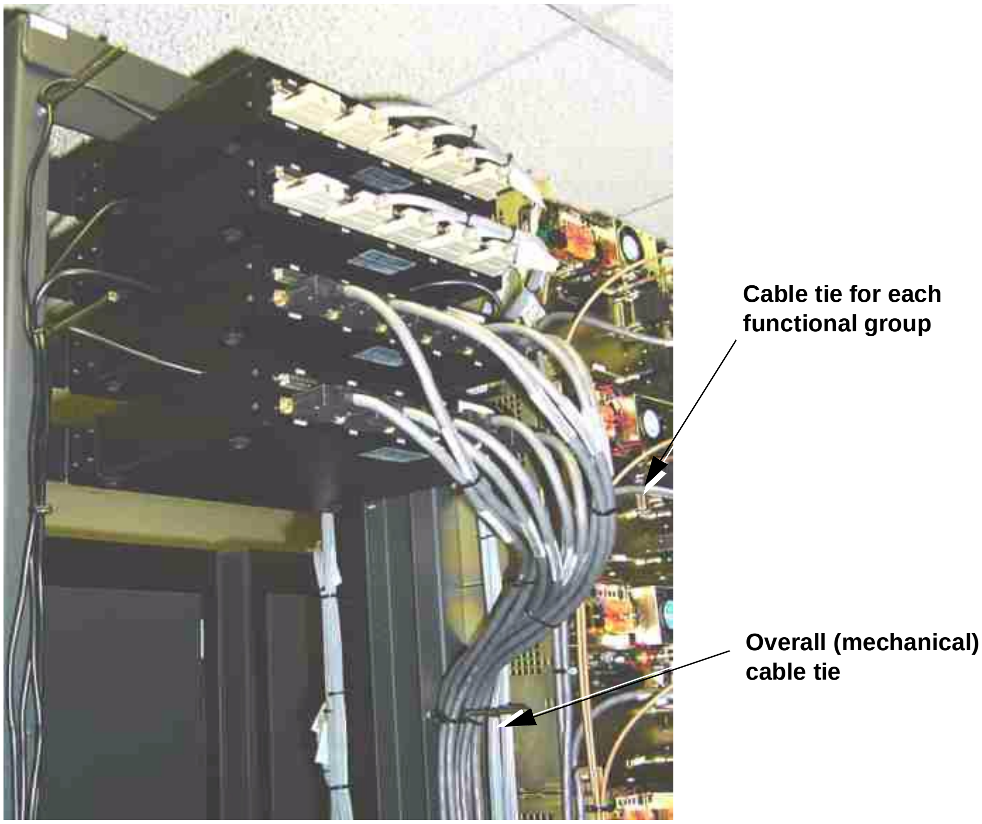


FIGURE 11-6 PROPER CONTROL CABLING DRESS

11.8.7 COMPUTER NETWORK CABLING

Computer network cabling typically consists of Category 5 (CAT 5) cabling terminated with 8-pin modular connectors.

The proper installation of computer network cabling is critical to the safe and reliable operation of the computer network. It is recommended that standards developed by the Telecommunications Industry Association/Electronic Industries Association (TIA/EIA) and the Canadian equivalent (or equivalent standards in other countries) be followed. Applicable NFPA codes, local electrical codes, local building codes and other standards in this manual **shall** also be conformed to when installing computer network cabling.

NOTE: It is recommended that computer network cable installations be performed by a specialist in the installation of computer networks. The specialist should have the expertise, knowledge of applicable local codes, and the test equipment required for a quality install.

NOTE: This section cites standards from the American National Standards Institute (ANSI), the Electronic Industry Association (EIA), the Telecommunications Industry Association/Electronic Industries Association (TIA/EIA, and the Canadian Standards Association (CSA). Even in non-domestic installations, these standards should be adhered to.

11.8.7.1 CABLE TYPE

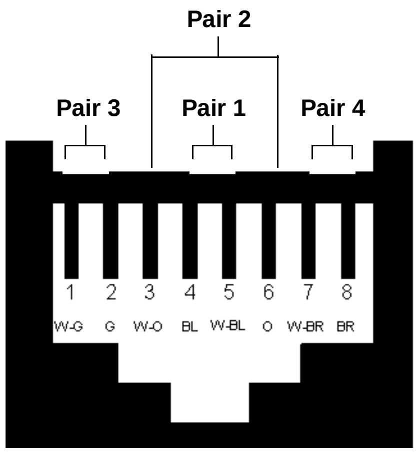
CAT 5 Unshielded Twisted Pair (UTP), 100-ohm cable is the recommended cable type for computer network cabling, and will be the assumed cable type throughout this section. CAT 5 cable is preferred over CAT 3 and CAT 4 cables because of its ability to support 100Mbps (Megabits per second) systems and because of its better immunity to Electromagnetic Interference (EMI) and Radio Frequency Interference (RFI). See *American National Standards Institute/ Telecommunications Industry Association/ Electronic Industries Association (ANSI/TIA/EIA)-568-A* and *Canadian Standards Association (CSA)-T529* for more information.

11.8.7.2 CONNECTING HARDWARE

UTP cables **shall** be terminated with connecting hardware of the same category rating or higher. This includes all connectors, punch blocks, cross-connect jumpers and patch cords. It is recommended that hardware used to terminate cables be of the insulation displacement (IDC) type. Modular connectors **shall** also be of the proper typed for the cable used; solid conductor cable uses a different connector than stranded cable. See *ANSI/TIA/EIA-568A* and *CSA-T529* for more information.

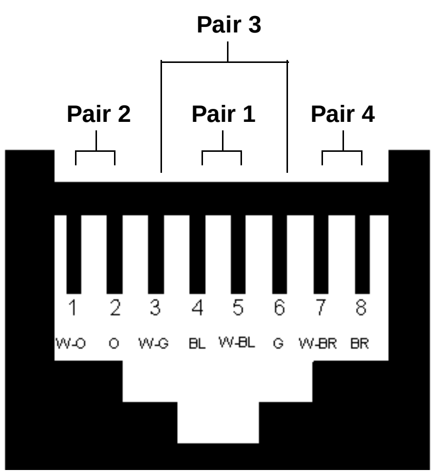
11.8.7.3 CABLE AND CONNECTOR WIRING

Appropriate color-coding and jack pair assignments should be followed when wiring modular jacks, connectors, and cables. The same wiring standard **shall** be used throughout the cabling system. ANSI/TIA/EIA T568A and T568B are the recommended standards. Figure 11-7 shows end views of an 8-pin Modular female jack for both standards with the pairs and colors identified. See *ANSI/TIA/EIA-568-A* and *CSA-T529* for more information.



Cable Pair	Color
1 (term 4, 5)	white-blue (W-BL) blue (B)
2 (term 3, 6)	white-orange (W-O) orange (O)
3 (term 1, 2)	white-green (W-G) green (G)
4 (term 7, 8)	white-brown (W-B) brown (BR)

T568A Connections



Cable Pair	Color
1 (term 4, 5)	white-blue (W-BL) blue (B)
2 (term 1, 2)	white-orange (W-O) orange (O)
3 (term 3, 6)	white-green (W-G) green (G)
4 (term 7, 8)	white-brown (W-B) brown (BR)

T568B Connections

NOTE: For both connectors, female jack is shown (view from FRONT (mating) end of connector shown

FIGURE 11-7 8-PIN MODULAR JACK PINOUT

11.8.7.4 CABLE INSTALLATION AND ROUTING

In general, the following considerations need to be observed for the routing of computer network cabling:

- Consideration should be given to using some method of cable management and containment for runs of CAT 5 cable. Such methods can be dedicated cable runs, lay-in wireways, cable runways and conduits. See *ANSI/TIA/EIA-569-A* and *CSA-T530* for more information.
- CAT 5 cable **shall not** be installed in the same conduit, cable runway, outlet box, or similar device with AC power cables, unless separated by a barrier as allowed in NFPA 70, Article 800-52. Doing so can be unsafe and is likely to cause EMI onto the CAT 5 cable, causing network errors. See *NFPA 70, Article 800-52*, *ANSI/TIA/EIA-568-A, 569-A*, and *CSA-T529, T530* for more information.
- Precautions should be taken to avoid routing CAT 5 cable near sources of EMI/RFI. Such noise sources may be electrical power wiring, dimmer switches, radio frequency transmitters, motors, generators, and fluorescent lights. Precautions may include, increasing the physical distance between the CAT 5 cable and the source of the EMI/RFI, installing the CAT 5 cable inside of a grounded metallic conduit, or use of a CAT 5 100-ohm screened twisted pair cable as permitted by ANSI/TIA/EIA-568-A. Routing cables near sources of EMI/RFI can cause data errors and degraded system performance. See *ANSI/TIA/EIA-568-A*, *569-A* and *CSA-T529*, *T530* for more information.
- Cables **shall** be separated by at least 5.1 cm (2 in.) from AC power conductors. See *NFPA 70, Article 800-52* for more information.
- CAT 5 cables installed in ducts, plenums, and other air-handling spaces **shall** be installed in accordance with other chapters of this manual and *NFPA 70, Article 300-22*. See also *NFPA 70, Article 645*.
- CAT 5 cables installed in hazardous areas as defined in NFPA 70, Article 500 **shall** be installed in accordance with NFPA 70, Article 500 and any other applicable electrical and building codes.
- CAT 5 cable **shall not** be attached by any means to the exterior of a conduit or other raceway as a means of support. See *NFPA 70, Article 725-54* and *NFPA 70, Article 800-52* for more information.
- Suspended ceiling support rods and wires may be used as a means of support for computer network cabling if used in conjunction with appropriate cable fasteners. See *ANSI/TIA/EIA-569-A* and *CSA-T530* for more information.
- CAT 5 cables **shall not** be laid directly on the tiles of a false ceiling. See *ANSI/TIA/EIA-569-A* and *CSA-T530* for more information.
- CAT 5 cables **shall not** be run from one building to another building. If the computer network needs to be extended to another building, a specific cabling system **shall** be engineered. Options for extending from one building to another may include the use of fiber optic cable or a T-1. Computer network cabling entering and/or leaving a building **shall** be properly grounded and protected from surges as required elsewhere in this manual.

11.8.7.5 INSTALLATION PRACTICES

- Avoid any unnecessary junction points and cross-connects. Every added junction point and cross-connect can decrease the performance of the network.
- Multiple appearances of the same cable at different locations, referred to as bridge taps **shall** be avoided (see Figure 11-8). Each cable segment **shall** have only one source and one destination.

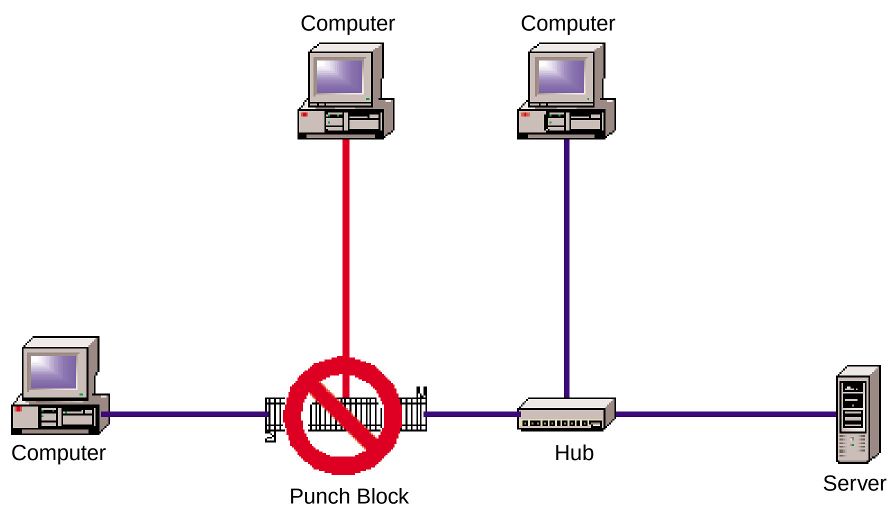


FIGURE 11-8 DISALLOWED "BRIDGE TAP" CONNECTION

- Never untwist the twisted pairs of a CAT 5 cable beyond 1.3 cm (0.5 in.) from the point of termination. Untwisting the wires can decrease the cable's category performance rating and degrade system performance. See *ANSI/TIA/EIA-568-A* and *CSA-T529* for more information.
- Do not make sharp bends in CAT 5 cable. The bend radius for CAT 5 cable **shall not** be less than ten times the outside diameter of the cable. Bending the cable with a shorter bend radius can effect the electrical characteristics of the cable and degrade system performance. See *ANSI/TIA/EIA-568-A* and *CSA-T529* for more information.
- Do not pull a CAT 5 cable with excessive force. CAT 5 cable should not be pulled with a force greater than 110 Newtons (25 lbs-force), or as suggested by the cable manufacturer. Pulling a cable with too much force can change the cable's electrical characteristics and degrade its performance. See *ANSI/TIA/EIA-568-A* and *CSA-T529* for more information.
- Do not over-tighten CAT 5 cable with cable ties or other supports. Over-tightening cable ties or other supports can change the electrical characteristics of the cable and degrade the system performance. See *ANSI/TIA/EIA-568-A* and *CSA-T529* for more information.

11.8.7.6 TOPOLOGY

Computer network cabling **shall** utilize a “Star” topology, unless the specific design of the network calls for a different topology. Figure 11-9 shows a star topology example. See *ANSI/TIA/EIA-568-A* and *CSA-T529* for more information.

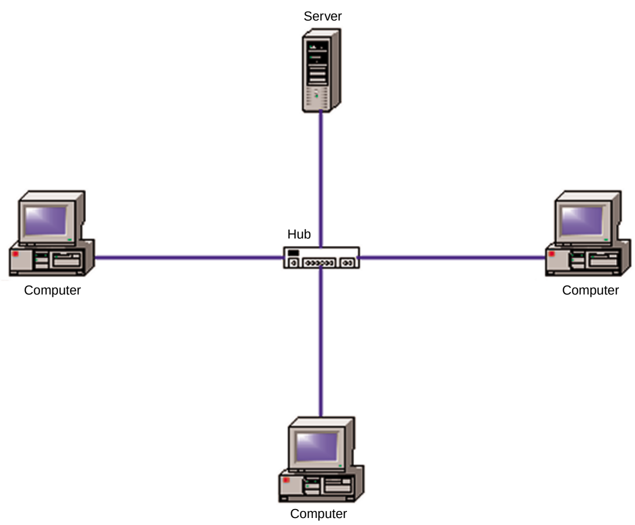


FIGURE 11-9 STAR TOPOLOGY

- CAT 5 segment lengths **shall not** exceed 100 m (328 ft.). This includes 90 m (295 ft.) of building cabling and up to 10 m (32.8 ft.) of equipment cords, cross-connects and patch cords. Of the 10 m (32.8 ft.) allowed for equipment cords, cross-connects and patch cords, a maximum of 3 m (9.8 ft.) should be used from the computer workstation to the information outlet. See *ANSI/TIA/EIA-568A* and *CSA-T529* for more details. Figure 11-10 shows the maximum cabling lengths between various network elements.

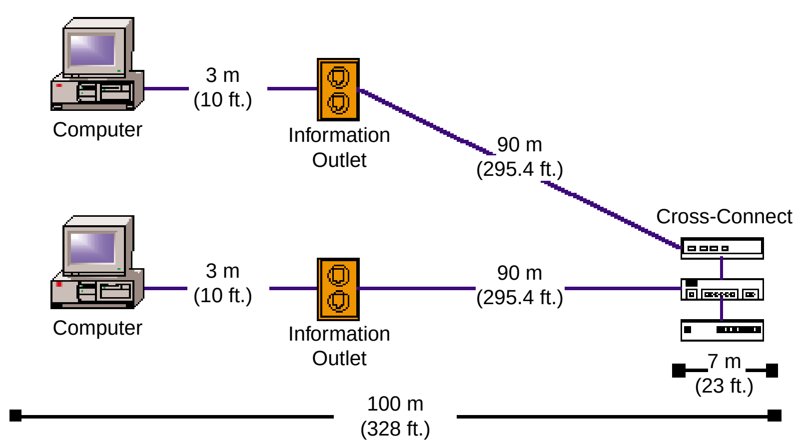


FIGURE 11-10 NETWORK SEGMENT LENGTHS LIMITATIONS

- For simplifying installation and reducing cable runs, a single CAT 5 cable may be run from the equipment room hub to an additional hub in the computer workstation area for distribution to the individual computers. This can reduce the number of cables required between the equipment room and the individual computers. Figure 11-11 shows an example of a single cable run. Refer to *ANSI/TIA/EIA- 569-A* for more information.

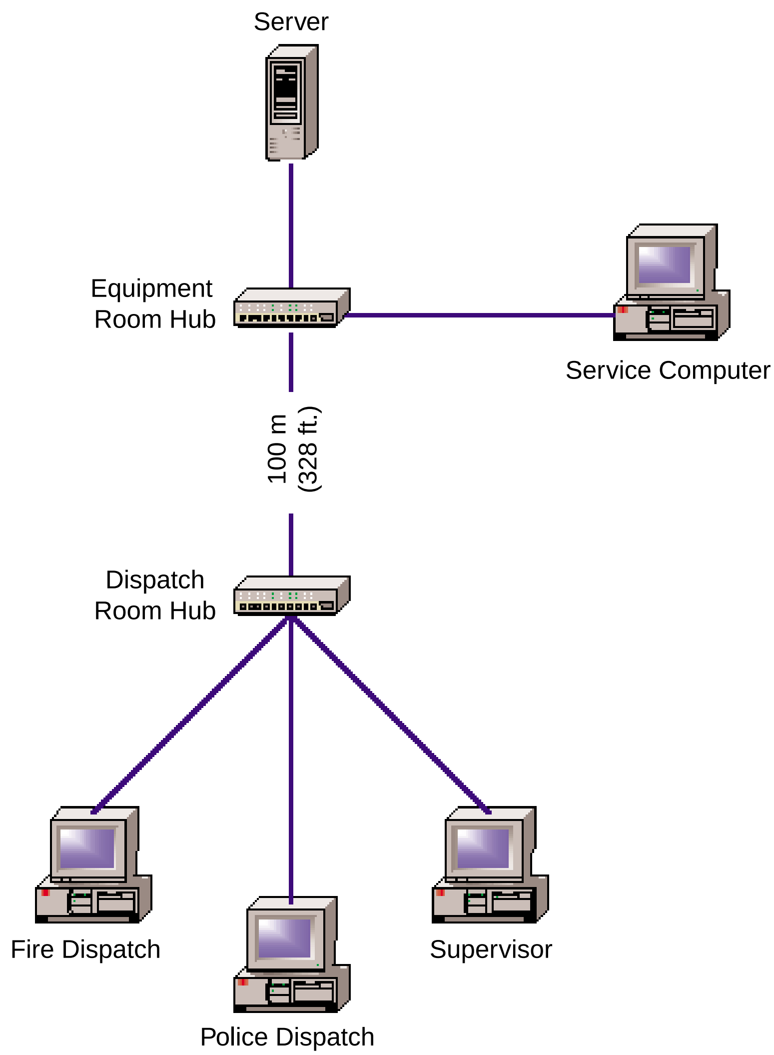


FIGURE 11-11 ADDITIONAL HUB USED IN SINGLE CABLE RUN

- If cable segments need to be extended beyond 100 m (328 ft.), an additional hub may be installed. Each individual segment between hubs **shall** not exceed 100 m (328 ft.). Figure 11-12 shows the cabling and network elements for distances exceeding 100 m (328 ft.). Note that no more than the one intermediate hub **shall** be used. If the required distance is greater than as shown in Figure 11-12 on page 11-26, a specific cabling system **shall** be engineered. Refer to *ANSI/TIA/EIA-569-A* for more information.

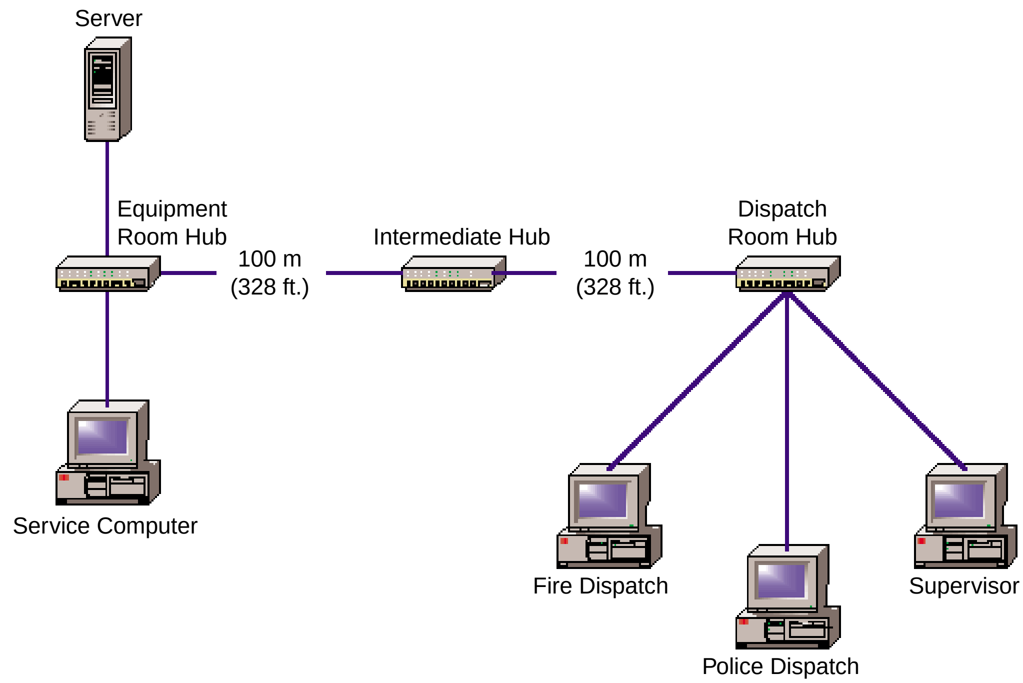


FIGURE 11-12 ADDITIONAL HUB USED FOR DISTANCES GREATER THAN 100 M

11.8.7.7 GROUNDING

Grounding **shall** comply with Chapter 7, "Internal Grounding," of this manual, NFPA 70, Article 250; ANSI/TIA/EIA-607, and CSA-T527.

11.8.7.8 LABELING

Cables **shall** be labeled at both ends and at any pull boxes or junctions as described in "Cable Labeling" on page 11-33. See also *ANSI/TIA/EIA-606* and *CSA-T528* for detailed labeling guidelines and suggestions.

11.8.7.9 TESTING NETWORK CABLING

Every effort should be made to ensure a quality installation of the computer network cabling system. Even the best installation effort cannot guarantee a properly working system. It is therefore required that a computer network cabling system be tested for proper performance.

The procedures and specifications in the *TIA/EIA Telecommunications System Bulletin (TSB) 67* **shall** be used for this testing. TSB 67 has four primary parameters to test. Below is an overview of the four test parameters needed to assure a properly working system.

11.8.7.9.1 WIRE MAP

The wire map test is used to verify wire pair to pin termination at each end of the cable and check for installation connectivity errors. Each of the 8 conductors in the cable are tested for:

- Conductor continuity to the remote end of the cable
- Shorts between any two or more conductors in the cable
- Crossed pairs in the cable
- Reversed pairs in the cable
- Split pairs in the cable
- Any other wiring errors in the cable

11.8.7.9.2 LENGTH

The length test is used to determine the maximum physical length of the cable segments.

11.8.7.9.3 ATTENUATION

Attenuation is the measure of signal loss in the cable segment.

11.8.7.9.4 NEAR-END-CROSSTALK (NEXT) LOSS

NEXT loss is a measure of signal coupling from one wire pair to another within a single UTP cable segment.

11.8.8 OPTICAL FIBER CABLING

WARNING

Never look into an optical fiber cable. Optical fiber cables use invisible laser light that is dangerous and can cause damage to the eye.

Optical fiber cable are grouped into three general categories as described below. (See *NFPA 70, Article 770-5* for more information.)

- Non-conductive - These cables contain no conductive materials.
- Conductive - These cables contain noncurrent-carrying conductive members, such as metallic strength members, metallic vapor barriers, and metallic armor or sheath.
- Composite - These cables contain optical fibers and current-carrying electrical conductors. These cable may also contain noncurrent-carrying conductive members, such as metallic strength members and metallic vapor barriers.

Observe the following general considerations for the installation of optical fiber cabling:

- Optical fiber cable installations **shall** conform to ANSI/TIA/EIA-568-A.
- Bend radius **shall not** be shorter than 10 times the diameter of the optical fiber cable, or as recommended by the cable manufacturer.
- Optical fiber cables **shall not** be installed in such a way that it prevents access to electrical equipment and removal of panels, including suspended ceiling panels. (See *NFPA 70, Article 770-7* for more information.)
- Optical fiber **shall** be installed in a neat manner. Cables **shall** be supported in such a manner that the optical fiber cable will not be damaged by normal use of the building. (See *NFPA 70, Article 770-8* for more information.)
- Conductive optical fiber cables entering or leaving the building **shall** be have the noncurrent-carrying metallic members grounded as close as practical to the building entry. (See *NFPA 70, Article 770-33* and Chapter 7, "Internal Grounding," for more information.)
- Optical fiber cables installed in plenums and other air-handling spaces **shall** be Plenum- rated cable and installed in accordance with *NFPA 70, Articles 300-22* and *770*, and "Cabling Requirements for Plenums and Other Air-Handling Spaces" on page 11-14. Plenum-rated optical fiber cable may be OFNP (Optical Fiber Non-conductive Plenum) or OFCP (Optical Fiber Conductive Plenum).
- Optical fiber cables installed in vertical runs penetrating more than one floor, or cables installed in vertical runs in a shaft **shall** be Riser or Plenum-rated cable. Riser rated optical fiber cable may be OFNR (Optical Fiber Non-conductive Riser) or OFCR (Optical Fiber Conductive Riser). (See *NFPA 70, Article 770* for more information.)
- Non-conductive optical fiber cable **shall** be permitted to occupy the same cable runway or raceway with conductors for electric light, power, Class 1, nonpower-limited fire alarm, or medium power network-powered broadband communications circuits operating at 600 Volts or less. (See *NFPA 70, Article 770-52* for more information.)
- Conductive optical fiber cable **shall not** be permitted to occupy the same cable runway or raceway with conductors for electric light, power, Class 1, nonpower-limited fire alarm, or medium power network-powered broadband communications circuits. (See *NFPA 70, Article 770-52* for more information.)
- Composite optical fiber cables containing only current-carrying conductors for electric light, power, Class 1 circuits rated 600 Volts or less **shall** be permitted to occupy the same cabinet, cable runway, outlet box, panel, raceway, or other termination enclosure with conductors for electric light, power, or Class 1 circuits operating at 600 Volts or less. (See *NFPA 70, Article 770-52* for more information.)
- Non-conductive optical fiber cables **shall not** occupy the same cabinet, outlet box, panel, or similar enclosure housing the electrical terminations of an electric light, power, Class 1, nonpower-limited fire alarm, or medium power network-powered broadband communications circuit, unless the optical fiber cable is functionally associated with the other cables. (See *NFPA 70, Article 770-52* for more information.)
- Noncurrent-carrying conductive members of an optical fiber **shall** be grounded in accordance with NFPA 70, Article 250 and Chapter 7, "Internal Grounding," of this manual.

- Conductive and non-conductive optical fiber cable **shall** be permitted in the same cable runway, enclosure, or raceway with conductors of Class 2 and Class 3 remote-control, signaling, and power-limited circuits (as defined by NFPA 70, Article 725); Communications circuits (as defined by NFPA 70, Article 800); Community Antenna Television and Radio distribution systems (as defined by NFPA, Article 820); and Low power network-powered broadband communications circuits (as defined by NFPA, Article 830).
- (See Figure 11-13.) Where fiber optic cabling is used, the fiber optic cable **shall** be labeled to distinguish it from electrical signal cabling.

FIGURE 11-13 FIBER OPTIC CABLE LABELING

11.8.9 RF CABLING

RF cabling typically consists of 0.635 cm (0.25 in.) or 1.25 cm (0.5 in.) coaxial cables of foam filled or superflexible construction.

RF cabling **shall not** be run nearer than 5 cm (2 in.) to conductors of other wiring systems (NFPA 70, Articles 810-18 and 820-52). Bend radius considerations **shall** be observed as specified below, or as otherwise specified by the cable manufacturer.

Minimum bend radius for superflexible cable sizes:

- 0.635 cm (0.25 in.) diameter cable: 2.5 cm (1 in.) bend radius
- 1.25 cm (0.5 in.) diameter cable: 3.2 cm (1.25 in.) bend radius

Minimum bend radius for foam-filled cable sizes:

- 1.25 cm (0.5 in.) diameter cable: 12.7 cm (5 in.) bend radius
- 2.22 cm (0.875 in.) diameter cable: 25.4 cm (10 in.) bend radius
- 3.175 cm (1.25 in.) diameter cable: 38.1 cm (15 in.) bend radius
- 4.128 cm (1.625 in.) diameter cable: 50.8 cm (20 in.) bend radius

11.8.10 CABLING IN TELEPHONE WIRING ENVIRONMENTS

NOTE: The following considerations apply only in cases where customer work must meet specifications stipulated by a telephone utility. If no special stipulations are stated by the telephone company, best commercial practices may be used for telephone company cabling within the communication site. When installing cabling that connects with telephone company assets or a demarcation point, inquire about any lacing requirements before work is performed.

11.8.10.1 ELECTRICAL INTERFACE REQUIREMENTS

Connection to telephone company assets may require the use of surge suppression for customer signal circuits that interface to telephone company circuits. Inquire through the telephone company regarding these requirements before connecting to telephone company circuits.

11.8.10.2 CABLING LACING REQUIREMENTS

When installing a system for telephone company or possibly other utility companies, special cabling methods **may** be required. If required, the following considerations need to be observed for the installation of telephone company cabling:

- Lacing, rather than nylon cable ties, **shall** be used as the preferred means of cable attachment to cable runway. This method eliminates the possibility of sharp edges found on cut cable ties.
- The lacing method specified by the telephone company **shall** be used. Typically, the lacing methods are the “Chicago” and “Kansas City” stitches, as shown in Figure 11-14.

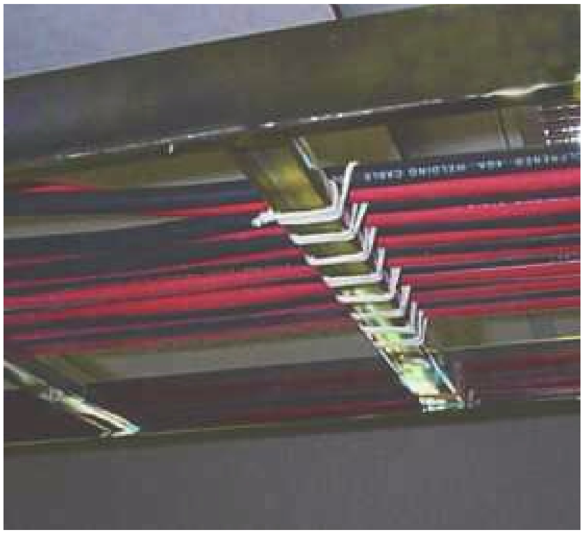


FIGURE 11-14 TELEPHONE COMPANY LACING METHODS

- Lacing **shall** be performed with either 4- or 9-ply waxed polyester twine.
- Lacing of horizontal cables in cable runways should be performed every 91 cm (3 ft.).
- Lacing of vertical cables to a cable ladder should be performed at every rung of the cable ladder. Any cable hanging between horizontal/vertical runways and racks cannot be unsupported for more than 61 cm (24 in.).

11.8.11 DISTRIBUTION FRAME CONFIGURATIONS

A distribution frame (Figure 11-15 on page 11-31) provides a centralized cross-connection point for audio, data, and alarm and control wiring between different pieces of equipment at a site and between the site and external lines. Distribution frames **shall** be implemented using one of the following methods:

- Type 66 punch blocks affixed to a plywood panel that is mounted on a wall or a rack.
- Type 66 punch blocks (or other types) mounted on open-rack frames available from various manufacturers. These frames can be anchored to the floor; they save wall space at the cost of floor space.
- Typically, a distributed (as opposed to centralized) method is used. Pre-wired cross-connect panels (each 1 rack unit in height) distribute connections on a rack-by-rack basis. Typically, remote sites require one panel and the prime site is equipped with one to three panels, depending on the application.
- Cables should be dressed up into the cable runway or down into the under-floor raceway as dictated by the site design.

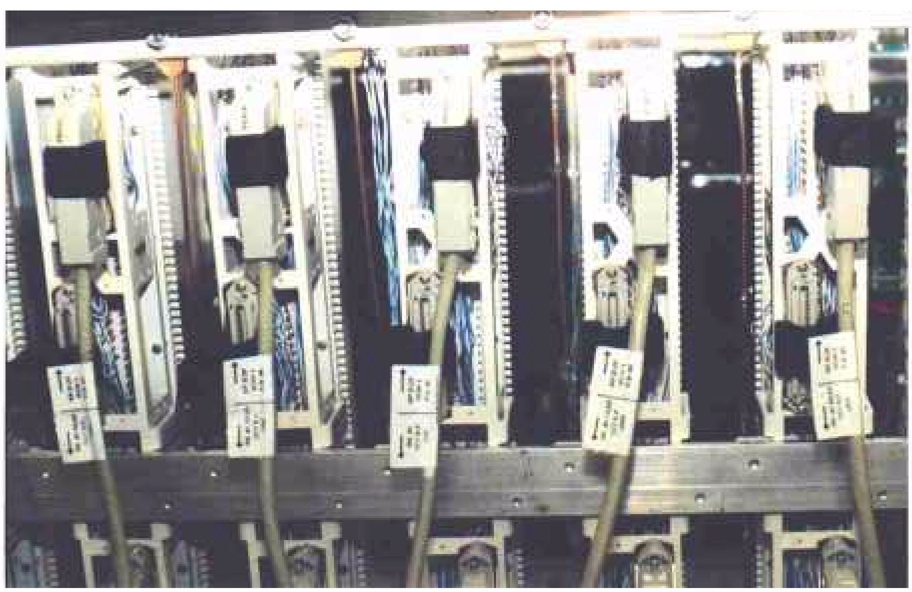


FIGURE 11-15 TYPICAL DISTRIBUTION FRAME

11.8.12 DISTRIBUTION FRAME CROSS-CONNECT WIRING

- Cross-connect wires **shall** be AWG #20 - #26 plastic-insulated **solid** copper wire. Stranded wire is **not** acceptable.
- Individual wires **shall** enter the punch terminal from the top so that the wire tail points down after punch-down. (CAT3, 4, or 5 data wiring **shall** enter punch terminals from the middle such that one wire points up while the other points down. In this manner, the cable twist that maintains the cable impedance stays intact.)
- The wiring **shall** dress down the source block column, across the bottom of the frame, and up the destination block column. Approximately 5 cm (2 in.) of service loop at each end of the punched down wire **shall** be allowed.
- Wiring **shall** be tie-wrapped.

11.8.13 CABLE LABELING

Cabling **shall** be identified with a standardized, double-ended system to facilitate cable and equipment connection identification. (Refer to ANSI/TIA/EIA-606 for more information.) Figure 11-16 shows an example of one type of cable labeling. The labeling should show the following:

- Equipment identification for each end of cable
- Connector reference designator for each end of cable
- Direction along the cable where terminating equipment is located

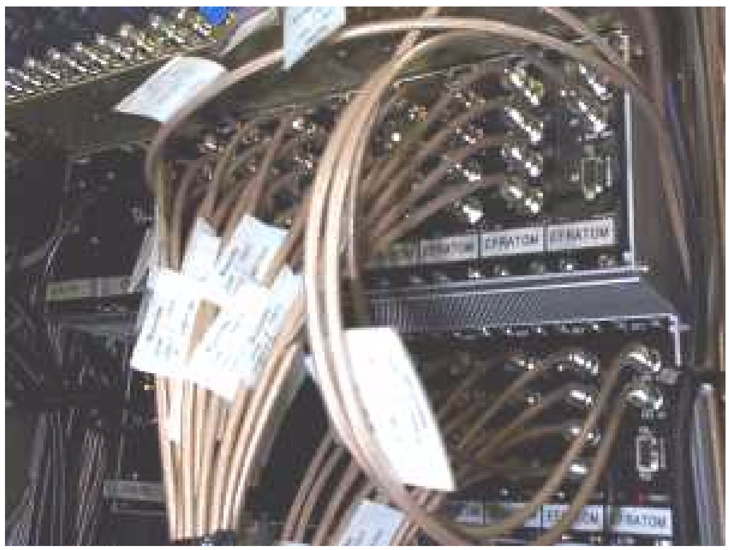


FIGURE 11-16 PROPER CABLE LABELING

In general, the following considerations need to be observed in implementing a labeling system:

- Labeling **shall** indicate the destination ends of the cable, in terms of equipment name and connector reference designator or name. This applies to connectorized, lugged, or punched down cable terminations; regardless of the application (RF, audio, or control).
- Labeling **shall** be imprinted on white opaque material (preferably plastic or plasticized paper) using indelible black ink.
- Labeling should wrap entirely around the cable. It should be secure enough to assure label retention if cable is to be pulled through conduit.
- Label placement **shall** be between 10 to 16 cm (4 to 6 in.) from each end of the cable (or the most logical point that would allow the label to be easily read).
- Information printed on each label should be brief but clearly understandable. Because of limited space, abbreviations and acronyms should be used. If abbreviations are used, they should be industry standard.

11.9 ELECTROSTATIC DISCHARGE CONSIDERATIONS

Installation of certain equipment will require removal and replacement of Field Replaceable Units (FRUs) within the equipment for purposes of setting configurations or installing FRUs specific to site applications.

In such cases where an equipment must be opened, electrostatic discharge (ESD) precautions **shall** be adhered to. In general, the following requirements **shall** be met:

- An ESD-protected work area **shall** be present.
- An ESD wriststrap **shall** be worn when handling ESD-sensitive modules.
- ESD-protected packaging **shall** be available for containing modules removed from equipment.

All precautions specifically stated for the equipment being worked on **shall** be adhered to in accordance with the respective documentation for the equipment. Additionally, Motorola publication 68P81106E84 provides complete ESD protection information and **shall** be consulted for additional information.

APPENDIX A

DUTIES AND RESPONSIBILITIES OF SITE DEVELOPMENT SUPERVISOR

To help determine applicants' qualifications, they should be interviewed by someone with management experience in large construction projects.

- Reports to the Project Manager and is responsible for all site development supervision, site specific testing/inspection and resolution of punchlist items.
- Manages and verifies safety logs, meetings, and random inspections to ensure compliance with contractor safety programs.
- Manages and maintains the construction schedule as directed by the Project Manager.
- Verifies, documents, and ensures that each site is complete and ready for final customer inspection. QA/QC checklists and test plans must be completed and signed off prior to final inspections.
- Has extensive industrial construction schedule development and management experience.
- Can perform constructability evaluations to ensure optimum use of construction knowledge and experience in planning, design, procurement and field operations to achieve project goals and objectives.
- Understand, implement and manage all aspects of site development safety.
- Directs contractors and vendors as required.
- Maintains detailed daily activity reports, field logs, including manpower and equipment allocations, photo logs, and labeling.
- Maintains progress and percentage complete evaluation and reports. Update site development matrix.
- Coordinates construction, inspection and vendor delivery schedules.
- Travels extensively as required.

The following specific knowledge and skills are job requirements:

- Extensive large industrial and commercial project construction management experience.
- Ability to read and interpret blueprints, drawings, specifications, topographic and boundary surveys.
- Proficiency in the use of survey equipment to physically verify site boundaries, site layouts and tower equipment elevations.

- Extensive QA/QC experience.
- Sound and confident decision making ability with a high level of attention to details and specifications. Not afraid to ask questions or question direction.
- Ability to competently monitor and manage the following construction activities, including but not limited to:
  - Large caisson drilling and installation
  - Building and mat type foundation excavations and installations
  - Compaction and concrete testing
  - Back-up power systems
  - Small and large concrete and rebar installations
  - All types of civil installations, including roadway and wetland installations
  - Above and below ground electrical installations and connections
  - Heavy rigging and crane operations
  - HVAC and Mechanical installations
  - Large guyed, self-supporting and monopole tower installations
- Familiar with latest version of applicable jurisdictional codes and specifications, including but not limited to:
  - NFPA
  - American Concrete Institution
  - EIA-TIA 222
  - BOCA
  - ANSI
  - ASTM
- Understands and is competent in OSHA and other applicable safety standards, rules and regulations, including Motorola EHS standards.
- Capable of writing reports, manipulating spreadsheets, and using common business software applications.
- Understands Electromagnetic Energy (EME) Standards ANSI/IEEE C95.1-1992.

The qualified applicant should, at a minimum, also have access to the following tools:

- Four-wheel drive utility vehicle or truck equipped with straight pull winch, 9000 lb. minimum
- Laptop computer with adequate processor and memory (minimum 266 Pentium and 128 MB RAM recommended) with a portable laser printer
- Digital Theodolite type transit and stand with 90° eyepiece
- Digital Multimeter
- Gas pressure meter (capable of measuring up to 11 in, H_2O)
- Digital camera with voice labeling capability
- Cellular or Satellite Phone

- Pager
- Binoculars
- Must have and know how to use current versions of the following tools:
  - Microsoft Word
  - Microsoft Excel
  - Microsoft Access (Optional)
  - Autocad LT
  - Microsoft Project (Depending on project scheduling platform)
  - Internet Access
  - E-mail

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APPENDIX B

SITE DEVELOPMENT INFORMATION

This appendix provides examples of some of the information required during site development. It contains the following:

- Example of an electrical utility information form - provides examples of the type of information most utility companies need in order to bring electrical service to a communications site.
- Typical example of a tower site information form - This form is to be used as an example of the kind of data that must be provided when proposing a tower.
- Antenna Installation and Identification Matrix
- Example of a Concrete Placement Log, used to record information on concrete deliveries to a site.
- Motorola Land Mobile Products Group Tower Climbing Safety manual prepared by Motorola Environmental Health and Safety

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MOTOROLA

Insert Project Name Here

ELECTRICAL UTILITY INFORMATION FORM

Service/Owner Name:	
Reference Number:	
Service Address:	To Be Assigned
Location Description:	Enter nearest crossroads
Township	
Town/Range/Section (if available):	
County:	
Nearest Cross Road	
Site Map and Construction Plans:	Attach
Legal Description, Boundary, and Topographic Survey	Attached
Easement Information	Attached
Construction Start Date:	
Date Service Needed:	
Service Type	Above/below ground, distance
Service Voltage:	Enter voltage type and phase requirements. Example: 120/240 Single phase
Service Entrance Size:	Enter amperage
Connected Load on Service:	Enter calculated total equipment load in watts and/or kilowatts
Usage:	Specify seven days a week, 24 hours a day
Construction Cost (determined by utility):	
Construction Billing Address:	Specify complete address to which bill for service is to be sent, and name of person to whom it should be directed.
Management Information	Enter project manager's name, phone number, and FAX number.
Utility Company Location:	Enter location and contact information for utility company.

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NOTE: This form is an example of the kind of information required for a tower site.

Tower Site Information Sheet

Site Designator: **1234D**

MSPNo: **1234D**

Address/Location:

City:

County:

Phase:

District:

Owner:

Site Type: RF Site

Status: Proposed

	Latitude	Longitude	AMSL
Field			
Certified			

USGS Map Name/Number:

Section: **Township:** **Range:**

Fractional Legal Description:

Additional Detailed Legal Description:

Directions:

Tower Type: Guyed

Tower Height (BAFO):

Greatest Antenna Height:

TX Ant Mounting Ht:

Rx Ant Mounting Ht:

Highest Antenna **Tx** **Rx**

Reference Azimuth:

RF ERP (dBm): 53.8

City:

Distance to City:

Azimuth to City

Contact (if applicable):

Comments:

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Antenna Installation and Identification Matrix

SITE NUMBER ______________ SITE NAME ________________________

Microwave Dishes

AZIMUTH 0-120			AZIMUTH 121-240			AZIMUTH 241-359.99		
Path #1	Main	Diversity	Path #1	Main	Diversity	Path #1	Main	Diversity
Destination		SAME	Destination		SAME	Destination		Same
Azimuth		SAME	Azimuth		SAME	Azimuth		Same
Dish Size			Dish Size			Dish Size		
Height			Height			Height		
Polarization		SAME	Polarization		SAME	Polariztion		Same
Face/Leg			Face/Leg			Face/Leg		
Color Code	Green White	Green White White	Color Code	Blue White	Blue white White	Color Code	Brown White	Brown White White
Path #2	Main	Diversity	Path #2	Main	Diversity	Path #2	Main	Diversity
Destination		SAME	Destination		SAME	Destination		SAME
Azimuth		SAME	Azimuth		SAME	Azimuth		SAME
Dish Size			Dish Size			Dish Size		
Height			Height			Height		
Polarization			Polarization			Polarization		
Face/Leg			Face/Leg			Face/Leg		
Color Code	Green Yellow	Green Yellow Yellow	Color Code	Blue Yellow	Blue Yellow Yellow	Color Code	Brown Yellow	Brown Yellow Yellow
Path # 3	Main	Diversity	Path # 3	Main	Diversity	Path # 3	Main	Diversity
Destination		SAME	Destination		SAME	Destination		SAME
Azimuth		SAME	Azimuth		SAME	Azimuth		SAME
Dish Size			Dish Size			Dish Size		
Height			Height			Height		
Polarization			Polarization			Polarization		
Face/Leg			Face/Leg			Face/Leg		
Color Code	Green Orange	Green Orange Orange	Color Code	Blue Orange	Blue Orange Orange	Color Code	Brown Orange	Brown Orange Orange

*** Start with the lowest mounted main dish (and its associated diversity, dish if applicable) in each azimuth range as path # 1 and go progressively higher**

Antennas

Antenna	RX1	TX1	TX2	TX 3
Type				
Color Code				Blue Blue Blue
Height				
Face/Leg				

Relocated Antennas

Ant.	Organization	Color Code	Height
1			
2			
3			
4			
5			

Strobe Cables	Color
Master	Red
Slave 1	Blue
Slave 2	Blue Blue

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Concrete Placement and Testing Log

				Concrete Placement and Test Data							*Coring Methods*			
Motorola Site Number	**Concrete Placement Location/Item**	**Date Placed**	**Design Mix/Batch Strength (Psi)**	**Cylinder Designation (A-D)**	**Seven Day Break - "A" Cylinder**	**Twenty-Eight Day Break - "B" Cylinder**	**Twenty-Eight Day Break - "C" Cylinder**	**Fifty-Six Day Break - "D" Spare Cylinder**	**Yield Strength***	**Core Number**	**Location of Core**	**Date Drilled**	**Date Tested**	**Length and Diameter of Core**	**Yield Strength**
1234 - Phase II	East Caisson Foundation	1/9/98	3000	1A-D	3580	4885	5050	N/A	166%						
1234 - Phase II	East Caisson Foundation	1/9/98	3000	2A-D	3360	4970	4895	N/A	164%						
1234 - Phase II	East Caisson Foundation	1/9/98	3000	3A-D	3390	5250	4960	N/A	170%						

*: Yield strength will be derived from the average of both 28 day break cylinders. If 28 day yield is deficient, the yield will then be derived from the 56 day break.

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MOTOROLA CONTRACTORS FALL PROTECTION PROGRAM

1.0 PURPOSE

The purpose of this program is to provide systems and procedures designed to prevent employees from falling off, onto, or through working levels and to protect personnel from being struck by falling objects.

2.0 SCOPE

Applicable to all Motorola employees and Motorola Contractors and Subcontractors

3.0 DEFINITIONS

Anchorage - A secure point of attachment for lifelines, lanyards or deceleration devices.

Body belt - A strap with means both for securing it about the waist and for attaching it to a lanyard, lifeline, or deceleration device.

Body harness - Straps that may be secured about the person in a manner that distributes the fall-arrest forces over at least the thighs, pelvis, waist, chest, and shoulders with a means for attaching the harness to other components of a personal fall arrest system.

Connector - A device that is used to couple (connect) parts of a personal fall arrest system or positioning device system together.

Controlled access zone - A work area designated and clearly marked in which certain types of work (such as overhand bricklaying) may take place without the use of conventional fall protection systems – guardrail, personal arrest or safety net – to protect the employees working in the zone.

Deceleration device - Any mechanism-such as rope, grab, ripstitch lanyard, specially woven lanyard, tearing or deforming lanyards, automatic self-retracting lifelines/ lanyards-which serves to dissipate a substantial amount of energy during a fall arrest, or otherwise limits the energy imposed on an employee during fall arrest.

Deceleration distance - The additional vertical distance a falling person travels, excluding lifeline elongation and free fall distance, before stopping, from the point at which a deceleration device begins to operate.

Guardrail system - A barrier erected to prevent employees from falling to lower levels.

Hole - A void/gap of 5 cm (2 in.) or more in the least dimension in a walking/working surface.

Lanyard - A flexible line of rope, wire rope, or strap that generally has a connector at each end for connecting the body belt or body harness to a deceleration device, lifeline, or anchorage.

Lifeline - A component consisting of a flexible line for connection to an anchorage at one end to hang vertically (vertical lifeline), or for connection to anchorage at both ends to stretch horizontally (horizontal lifeline), and that serves as a means for connecting other components of a personal fall arrest system to the anchorage.

Low-slope roof - A roof having a slope less than or equal to 4 in 12 (vertical to horizontal).

Opening - A gap or void of 76 cm (30 in.) or more high and 45.7 cm (18 in.) or more wide, in a wall or partition, through which employees can fall to a lower level.

Personal fall arrest system - A system including but not limited to an anchorage, connectors, and a body harness used to arrest an employee in a fall from a working level.

Positioning device system - A body belt or body harness system rigged to allow an employee to be supported on an elevated vertical surface, and work with both hands free while leaning backwards.

Rope grab - A deceleration device that travels on a lifeline and automatically, by friction, engages the lifeline and locks to arrest a fall.

Safety-monitoring system - A safety system in which a competent person is responsible for recognizing and warning employees of fall hazards.

Self-retracting lifeline/lanyard - A deceleration device containing a drum-wound line that can be slowly extracted from, or retracted onto, the drum under minimal tension during normal employee movement and which, after onset of a fall, automatically locks the drum and arrests the fall.

Snaphook - A connector consisting of a hook-shaped member with a normally closed keeper, or similar arrangement, which may be opened to permit the hook to receive an object and, when released automatically closes to retain the object.

Toeboard - A low protective barrier that prevents material and equipment from falling to lower levels.

Unprotected sides and edges - Any side or edge (except at entrances to points of access) of a walking/working surface where there is no wall or guardrail system at least 99 cm (39 in.) high.

Walking/working surface - Any surface, whether horizontal or vertical, on which an employee walks or works, including but not limited to floors, roofs, ramps, bridges, runways, formwork, and concrete reinforcing steel. Does not include ladders, vehicles, or trailers on which employees must be located to perform their work duties.

Warning line system - A barrier erected on a roof to warn employees that they are approaching an unprotected roof side or edge and which designates an area in which roofing work may take place without the use of guardrail, body belt, or safety net systems to protect employees in the area.

4.0 REQUIREMENTS

It is the policy of Motorola to conduct all operations in a responsible manner, free from recognized hazards. This program applies to any & all towers and structures whether owned by Motorola or not, where while climbing or performing work and employee or contractor's worker would fall greater than 1.83 m (6 ft.). This includes self-supporting and guyed towers, water towers, monopoles, building tops and other structures of similar construction.

This program also includes those towers equipped with elevators where leaving the confines of the elevator the employee would be at risk. This procedure is based on 100% fall protection required at all times.

4.1 Whenever an affected employee or contractor is 1.83 m (6 ft.) or more above a lower level, they must be protected from fall hazards and all personnel must be protected from falling objects.

4.2 Protection must also be provided for employees and contractors who are exposed to the hazard of falling into dangerous equipment or hazardous chemicals. Requirements for workers on scaffolds and ladders are covered in other programs.

4.3 Any employee or contractor on a non-standard walking/working surface (horizontal and vertical surface) with an unprotected side or edge which is 1.83 m (6 ft.) or more above a lower level must be protected from falling by the use of a fall protection system (excluding excavation sites).

4.4 Any employee or contractor on a roof with unprotected sides and edges 1.83 m (6 ft.) or more above lower levels must be protected from falling by a fall protection system. (For low-sloped and flat roofs, a warning line system can be used.)

4.5 When employees or contractors are exposed to falling objects, hard hats must be worn and a system to prevent materials from falling must be erected. This system may consist of toe boards, screens or guardrail systems, a canopy structure or barricades.

4.6 Personal fall protection systems must be specified by the safety engineer and inspected before each use. Anchorage points must meet minimum structural requirements (an impact load of 22250 N (5000 lb.)) or 2 times the maximum intended impact load determined by a qualified individual). The fall arrest system must limit the arresting forces to 8010 N (1800 lb.).

4.7 Skylights that do not meet the structural requirements of a hole cover must be protected.

4.8 All excavations of 1.2 m (4 ft.) or more depth must be reviewed and inspected by a qualified person. All employees must be protected from cave-ins by shields, sloping or shoring. Fall protection is required for walkways and bridges over trenches. A fall protection system or barricade must be used when the excavation is not readily visible.

5.0 PROCEDURES

5.1 Pre-planning Meeting and Safety Checklist

A pre-planning session must be conducted prior to beginning the climb of any tower or structure. This session should include:

- Before going to the site determine the type and height of tower or structure, the location and types of antennas, the tools and safety equipment required, how to access the site and whether the owner need to be notified.
- Once at the site, does the tower or structure appear to be sound, are the guy wires secure and in good condition, is the ladder or bolts secure and is there a safety cable installed. Never climb a tower or structure that is believed to be not safe.
- Also determine the path to climb, whether power to equipment needs to be turned off or reduced, is the current weather satisfactory and is it expected to changes before completing the job.
- Check personal protection equipment to include hard hat, safety glasses, gloves, and foot protection are in proper condition. (See 6.3)

5.2 Personal Fall Arrest Systems

- The personal fall arrest system **shall** limit maximum arresting force on an employee to 8010 N (1,800 lb.) when used with a full body harness.
- Only full bodies harness with a retractable or shock absorbing lanyard that limits the free fall to 1.83 m (6 ft.) **shall** be used. In addition, positioning lanyards should also be used if a fall of less than 1.83 m (6 ft.) would result in contact with other equipment like antennas, dishes, star or side mounts. Lanyards **shall** have a minimum breaking strength of 22250 N (5000 lb.). Body belts are not to be used.
- Only locking snaphooks are to be used on the lanyards and must be sized for the anchorage being used. All D-rings and snaphooks **shall** have a minimum tensile strength of 22250 N (5000 lb.).
- The attachment point for a full body harness **shall** be located in the center of the wearer's back near shoulder level. The anchorage point should be above or in front to reduce the free-fall to the shortest possible distance.
- Personal fall arrest systems that have been used in a fall **shall** be immediately removed from service and not be used again until inspected by a competent person as defined by OSHA and determined to be undamaged and suitable for reuse.

5.3 Inspections

- Full Body Harness

Examine webbing for burn marks, torn, frayed or broken fibers, pulled stitches or frayed edges anywhere on the harness. Examine the D-ring for excessive wear, pits, deterioration or cracks.

Verify the buckles are not deformed, cracked and operate correctly and that the tongue/straps do not have excessive wear from repeated buckling.

Check that all grommets are secure and not damaged and that all rivets are tight.

- Retractable Lanyards

  Ensure that there is no physical damage to the body and that all back nuts and rivets are tight.

  Ensure cable ends are securely crimped and cable eye and rubber stops are in place. Ensure that cable/nylon strap are undamaged and retract freely.

- Snap Hooks

  Look at the locking snaphooks for any cracks, pitting or corrosion on the surfaces or distortions in the hook or eye.

  Test the locking mechanism to verify proper locking of the keeper latch. Check the keeper latch is not bent, distorted or obstructed and that it seats in the nose without binding.

5.4 Emergency Medical and Rescue Plan

An emergency medical plan that includes provisions for rescue **shall** be in place prior to start of work at a tower site and must be reviewed during the pre-climb meeting.

- The methodology to be used on a site by site basis in case of a medical emergency or rescue would be required.
- Emergency phone numbers on a site by site basis and communications equipment available to notify emergency or medical response services.
- Notification procedures in case of serious injury or death.

5.5 Training

- All workers approved to climb **shall** be trained by a competent person qualified in the nature of fall hazards in the work area and the proper use of personal fall arrest system and equipment being used before the worker is allowed to climb.
- Retraining is required on an annual basis by a competent person and when there are changes to this policy, conditions in the work area, or if there is a reason to believe that the worker's knowledge or understanding is inadequate.
- A tracking system **shall** be in place to verify that all identified employees or contractors have received initial training and retraining as required. The name and signature of the worker, the date of training, the length of the training and signature of the competent person conducting the training **shall** be tracked. In addition, a copy of the training material **shall** be kept on file for the previous five years.

7.0 GENERAL

- The weather must be safe and stable for the climb to occur. No climbs are to be made at night.
- No one is ever permitted to climb alone. Two or more persons must be present at the tower site, preferably a member of supervision and/or competent person. The person on the ground must have emergency response training.
- All employee and contractors at the site **shall** be trained in the hazards of non-ionizing radiation and how to minimize exposure.

- All employees and contractors at the site must complete a thorough equipment check to be certain the correct safety harness, shoes, glasses, and helmets, etc. are in good order, and safe to use before the climb begins.
- The contractor's workers climbing must complete a pre-climb Safety Awareness checklist with the manager or supervisor and all items must be satisfactory. The checklist must be signed and dated by the manager and person climbing the tower.
- Two-way radio communication equipment must always be available and used when necessary to provide communications between the person climbing and the ground crew(s)

8.0 REFERENCES

ANSI Z359	American National Safety Institute - Requirements for personal fall arrest systems, subsystems and components
ZED 259	Canadian Standards Association - Requirements for personal fall arrest systems
ISO/TC94/SC4	International Standard - Personal equipment for protection against falls
ANSI A10.14	Requirements for Safety Belts, Harnesses, Lanyards, and Lifelines for Construction and Demolition use
ANSI A14	Ladders
29CFR1926	Code of Federal Regulations 1926. Sub-part M (OSHA)

The following is a previously separate appendix which has been included here for reference and information.

ADDITIONAL GUIDELINES FOR REVIEWING CONTRACTOR FALL PROTECTION PROGRAMS

1.0 WORK OPERATIONS OPTIONS WHEN FALL HAZARD PRESENT

1.1 Controlled Access Zones

- A Controlled access zone is a work area designated and clearly marked in which certain types of work may take place without the use of conventional fall protection systems-guardrail, personal arrest or safety net-to protect the employees working in the zone. Access to the zone is controlled.
- Controlled access zones, when created to limit entrance to areas where leading edge work and other operations are taking place, must be defined by a control line or by any other means that restrict access. Control lines **shall** consist of ropes, wires, tapes or equivalent materials, and supporting stanchions, and each must be:
  - Flagged or otherwise clearly marked at not more than 1.83 m (6 ft.) intervals with high-visibility material;
  - Rigged and supported in such a way that the lowest point (including sag) is not less than 99 cm (39 in.) from the walking/working surface and the highest point is not more than 1.14 m (45 in.) from the walking/working surface;
  - Minimum breaking strength of 890 N (200 lb.). Control lines **shall** extend along the entire length of the unprotected or leading edge and **shall** be approximately parallel to the unprotected or leading edge.
  - When control lines are used, they **shall** be erected not less than 1.83 m (6 ft.) nor more than 7.62 m (25 ft.) from the unprotected or leading edge. The control line **shall** be connected on each side to a guardrail system on wall.

1.2 Excavations

- All excavations 1.83 m (6 ft.) or more deep **shall** be protected by guardrail systems, fences, barricades, or covers.
- Where walkways are provided to permit employees to cross over excavations, guardrails are required on the walkway if it is 1.83 m (6 ft.) or more above the excavation.

1.3 Hoist Areas

- Each worker in a hoist area **shall** be protected from falling 1.83 m (6 ft.) or more by guardrail systems or personal fall arrest systems.
- If guardrail systems (or chain gate or guardrail) or portions thereof must be removed to facilitate hoisting operations, as during the landing of materials, and a worker must lean through the access opening or out over the edge of the access opening to receive or guide equipment and materials, that worker must be protected by a personal fall restraint or fall arrest system.

1.4 Holes

- Personal fall arrest systems, covers, or guardrail systems **shall** be erected around holes (including skylights) that are more than 1.83 m (6 ft.) above lower levels.

1.5 Low-slope Roofs

- Each worker engaged in roofing activities on low-slope roofs with unprotected sides and edges 1.83 m (6 ft.) or more above lower levels **shall** be protected from falling by:
  - guardrail systems, safety net systems, personal fall arrest systems or
  - a combination of a warning line system and guardrail system, warning line system and safety net system, warning line system and personal fall arrest system, or warning line system and safety monitoring system.
- On roofs 15.3 m (50 ft.) or less in width, the use of a safety monitoring system without a warning line system is permitted.

1.6 Wall Openings

- Each worker working on, at, above, or near wall openings where the outside bottom edge of the wall opening is 1.83 m (6 ft.) or more above lower levels and the inside bottom edge of the wall opening is less than 99 cm (39 in.) above the walking/working surface must be protected from falling by the use of a guardrail system, a safety net system, or a personal fall arrest system.

2.0 RECOMMENDED FALL PROTECTION SYSTEMS CRITERIA & PRACTICES

2.1 Guardrail Systems

- If the Facility Supervisor chooses to use guardrail systems to protect workers from falls, the systems must meet the following criteria.
  - Toprails and midrails of guardrail systems must be at least 6.35 mm (1/4 in.) nominal diameter or thickness to prevent cuts and lacerations.
  - If wire rope is used for toprails, it must be flagged at not more 1.83 m (6 ft.) intervals with high-visibility material.
  - Steel and plastic banding cannot be used as toprails or midrails.
  - The top edge height of toprails, or (equivalent) guardrails must be 1 m (42 in.) plus or minus 7.6 cm (3 in.) above the walking/working level.
- Screens, midrails, mesh, intermediate vertical members, or equivalent intermediate structural members must be installed between the top edge of the guardrail system and the walking/working surface when there are no walls or parapet walls at least 53.3 cm (21 in.) high.
  - When midrails are used, they must be installed at a height midway between the top edge of the guardrail system and the walking/working level.
  - When screens and mesh are used, they must extend from the top rail to the walking/working level and along the entire opening between top rail supports.
- The guardrail system must be capable of withstanding a force of at least 890 N (200 lb.) applied within 5 cm (2 in.) of the top edge in any outward or downward direction at any point along the top edge.

  - When the 890 N (200 lb.) test load is applied in a downward direction, the top edge of the guardrail must not deflect to a height less than 99 cm (39 in.) above the walking/working level.
  - Guard rail systems **shall** be surfaced to prevent injury to a worker from punctures, lacerations and to prevent snagging of clothing.
- Midrails, screens, mesh, intermediate vertical members, solid panels, and equivalent structural members **shall** be capable of withstanding a force of at least 668 N (150 lb.) applied in any downward or outward direction at any point along the midrail or other member.

2.2 Safety Net Systems

- Safety nets must be installed as close as practicable under the walking/working surface on which employees are working but in no case more than 9.2 m (30 ft.) below such level.
- Defective nets **shall not** be used. Safety nets **shall** be inspected at least once a week for wear, damage, and other deterioration.
- The maximum size of each safety net mesh opening **shall not** exceed 232.3 cm^2 (36 sq in.) nor be longer than 15.2 cm (6 in.) on any side, and the openings, measured center-to- center, of mesh ropes or webbing, **shall not** exceed15.2 cm (6 in.).
- All mesh crossings **shall** be secured to prevent enlargement of the mesh opening. Safety nets **shall** be installed with sufficient clearance underneath to prevent contact with the surface or structure below.
- Safety nets **shall** be capable of absorbing an impact force of a drop test consisting of a 181.4 kg (400 lb.) bag of sand76 cm (30 in.) in diameter dropped from the highest walking/working surface at which workers are exposed, but not from less than 1 m (42 in.) above that level.

2.3 Personal Fall Arrest Systems

- These consist of an anchorage, connectors, lanyard, and a body harness and may include a deceleration device, lifeline, or suitable combinations. If a personal fall arrest system is used for fall protection, it must do the following:
  - Limit maximum arresting force on an employee to 8010 N (1,800 lb.) (35600 N (8000 lb.) when used with a body harness);
  - Be rigged so that an employee can neither free fall more than 1.83 m (6 ft.) nor contact any lower level;
  - Bring an employee to a complete stop and limit maximum deceleration distance an employee travels to 1.1 m (3.5 ft.); and
  - Have sufficient strength to withstand twice the potential impact energy of an employee free falling a distance of 1.83 m (6 ft.) or the free fall distance permitted by the system, whichever is less.
- Personal fall arrest systems must be inspected prior to each use for wear damage, and other deterioration. Defective components must be removed from service. Personal fall arrest systems will be inspected semi-annually by a competent person.
- Unless the snaphook is a self-locking type and designed for the following connections, they **shall not** be engaged:
  - directly to webbing, rope or wire rope;

  - to each other;
  - to a dee-ring to which another snaphook or other connector is attached;
  - to a horizontal lifeline; or
  - to any object incompatible in shape or dimension relative to the snaphook, thereby causing the connected object to depress the snaphook keeper and release unintentionally.

- Self-retracting lifelines and lanyards that automatically limit free fall distance to 61 cm (2 ft.) or less **shall** be capable of sustaining a minimum tensile load of 13350 N (3,000 lb.) applied to the device with the lifeline or lanyard in the fully extended position.
- Self-retracting lifelines and lanyards that do not limit free fall distance to 61 cm (2 ft.) or less, ripstitch lanyards, and tearing and deforming lanyards **shall** be capable of sustaining a minimum tensile load of 22250 N (5,000 lb.) applied to the device with the lifeline or lanyard in the fully extended position.
- Ropes and straps (webbing) used in lanyards, lifelines, and strength components of body harnesses **shall** be made of synthetic fibers.
- Anchorage's **shall** be designed, installed, and used under the supervision of a qualified person, as part of a complete personal fall arrest system that maintains a safety factor of at least two; i.e., capable of supporting at least twice the weight expected to be imposed upon it.
- Anchorage's used to attach personal fall arrest systems **shall** be independent of any anchorage being used to support or suspend platforms and must be capable of supporting at least 22250 N (5,000 lb.) per person attached.

3.0 ADDITIONAL FALL PROTECTION SYSTEMS CRITERIA AND PRACTICES

3.1 Positioning Device Systems

- These body belt or body harness systems are to be set up so that a worker can free fall no farther than 61 cm (2 ft.).
- They **shall** be secured to an anchorage capable of supporting at least twice the potential impact load of an employee's fall or 13350 N (3,000 lb.), whichever is greater.
- Requirements for snaphooks, dee-rings, and other connectors used with positioning device systems must meet the same criteria as those for personal fall arrest systems as identified in 1926 Subpart M.

3.2 Safety Monitoring Systems

- When no other alternative fall protection has been implemented, the Contractor **shall** implement a safety monitoring system.
  - Workers must appoint a competent person to monitor the safety of workers and the employer **shall** ensure that the safety monitor:
  - Is competent in the recognition of fall hazards;
  - Will warn workers of fall hazard dangers and in detecting unsafe work practices;
  - Is operating on the same walking/working surfaces of the workers and can see them;

  - Is close enough to work operations to communicate orally with workers and has no other duties to distract from the monitoring function.

- Mechanical equipment **shall not** be used or stored in areas where safety monitoring systems are being used to monitor employees engaged in roofing operations on low-sloped roofs.
- No worker, other than one engaged in roofing work (on low- sloped roofs), **shall** be allowed in an area where an employee is being protected by a safety monitoring system.
- All workers in a controlled access zone **shall** be instructed to promptly comply with fall hazard warnings issued by safety monitors.

3.3 Warning Line Systems

- Warning line systems consist of ropes, wires, or chains, and supporting stanchions and are set up as follows:
  - Flagged at not more than 1.83 m (6 ft.) intervals with high-visibility material;
  - Rigged and supported so that the lowest point (including sag) is no less than 86.3 cm (34 in.) from the walking/working surface and its highest point is no more than 99 cm (39 in.) from the walking/working surface.
  - Stanchions, after being rigged with warning lines, **shall** be capable of resisting, without tipping over, a force of at least 71.2 N (16 lb.) applied horizontally against the stanchion, 76.2 cm (30 in.) above the walking/working surface, perpendicular to the warning line and in the direction of the floor, roof, or platform edge;
  - The rope, wire, or chain **shall** have a minimum tensile strength of 2225 N (500 lb.) and after being attached to the stanchions, must support without breaking the load applied to the stanchions as prescribed above;
  - **shall** be attached to each stanchion in such a way that pulling on one section of the line between stanchions will not result in slack being taken up in the adjacent section before the stanchion tips over.
- Warning lines **shall** be erected around all sides of roof work areas:
  - When mechanical equipment is being used, the warning line **shall** be erected not less than 1.83 m (6 ft.) from the roof edge parallel to the direction of mechanical equipment operation, and not less than 3 m (10 ft.) from the roof edge perpendicular to the direction of mechanical equipment operation.
  - When mechanical equipment is not being used, the warning line must be erected not less than 1.83 m (6 ft.) from the roof edge.

3.4 Covers

- Covers located in roadways and vehicular aisles must be able to support at least twice the maximum axle load of the largest vehicle to which the cover might be subjected.
- All other covers must be able to support at least twice the weight of employees, equipment, and materials that may be imposed on the cover at any one time. To prevent accidental displacement resulting from wind, equipment, or workers' activities, all covers must be secured.

4.0 PROTECTION FROM FALLING OBJECTS

4.1 Guardrail Systems

- When guardrail systems are used to prevent materials from falling from one level to another, any openings must be small enough to prevent passage of potential falling objects. No materials or equipment except masonry and mortar **shall** be stored within 1.2 m (4 ft.) of working edges.
- During roofing work, materials and equipment **shall not** be stored within 1.83 m (6 ft.) of a roof edge unless guardrails are erected at the edge, and materials piled, grouped, or stacked near a roof edge must be stable and self-supporting.

4.2 Toeboards

- When toeboards are used as protection from falling objects, they must be erected along the edges of the overhead walking/working surface for a distance sufficient to protect persons working below. Toeboards **shall** be a minimum of 10.2 cm (4 in.) tall.
- Where tools, equipment, or materials are piled higher than the top edge of a toeboard, paneling or screening must be erected from the walking/working surface or toeboard to the top of a guardrail system's top rail or midrail, for a distance sufficient to protect employees below.

5.0 TRAINING

A training program must be in place (taught by a competent person) that teaches workers who might be exposed to fall hazards how to recognize such hazards and how to minimize them.

Workers are trained in the following areas: (a) the nature of fall hazards in the work area; (b) the correct procedures for erecting, maintaining, disassembling, and inspecting fall protection systems; (c) the use and operation of controlled access zones and guardrail, personal fall arrest, safety net, warning line, and safety monitoring systems; (d) the role of each employee in the safety monitoring system when the system is in use; (e) the limitations on the use of mechanical equipment during the performance of roofing work on low- sloped roofs; (f) the correct procedures for equipment and materials handling and storage and the erection of overhead protection; (g) employees' role in the fall protection program; and (h) the OSHA fall protection regulations.

Documentation **shall** be maintained on worker training. Retraining **shall** also be provided when deemed necessary, but the frequency will not exceed 2 years between classes for persons in the program.

APPENDIX

C

CELLULAR GROUNDING INFORMATION MANUAL

The Cellular approach to grounding is similar to that presented in Chapters 6 and 7 of this manual. However, because of some differences in application, there are some areas that receive additional or different coverage in the Grounding Guideline for Cellular Radio Installations, Motorola document 68P81150E62, provided here in its entirety.

Differences include, but are not limited to, Cellular's use of a PANI layout for grounding connections to a Main Ground Bar, and the recommendation to use an Isolated Ground Zone (IGZ) in cellular switch rooms.

Until concurrent revisions of both manuals can be executed, Cellular installations should be grounded in accordance with Appendix C. All other installations **shall** be grounded in accordance with Chapters 6 and 7.

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MOTOROLA

GROUNDING GUIDELINE

for Cellular Radio Installations

information manual

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MOTOROLA
General Systems Sector
Cellular Infrastructure Group

GROUNDING GUIDELINE

FOR CELLULAR RADIO INSTALLATIONS

CONTENTS

Technical Education & Documentation
1501 W. Shure Drive, Suite 3223B, Arlington Heights, Il 60004

68P81150E62–A
7/23/92 – UP

1. INTRODUCTION

1.1 PURPOSE

This document is intended to provide methods and practical standards for installing ground systems which will minimize the hazards to personnel, protect the equipment from permanent damage, and where practical, prevent temporary disruptions of the cellular system operation during lightning surges and ground faults.

1.2 ASSUMPTIONS

It is assumed throughout this document that the soil in which a ground system is to be established is of average resistivity and that subsurface formations do not prevent ground rods from being driven to the depths specified. Should local conditions prevent the above assumptions from being met, contact Systems Engineering for the special engineering that will be required.

1.3 OVERVIEW

A cellular radio grounding system is made up of a number of sub–systems, both interior and exterior. These consist of certain basic components arranged to achieve the goals of the ground system and adapted to the characteristics of each individual site. Although the exact configurations vary from place to place, the components which are included in a ground system generally remain the same, and the general guiding principles always do. While the specifics of those principles can fill volumes, and this document is not intended to be a theoretical teaching medium, the basic philosophy of this type of ground system can be summed up quite briefly.

NOTE
Local codes take precedence if they are more conservative.

2. GENERAL TECHNIQUES

The general techniques by which a ground system is implemented are described below. While these statements are somewhat simplified, it can be fairly stated that most cellular radio grounding is based on these principles and techniques, and adapted when necessary to meet special requirements at particular sites.

2.1 EXTERNAL GROUND SUB–SYSTEM

For sites with radio towers, the purpose of the ground system is to provide the lowest impedance path possible (within practical limits) from the antennas and tower to ground, external to the building. Several sub–systems are used to achieve this goal. The tower ground consists of a buried ring of wire encircling the tower base. The external building ground usually takes the form of a buried ring of wire around the building, although it may be necessary to use other designs. This external ground ring (EGR) provides the primary connection to earth for the remainder of the site. The EGR and the tower ring are connected together and supplemented with ground rods. Finally, all rf transmission line shields are grounded at several points.

2.2 INTERNAL GROUND SUB–SYSTEM

The internal system must have a low impedance path to ground and also achieve a minimal potential difference between conductive structures within the site, while eliminating (or at least minimizing) any surge current flow through the site equipment. Safety of personnel and equipment is the overriding concern of this document, not signal grounding. The construction of cellular fixed equipment achieves good internal signal grounding through the inherent quality of the equipment design.

Internal ground connections are made to the Master Ground Bar (MGB). The MGB is a large copper bar used as a low resistance junction point for all internal grounds. All rf equipment is tied directly to this main bar. The MGB is tied to the external ground system, the commercial ac ground, and other ground sources such as building steel. Other ground bars, tied back to the MGB, are used to tie clusters of associated equipment together. This isolates equipment clusters from surges while minimizing inter–equipment voltage potentials within that local cluster. Equipment racks or bays must be isolated from any unplanned ground paths to avoid surge current flow. This can usually be achieved by placing the racks or bays on insulating pads. Finally, an elevated wire ring (Internal Ground Ring, IGR) encircling the equipment area ties miscellaneous conductive items, such as door frames, to the ground bar. The elevated wire ring is also tied to the outside ground system at several points. This improves the effectiveness of the MGB.

2.3 SURGE PROTECTION

To prevent the above efforts from being circumvented by surges entering "by the back door", all conductors that enter the building must be protected by devices such as gas tube or MOV protectors. These conductors include all power, telecommunications, and tower lighting lines. The protectors will dissipate surges arriving on those conductors. There are various types of surge protection devices, and care must be taken to see that the type provided by utilities companies, the customer, or Motorola are of the correct type and rating for the application.

3. DEFINITIONS

A summary of the various terms and component parts used in ground systems, with their abbreviations and definitions, are given in the following paragraphs.

3.1 CADWELD® PROCESS

CADWELD (registered trademark of Erico Products, Inc., Cleveland, Ohio) is a process for making exothermic welds. Instead of gas or arc welding apparatus, a unique powdered metal mixture is used in conjunction with special graphite molds. The powder reacts to produce molten copper, which flows around and slightly melts the items being joined. The result is a permanent, high quality, strong, and low resistance joint. Examples of various *CADWELD* products are given in Appendix E, Figure 13 through Figure 15.

3.2 EXTERNAL GROUND BAR (EGB)

The EGB is a large copper bar with pre–drilled holes for mounting lugs. It may be equipped with a 2” copper strap, 1/16 inch thick to serve as a connection to the EGR. It serves as a convenient, low resistance tie point for ground leads from the transmission line ground kits at the point of entry to the equipment room. It is located directly under the waveguide entry window on the outside of the equipment room. Refer to Figure 2 (Appendix E).

3.3 EXTERNAL GROUND RING (EGR)

The EGR is a buried external bare wire that is usually in the form of a ring around the building. The EGR together with the tower ring and associated ground rods form the main ground terminus for the site. The EGR may take the physical form of a “C” or an “L” shape in cases where all sides of the building are not accessible. Also see paragraph **3.11 Ufer Grounds** on page 4of this document.

3.4 GROUND RODS

Ground rods are usually copper–clad steel and a minimum of 8–feet long and 5/8–inch diameter. Longer and larger diameter rods are available. Also, stainless steel rods are required if objects of corrosion–prone metal are buried near the copper of the ground system installation. (Refer to Appendix C to determine if stainless steel rods are required.)

3.5 INTERNAL GROUND RING (IGR)

This is a ring of bare wire (sometimes referred to as the “halo”) mounted on the equipment room walls. It serves to connect the miscellaneous metal, non–surging equipment or objects to a common ground at the master ground bar. The IGR is grounded to the EGR at several points.

3.6 ISOLATED GROUND BAR (IGB)

IGB is similar to, but usually smaller than the MGB. IGB serves as a single grounding point for all equipment within the Isolated Ground Zone (IGZ). The IGB references the IGZ equipment to the same potential, and is only connected to ground through the MGB.

3.7 ISOLATED GROUND ZONE (IGZ)

The IGB is an association of non–surging, switch–related equipment (i.e., equipment that is not likely to be exposed to lightning surges). This equipment is directly connected to a local common ground point called the “Isolated Ground Bar”, which in turn is connected to the MGB. The ac outlets in the IGZ must be grounded to the IGB in order to prevent another connection to ground.

3.8 MASTER GROUND BAR (MGB)

This is a large copper bar with pre–drilled holes for mounting lugs. The MGB serves as a convenient, low resistance tie point for ground leads either directly from the equipment or indirectly through the IGR or IGB. An example of MGB usage is shown in Figure 5 (Appendix E); different types are illustrated in Figure 10 (Appendix E).

3.9 MULTI–GROUNDED NEUTRAL (MGN)

This is the ground lead that is the third wire of a single phase ac service drop, or the fourth wire of a three phase ac service drop. It is labeled multi–grounded because of the typical (though not always required) power industry practice of grounding this lead at several points along the utility transmission path.

3.10 TOWER GROUND RING

This is a ring of bare, buried wire surrounding the tower base, connecting the several tower ground rods together. It is connected to the tower by one or more conductors. It must also be connected to the EGR.

3.11 UFER GROUNDS

Named after the engineer who first developed this grounding technique, this term refers to the use of concrete as an interface medium between a ground conductor (in the form of a wire in a concrete–filled trench, or a wire mesh embedded in a concrete slab) and the surrounding earth. Ufer grounds are usually used at sites where the local soil exhibits poor conductivity or on rocky sites covered with little or no soil cover. The concrete, being highly hygroscopic, absorbs and retains moisture from the surrounding soil, thus enhancing its conductivity. Because the concrete makes direct contact with the imbedded conductor, and has a large surface area in contact with the soil or rock, the effectiveness of the grounding system is greatly improved. In more normal sites, a significant benefit results from connecting the ground system to the site foundation if it is made of reinforced concrete because this type of foundation is basically a Ufer ground.

4. GENERAL PRACTICES

4.1 CONDUCTORS

These are the wires, straps, and rods which form ground rings and allow connection of objects to be grounded to the ground system. Conductor type and size are determined by impedance, and ability to withstand fusing and corrosion (particularly underground).

NOTE

Conductors which are only partially underground (e.g. connections from the tower ring) are to be treated as below ground conductors.

4.1.1 Conductor Types

Above Ground: Either solid or stranded copper wire is permitted. Internal ground ring (IGR) and all external conductors must be bare. Equipment ground leads in cable trays must be insulated. (Green color insulation is desirable for ready identification.) Miscellaneous interior grounds from the IGR to door frames, etc., may be insulated if desired.

Below Ground: Rings or wires connecting to rings are to be tinned, solid copper wire.

Ground rods are to consist of copper clad steel, except incases where nearby steel or galvanized steel could contribute to galvanic corrosion. In this case, stainless steel rods are required.

NOTE

It is imperative that tinned copper wire be utilized for tower guy ground leads to prevent corrosion of galvanized guys. Refer to paragraph **6.3 Tower Grounding** on page **8**of this document.

4.1.2 Conductor Sizes

Above Ground: For ground rings and the interconnection of internal and external ground rings, #2 AWG or larger is required. For grounding of equipment and miscellaneous metallic objects, #6 AWG minimum is required.

Exceptions: Connection from the isolated ground bar (IGB) to master ground bar (MGB) shall be #2 AWG, minimum.

The EGB shall be grounded through a minimum 2–inch wide, 16–gauge copper strap, or alternately with two #2 AWG wires. The wires are to be connected at opposite ends of the EGB, with a minimum of 12 inches separation between them

Below Ground: All wire must be #2 AWG, minimum. Ground rods are to be a minimum of 8 feet in length and 5/8 inch in diameter. In the case of a deep basement adjacent to the rod, the rod must be long enough to extend a minimum of three feet below the basement floor.

4.2 CONNECTIONS

4.2.1 Below Ground

All below ground connections should be of an exothermic weld construction or equivalent.

Exceptions: Bolted clamps are recommended for the following:

- connections between tower and building ground systems
- connections between EGR and any other exterior ground system, such as a utility ground.

The purpose of these mechanical connections is to facilitate the testing and maintenance of the site ground system. As these connections can easily be removed and reconnected, each major component of the ground system can be tested separately to aid in isolating high impedance components of the system.

A mechanical, below ground connection such as this must be protected by locating it inside a covered test well (the side of this well must be constructed of non–metallic material). Materials utilized for the connection must not corrode, deteriorate, or loosen.

4.2.2 Above Ground

When two or more grounding conductors are to be joined above ground, either exothermic weld or split–bolt joint (copper alloy or pressure type crimp connectors) are acceptable, except that crimp connections shall not be used on solid conductors.

Exceptions: For connections which may be exposed to extreme stress such as weathering and/or surging, exothermic welds must be used at both ends. These include the following:

- connections between lightning arrestor bracket and EGR
- connections between EGB and EGR
- connections between tower leg and ground rod

4.2.3 Connection to Equipment

Connection of conductors to equipment should be by the use of lugs or clamps appropriate to the size and type of wire and provisions of the equipment being grounded.

4.2.4 Connection Joint Preparation

The surfaces of each conductor to be connected are to be well cleaned, removing all paint, dirt, and corrosion in the area of connection before each joint is made, whether it be a mechanical or welded joint. After mechanical joints are completed, application of an anti–oxidant compound, such as "NO–OX" or equivalent is recommended. When using non–welded mechanical connections, such as bolt–on lugs, the following practices should be followed:

- To ensure good electrical contact, the mating surfaces should be clean and flat.
- Two–holed lugs are required on all #2 AWG or larger ground leads mechanically attached to the MGB, IGB, and EGB, and are preferred for other grounding leads where the size of the wire (#6 AWG or larger) might exert sufficient stress on the lug to loosen a single mounting bolt.
- Stainless steel mounting hardware (nuts, bolts, etc.) is required on all outside connections as well as on the MGB and IGB, and is preferred for all other ground leads. Lugs may be tinned rather than stainless.
- The lug holes and stainless bolt sizes are to be chosen to match the mounting hole sizes, so that there is minimal play in the mechanical assembly prior to tightening the nuts. Split ring type lock–washers should be used to prevent the nuts from loosening. Refer to Figure 5, Detail A for proper hardware assembly.

NOTE

Exothermic connections may be made between some dissimilar metals (those which would corrode if mechanically connected together) as the discrete interface (which instigates the corrosion) between the two metals no longer exists in an exothermic weld. *An exception to this is a weld between aluminum and copper. An exothermic weld using these two metals will corrode in a very short period of time.* See appendix C for more information regarding corrosion from dissimilar metals.

4.3 SHARP BENDS IN CONDUCTORS

These are to be avoided as they add inductance and are prone to damage from lightning derived magnetic flux. A bending radius of 8 inches or more is required.

4.4 CABLE TRAYS

All cable tray sections are to be jumpered together using #6 wire. All paint around the connection area is to be removed, and a split–ring lock–washer is to be used to ensure good surface contact.

Exception: The cable tray in the IGZ is not to be connected to the non–IGZ cable tray.

4.5 INSULATING MATS

It is required that all EMX and surge producing racks be protected from any casual ground contacts. This can be implemented through the use of insulating mats and hardware in the rack floor mounting, as well as insulating hardware between the racks and the cable tray, should bracing to the cable tray be required.

4.6 RS–232 LINE PROTECTION

The RS–232 interfaces in the base station and the cellular switch are easily damaged by lightning surges if proper system design and/or installation procedures are not followed. Those interfaces include data modem ports on the base station and the switch, the base station maintenance modem port, and the TTY interfaces on the switch. If these RS–232 ports are connected through cables to other RS–232 devices, such as modems, DSUs, TTYs, etc., and the logic references at the opposite ends of the cable differ by more than 20–25 volts, the RS–232 device drivers at one or both ends of the RS–232 link may be destroyed during a lightning surge. For this reason, the base station data modems are normally dc powered off the same voltage buses that feed the BSC RS–232 circuitry. The cellular switch data modems are powered from the same dc circuitry as the switch itself. With this arrangement, the logic ground references at both ends of the RS–232 links are the same. In addition, frame grounding procedures at the cell and switch sites must be carefully followed. The maintenance modems normally supplied are only powered from the telco lines feeding them, and the RS–232 link is internally isolated to avoid destructive ground reference differences.

Special consideration must be given to the maintenance terminal (TTY) interface. The TTY RS–232 link is susceptible to surge damage if the TTY is not powered by ac source from within the IGZ (i.e. an isolated orange outlet). For this reason, if the TTY is powered from outside the IGZ, it is required that an isolation technique, as described in the following paragraph, be used.

If the RS–232 interfaces are not installed according to the above guidelines, specific surge protection devices must be added to the RS–232 links to protect the device drivers from damage by lightning induced surges. The best approach to surge protection is the use of back–to–back fiber optic RS–232 serial modems. The fiber optic link between the modems provides the ultimate in isolation between the two ends of the link. Another isolation approach is the use of back–to–back transformer isolated short haul modems. There must be no metallic ground connections between the two modems, so that the transformer isolation (with 1500 volt or higher isolation rating) will protect the RS–232 from damage.

Clamping type RS–232 surge protectors are not recommended. Although these devices may protect the RS–232 device drivers from damage during a surge, they will pass large surge currents into the equipment ground structure which may disrupt the operation of microprocessors, etc. Using the proper modems discussed earlier, will provide the proper RS–232 line protection.

5. UTILITY SERVICE ENTRANCES

5.1 GENERAL

Utility service entrances deserve discussion in themselves because, not only do surges tend to enter the site via the service entrances, but if properly installed, they have their own grounding systems. It is important that these separate systems be integrated into the cellular ground system. Note that the cellular grounding system does not constitute a substitute for the utility ground system, only a separate, complementary system. It is critical that all separate grounding systems at a site be electrically tied together in order to eliminate potential differences between the systems. For this reason, it is required that any ac neutral and the telephone grounding systems be connected to the MGB. In addition, the exterior grounding electrodes of these utilities are to be tied into the external cellular ground system. It is recommended that a mechanical connection be used (as described in section **4. General Practices** paragraphs beginning on page 4of this document). This allows for testing of the EGR system by temporarily opening the cross connection without removing the ground on the utility, which would create a safety hazard.

5.2 TELEPHONE LINES

Each telephone line pair (this includes telephone circuits for the cellular voice channels, data circuits, dial–up modems, alarm reporting auto–dial lines, and any other switched network or leased telephone lines) entering or leaving a site should be equipped with a three–electrode gas tube protector such as the Cook Electric 9A or equivalent.

If possible, negotiate with the local telephone utility to provide the type of protectors described above. Normally, telephone companies will provide carbon protectors which do no meet the above requirements. The ground for these protectors should then be connected to the cellular ground system as previously described in paragraph 5.1.

5.3 AC POWER SYSTEM PROTECTION

5.3.1 Commercial Power

It is critical that the ac power system be properly grounded, as this is a common “back–door” method for surges to enter the site. It is the commercial power authority’s responsibility to ensure proper external grounding of the Multi–Grounded Neutral (MGN). This consists of a connection from the MGN to a ground rod, usually at the last power pole before the power is brought into the customer’s power service entry. The customer is responsible for installing a separate grounding system at the ac power service entry to his facilities. This is at the first point of entry, usually at the main ac power disconnect. The requirement consists of a connection from the MGN to a ground rod connection. This grounding electrode system is to comply with applicable electrical codes, such as the NEC (Section 250–81). Refer to Figure 11 in Appendix E for further illustration.

In addition, surge protection is to be installed on the ac power system. Recommended are the Joslyn protectors, available for a variety of service entry configurations. Other equivalent ac surge protectors, when correctly sized for the application and potential energy levels, are also available. Cellular System Engineering can assist in the selection of an appropriate model for particular installations.

The protector must connect to and protect each under ground service conductor. These protectors are to be connected on the load side of the main disconnect.

5.3.2 Generators

If an outdoor generator exists on site, it is also recommended that a surge protector be installed on the load side of the generator transfer switch. This will ensure protection to the ac power distribution system when the commercial power is off–line.

If the generator is a separately derived source of power (i.e. its neutral is separate from the neutral of the commercial ac power source), the neutral of the generator must have its own grounding electrode system which is then tied into the cellular external ground system. A convenient way to determine if the generator is separately derived source is through inspection of the generator transfer panel. If the neutral on the load side of the transfer panel is switched between the commercial neutral and that of the generator, the generator is considered a separately derived source. If the neutral is unswitched (i.e. the commercial power neutral is at all times continuous with the generator neutral and the neutral to the loads), then the generator neutral must not have a separate grounding electrode system.

6. EXTERNAL GROUNDING SYSTEM

WARNING

Consult with the local utility (electric, gas, telephone, and water) companies to determine the location of any underground facilities prior to digging. *Failure to do so can result in expensive damage to those systems, as well as injury or death to personnel.*

6.1 OVERVIEW

The external ground system consists of the building ground, the tower and transmission ground (if radio equipment exists at the site), and any miscellaneous metal objects which are in proximity to any of the above. The objective of a good grounding system is two–fold:

- to connect all components together with the least impedance between components. This will minimize the potential difference between components should surge occur, which in turn will minimize damage.
- to provide the path of least impedance from the ground system components to earth ground. Any surge that does occur will then be dissipated quickly. In general, ground system resistances of less than 10–ohms must be achieved, with 5–ohms or less being the goal.

NOTE

Exceptions may be permitted in unusual circumstances if the impedance goal cannot be met. System Engineering must review such sites.

The following list is a summary of the drawings found in Appendix E that are applicable to the external ground system:

- Figure 2, External Ground Window Detail
- Figure 4, Typical Monopole Grounding
- Figure 6, Typical Cell Site Ground Plan
- Figure 7, Tower Base and Guy Wire Grounding Details
- Figure 8, Example of Ufer Ground Plan.

6.2 EXTERNAL BUILDING GROUND RING

6.2.1 Stand–alone Building

The building external ground system begins with a ground rod beneath the cable entry ground window, rods at each corner of the building, and additional rods as necessary, to reduce the distance between the rods to 16 feet. (If, for example, a building side is longer than 16 feet but shorter than 32 feet, one rod must be placed near the center.) The rods should be driven, using the proper tool to prevent rod deformation and thread damage to threaded coupling rods, if used. (The use of non–threaded rods joined by exothermic connections are recommended.) ***Ground rods are not to be placed in drilled holes***, *unless specifically approved by Systems Engineering*. The rods are to be sunk until the rod tops are at a minimum depth of 18 inches below finished grade. The majority (more than 2/3) of the rod length must be below the local frost line. The rods should be placed in a line approximately two feet from, and parallel to, the building foundation.

Rods will be connected in a ring (the external ground ring, or EGR) buried to the same depth as the tops of the ground rods. This wire interconnecting ring must be exothermically welded to each of the rods.

6.2.2 Inaccessible Building Sides

If all sides of a building are not accessible, constructing a straight or "L" shaped ground bus on each accessible side, supplemented by Ufer grounding, connections to the building steel, etc., will be acceptable. Refer to Figure 8.

An example of an inaccessible building would be a cell site in a shopping center, in which only the front and rear areas of the building are accessible to the customer. In this situation, ground wires and rods would be installed at the front and back in a manner similar to stand–alone building. These two sections would be interconnected by a #2 AWG wire laid in, or under, the building concrete, and supplemented by Ufer grounds if possible. The above information is for planning purposes only; consult with Systems Engineering for specific guidance.

6.2.3 Sites Located in Existing Buildings

Existing buildings can present a particularly difficult grounding situation. Usually the most difficult problem is to find a usable ground. Every effort should be made to determine what grounding provisions already exist in the building.

Particularly important is finding the building ground if it exists. Other alternatives are metallic water pipes (if they can be verified as completely metal runs) which are always accessible with some effort (the building's maintenance department will know where), and the building's structural steel, whether girders, elevator shaft vertical support beams or reinforcement rods. These can be effective when used to supplement one another.

While none of these will provide a very low impedance path to earth if the site is several stories up, the important goal is to keep everything within the site at nearly the same (albeit high) potential.

The foregoing assumes an older, reinforced concrete or brick building; in the case of a smaller, one story structure in which the site rests upon concrete slab in contact with the earth, a combination of external ground and an Ufer ground (obtained by cutting into the slab to find the reinforcing bar) may be the solution.

Finally, common sense plus a bit of creativity, guided by the underlying principles of the foregoing problems should at least allow initial planning to take place. However, before final grounding plans for an unusual site are completed, it is strongly suggested that System Engineering be sought for guidance and specific recommendations.

6.3 TOWER GROUNDING

In general, the tower base is surrounded by a ring installed according to the guidelines for buried conductors. The tower ring is to have a minimum of three ground rods (four in case of monopole tower). If the spacing between these rods is greater than 16 feet, additional rods are to be added to ensure a spacing of no more than 16 feet between the rods. It is recommended that two connections be made between the tower ring and the building external ground ring.

6.3.1 Lattice (Self–supporting) Towers

Lattice towers are to be grounded with at least one ground rod adjacent to each tower leg. Rods are to be connected to the tower leg with #2 AWG solid, tinned, copper wire, and to one another with a ring of #2 AWG solid, tinned, copper wire. The vertical wire from the tower leg to the ring should be insulated from earth contact for the first 12 inches or more by passing it through a PVC pipe. This is to reduce the step voltage in the immediate vicinity of the tower. (Refer to Appendix E, Figure 6, Inset A.) Exothermic weld joints are to be used for both the above and below ground connections. Again, if the distance between ground rods is more than 16 feet, additional rods will be driven midway between the two tower leg rods.

It is recommended that the base ground ring of unguyed towers be supplemented by at least two radial wires. If the diameter of the tower ground ring is less then 16 feet, then these radials are required if the size of the site permits (any exceptions should be reviewed by System Engineering). These should be approximately 20 feet, or as long as it is practical for the site, and extend away from the building. Ground rods should be placed at the middle and at the end. Refer to Appendix E, Figure 6 for more information.

6.3.2 Monopole Masts

These antenna supports typically exhibit much greater current surges when struck by lightning, as compared to guyed towers which have additional paths to ground. They must therefore be grounded with a minimum of four ground rods, connected together as specified in paragraph 6.3.1 above, and as shown in Figure 4 (Appendix E). The addition of two short radials (20 feet each is adequate) extended outward from the monopole base and away from the site building is required, if the size of the site permits. Any exceptions should be reviewed by System Engineering. This will serve to reduce the share of current on the rf transmission lines by lowering the base impedance of the tower. These ground radials should have a ground rod at the middle and at the end, and will otherwise follow the construction guidelines for external buried conductors. Any large metal objects such as fences encountered along their path will be jumpered to the radial, to reduce shock hazards.

6.3.3 Guyed Towers

Although the tower base is to be surrounded by a ring with three (minimum) ground rods, only one connection from the base to one of the ground rods is required. Guy wires added to an antenna tower not only add stability to the tower installation, but can also reduce the current share of the tower (and thus the surge voltage level of the MGB), since the tower guys become part of the overall ground circuit of the antenna installation. Another benefit of guyed towers is the wider area over which current can be dispersed, allowing more rapid dissipation and reduced step voltage. It is very important, however, that the guys be well grounded.

Each guy wire will be grounded at the anchor point. A ground rod will be installed at each guy anchor and connected to #2 AWG solid, tinned, copper wire, using an exothermic connection. This wire will pass through an insulating pipe such as PVC, or similar, extending from several inches above the ground to at least 12 inches below ground. This will greatly reduce the step voltage hazard. The connection from the tinned copper wire to the guy wires must be made with bronze, stainless steel, or galvanized steel clamps to avoid corrosion of the guys. Care must be exercised at the time of installation to maintain the integrity of the tin coating. ***Under no circumstance is bare copper wire permitted to be in contact with galvanized steel***, as a serious corrosion potential will exist. After tightening, the clamps should be well protected by an anti–oxidant compound such as “No–Ox”, as bare or taped joints will soon deteriorate. Refer to appendix E, Figure 7 for more information.

6.3.4 Roof Mounted Antennas

Antennas mounted on the roof of an existing building pose particular problems. If the roof is open to provide direct connection to the steel structure, the opportunity for a good ground is present, and the ground leads are to be attached to at that time. Other possibilities include elevator shaft steel support girders and pre–existing lightning protection system. Any of these alternate possibilities must be inspected or tested to confirm their electrical continuity to ground.

The antenna supporting structure should be grounded by a minimum of #2 AWG conductor to the building ground if possible. If multiple grounds or connection points are available, a ground ring around the base of the tower or group of antennas and transmission lines should be formed, much as at the ground level site. Connections, analogous to ground rods at a normal site, will be made from this ring to whatever good grounds are to be found.

6.4 TRANSMISSION LINE GROUNDING

6.4.1 Overview

The transmission line system is probably the most likely path for surges to enter the site. It is critical, therefore that this system be thoroughly grounded. All transmission lines, cellular and non–cellular must be properly grounded.

6.4.2 Outer Conductor Grounding

Where To Ground: The transmission line outer conductors shall be grounded at the following places:

- top of the vertical run on the tower.
- bottom of the vertical run on the tower.
- point of entrance to the radio equipment building.
- If the tower is greater than 200 feet, additional grounding kits must be installed. These additional kits are positioned such that there is no more than 200 feet of transmission line between ground kits.

How To Ground: Grounding of transmission lines is to be accomplished by use of an appropriate grounding kit supplied by the transmission line manufacturer. These kits are to be installed as follows:

- On top of the tower, each ground kit is to run from the transmission line to the tower or a steel bar attached to the tower (thereby establishing a good electrical connection with the tower). The tower then becomes the main conductor of any surges to ground. The same type connection is used at any mid–tower grounding points.

- At the bottom of the vertical run, the ground kits are run either to the tower or a steel bar attached to the tower. The tower again becomes the main conductor of any surges through the transmission line. It is not required to run a separate lead from the steel bar to ground, as the tower is a good conductor.

- At the point of entrance to the building, the ground kits are connected to the External Ground Bar (EGB). The EGB should be equipped with either a 2–inch copper strap or two #2 AWG tinned, solid, copper wires, positioned at opposite ends of the EGB. The strap (or wires) is to be exothermically bonded to the EGB and the EGR. All connections from the EGB to the EGR will pass through an insulating pipe such as PVC, extending from several inches above the ground to at least 12 inches below ground. This will greatly reduce the step voltage hazard.

- On monopole antennas, transmission line grounding arrangements must be specified when the monopole is purchased, to be sure top and bottom grounding connection points are provided.

- A very significant reduction in surge potential will be realized as the departure point of the transmission lines from the tower is lowered. Whenever site circumstances permit, the lines should be run to within seven feet of the ground or less before leaving the tower, to keep the shield potential (and the related current) as low as possible. The ideal situation is to run the transmission line to ground level before leaving the tower. This allows the ground kits to be attached to the tower at its base, thereby bringing the surge potential on the outer conductors closer to true ground potential.

6.4.3 Inner Conductor Grounding

Lightning protector equipment is to be installed on all transmission lines entering the building. This equipment is to be installed within 3 feet inside the waveguide entry window. The ground plane of this equipment is to be connected to the EGR via a #2 solid tinned wire (since it is partially buried) which will pass through the wall via non–conductive conduit.

6.4.4 Unused transmission Lines

Any unused transmission line should have its center conductor shorted to the outer conductor, or have a lightning arrestor installed.

6.5 MISCELLANEOUS EXTERNAL GROUND CONNECTIONS

Objects which should be connected to the external ground network include, but are not limited to, the following:

- Any metal fence within seven feet of the external ground network or any other grounded object.

- The transmission line entrance hatch (if metallic).

- Metal building parts not otherwise grounded by the internal ground ring, such as downspouts, siding, security grates over windows, metal ground mats, etc.

- Fuel storage tanks, whether above or below ground.

NOTE

> If fuel storage tanks are steel or galvanized (not stainless) and unprotected by an anti–corrosion coating, care must be taken to avoid a galvanic reaction source. Hardware of the same metal, or stainless steel hardware should be used to make any ground connections. Refer to Appendix C for further information on corrosion. As copper will react with steel (or galvanized steel), all copper grounding hardware must be kept a minimum of 5 feet from any source of these metals. If this is not feasible, then stainless steel grounding hardware must be used.

- A ground rod or rods provided by the power or telephone utility for grounding of ac ground or protectors.

- Any significant metal object (more than 2 sq. ft. in area) within seven feet of the external ground system or any other grounded object.

- Reinforcing bar in concrete floors, if accessible. (This is actually a type of “Ufer” ground—a very effective supplemental ground.) For sites on concrete slabs in contact with earth, the considerable ground system improvement which may be realized by including this ground will nearly always justify the effort required. However, because of the very high current density at the tower base, placing ground rods in tower foundations is not advised, to avoid possible heating effect damage to the concrete.

- Building skids or pier foundation anchors of pre–fabricated buildings.
- Exterior cable tray and ice shields, which are to be grounded at the tower end also.
- If the generator is a separately derived power source, its grounding electrode must be cross–tied to the external grounding system.

7. BUILDING INTERNAL GROUND SYSTEM

7.1 SINGLE POINT GROUND SYSTEM

7.1.1 Overview

The internal ground system consists of several major elements:

- surge producing equipment
- surge absorbing equipment
- internal ground ring (IGR), to which non–surging equipment is connected
- at the MTSO sites, the isolated ground zone (IGZ) in the EMX area.

The single point ground philosophy is one which dictates that all major elements of the system be grounded to a single point. The connections to this point are made in such a way that any surges which are produced will be taken to ground along the path of least impedance, inflicting as little damage as possible. Implementing this philosophy entails insulating surge producers from any casual connections to ground (such as through rack floor bolts connecting with re–bar and concrete in the floor), and installing a single low impedance connection from each surge producer to the single point ground. The single point ground is then methodically connected to various surge absorbers in order to dissipate any surges of energy.

Other major non–surging components of the internal ground system, such as the IGR and the IGZ, are also connected to the single point ground in order to minimize potential differences between various types of equipment. This in turn minimizes personnel safety hazards, as well as noise currents which may affect the operation of sensitive switching and computer equipment.

7.1.2 Location and Mounting

The single point ground consists of a heavy, rectangular, copper bar that has been drilled to accept a number of connecting lugs and exothermically welded straps and cables. The bar is referred to as the Master Ground Bar (MGB). The bar is to be insulated from its supporting structure. Appropriate types of bars are shown in Appendix E, Figure 10. The bar should ideally be mounted in a location central to all connecting equipment in order to make the shortest connections possible.

7.1.3 Connections to Single Point Ground

The MGB forms the central, key ground node of the internal grounding system. Its connections are arranged in four groups: surge producers, surge absorbers, non–surging equipment, and the Isolated Ground Zone. Appropriate grouping of the connections is illustrated in Appendix E, Figure 5. Figure 3 illustrates the internal grounding system at a collocated site.

7.2 SURGE PRODUCING EQUIPMENT

There are several sources of surge energy, whether from a local lightning strike or power surge, or from one more distant, coupled into the site via telephone or ac power lines. As these surges can be significant, it is critically important that surge producers, including ac power and telephone entrance panels be located as close to the MGB as possible. Connections from the surge producing equipment to the single point ground are to be made via #6 AWG minimum wire with green insulation for easy identification.

The following surge producers are to be directly connected to the MGB:

- Radio racks – Connection is to be made to the top of each rack, to the lug specifically designated for this purpose. Each rack is to be insulated from the building floor by installing insulating mats and mounting hardware. Adjoining racks may have casual contact with each other providing the adjoining rack is also directly connected to the MGB. Otherwise, insulating hardware must be used between adjoining racks.
- Waveguide entry window (if metallic)
- Receiver Multicoupler (RMC) – Each RMC is to have its own connection to the MGB. However, additional MGB connections to the RMC rack and RMC extenders (mounted in the same rack) are not neces-

sary if the RMC and RMC extenders have been rack mounted with threaded hardware. The RMC rack is to be insulated from the building floor in the same manner described for the radio racks.

- Telephone protector grounding terminal

- Emergency generator chassis

NOTE

A separate internal ground system in generator room may be used, but it must be connected to the site ground system at either the external ring or the MGB to equalize potentials.

- Channel banks

7.3 SURGE ABSORBING EQUIPMENT

Surge absorbers are those equipments or systems which can readily absorb an energy surge and quickly dissipate it into earth ground. The following surge absorbers are to be connected directly to the MGB:

- External ground ring using #2 AWG solid, tinned copper wire (minimum); a 2–inch copper strap may also be used. Either lead must pass through an insulating channel to the EGR by the most direct route. Sharp bends are not permitted.

- Metal water utility pipes on the street side of the meter (when permitted by local codes).

NOTE

Do not use gas pipe for grounding.

- The ac multi–grounded neutral. (The ac entry panel should be close to the MGB.)

NOTE

The multi–grounded neutral and the main disconnect panel are also to be connected to its own separate ground system as described in **5. Utility Service Entrances** paragraphs on page 6 of this document. The connections to the utility ground and the MGB must both take place within the main disconnect panel. The multi–grounded neutral must not be connected to ground at any other point within the facility.

4. Building steel (i.e., girders and/or reinforcement bar) if accessible.

7.4 INTERNAL GROUND RING (IGR)

7.4.1 General

The IGR (sometimes called the “halo”) allows short lengths of wire from non–surge producing metal objects (door frames, air ducts, etc.) to be connected to the internal ground system for safety purposes.

The IGR is to be connected to the master ground bar (MGB) as well as to the external ground at several points. This practice improves the effectiveness of the MGB grounding by reducing its inductance to the EGR and therefore to true ground. Refer to Figure 6 in Appendix E. The IGR is to consist of #2 AWG minimum, solid or stranded wire. It shall not be concealed or painted. This is to facilitate inspection and future add–ons of equipment.

7.4.2 IGR Location and Mounting

The IGR should encircle the radio equipment at cell sites, the EMX and related equipment at MTSO sites, and both radio and EMX equipment at collocated sites. The radio and EMX equipment is not to be directly connected to the IGR. These equipments are connected to the MGB or IGB as explained in later paragraphs. The ends of the IGR are to be connected to the MGB.

The IGR should be the lower of a level about six inches from the ceiling or 8 to 10 feet above the floor. It should be mounted on stand–offs or be suspended to permit easy connections.

7.4.3 Connections to the IGR

The following connections to the IGR are to be made with #6 AWG insulated stranded copper wire (green insulation is preferred):

- Ventilation louvers or sheet metal ductwork
- The non–IGZ cable tray system (at multiple points best)
- Metal door and window frames
- Metal battery racks
- Halon fire suppression system
- Generator transfer switch enclosure
- Any other permanent, significant, metal object within seven feet of any other grounded object

NOTE

Do not connect the main ac disconnect panel to the IGR as this is connected to the ac grounding system.

7.5 OTHER NON–SURGING EQUIPMENT

In addition to the IGR, the +24 V dc power plant ground bar and the –48 V dc power plant ground bar are to be connected to the non–surge producing section of the MGB.

7.6 ISOLATED GROUND ZONE (IGZ)

7.6.1 General

The EMX location uses an isolated ground window approach. This means all grounds are tied together at a single point, the isolated ground bar, which becomes a "window" to the actual ground. Examples are illustrated in Figure 10 in Appendix E. Conductors to the IGB shall be green insulated, minimum #6 AWG stranded copper wire.

7.6.2 Isolated electrical Outlets

All electrical outlets in the EMX isolated ground zone are to be of the isolated orange–coded type. The third or "green" wire grounds from these outlets are to be connected to the IGB. The purpose of this isolated ground wire system is two fold:

- It reduces noise currents in the IGZ.
- Should test equipment or TTYs be connected to the EMX during a surge, any potential difference across the equipment will be minimized, as all grounds within the IGZ are connected at the same point.

One of the most straightforward methods of implementing the isolated electrical outlets is to utilize a separate distribution panel which is powered from an appropriately sized circuit on the main distribution panel. Refer to Appendix E, Figure 12 for details.

7.6.3 Isolated Cable Trays

These trays are those which are carrying any switch–related cabling and may not carry any rf cabling. They are to be isolated from any non–IGZ trays.

7.6.4 Items to be Grounded to IGB

- MGB via #2 AWG wire
- The EMX (500, 250, and 100+) via a lug at the top of any of the bays (It is assumed the EMX frames have all been electrically connected together via the ground braid located at the bottoms of the racks.) For the EMX 2500, the PDF bay ground bus will be used.
- Third wire grounds from the isolated ac outlets in the IGZ
- Cable tray within the IGZ (connected at one point only)
- IGZ distribution frame, if no outside metallic lines or protector grounds are present.
- Modem frames, if not electrically connected to the EMX frames.
- Other EMX associated, non–surging equipment frames

7.6.5 Additional RS–232 Protection

Equipment which is connected both to ac outlets and cellular equipment is particularly susceptible to potential differences during surge conditions. It is therefore recommended that all RS–232 connections be further protected through the use of fiber–optic protectors. For more information, refer to the paragraphs of **4.6 RS–232 Line Protection** on page 5.

8. INTERCONNECTIONS OF THE EXTERNAL AND INTERNAL GROUND SYSTEMS

8.1 GENERAL

The interconnection is accomplished by connecting the MGB and the IGR to the EGR.

8.2 IGR TO EGR CONNECTION

The IGR to EGR connections are to be made with #2 AWG solid tinned bare wire routed through non–conducting conduit in the walls. These connections shall be made at each corner of the equipment room, and as needed between corners to keep all connections at a minimum of 16 feet apart.

8.3 MGB TO EGR CONNECTION

This connection is to be made either via a 2–inch wide by 1/16–inch thick copper strap or a #2 AWG solid, tinned, copper wire. It is recommended that the connection at the MGB be mechanical so that it may be temporarily disconnected during testing and maintenance of the ground system. The conductor is to be routed through the wall through a non–conductive conduit. All sharp bends are to be eliminated.

9. GROUND RESISTANCE MEASUREMENTS

The maximum ac resistance between any point on the ground system and a non–trivial reference ground should be 5 ohms or less. Exceptions may be permitted in unusual circumstances, with a slightly higher resistance being allowed in the case of very rocky sites. Such sites and circumstances shall always require review and evaluation by Systems Engineering; safety and certain warranty related issues being involved. An instrument designed specifically for this type of measurement (such as the Biddle Instruments' Megger Earth Testers) must be used and the instructions provided with the instrument should be followed for proper measurement method.

The "fall of potential" method is recommended for small sites with an overall ground system diameter of less than 100 feet. A Megger Earth Tester, or equivalent, is recommended for this test. Note that an accurate measurement requires a distant probe placed at a distance of at least five times the diameter of the overall ground system of the site; for large sites, this may not be practical. Should this situation be encountered, an alternative method may be used. Briefly, this consists of taking a series of closer–in readings which give false results, but which trend toward more accurate ones. By using a graph of these results, and extrapolating the trend, one may closely estimate true ground values. Refer to Appendix A for a detailed, step–by–step procedure.

All connections should be checked if this specification cannot be met, and after a thorough inspection, System Engineering should be consulted for a special evaluation of the grounding system.

10. MAINTENANCE AND INSPECTIONS

A ground system by its very nature is exposed to weathering corrosion. This coupled with the importance of the ground system to the safety of personnel and equipment makes it mandatory that periodic inspections be made of all ground system components. A suggested schedule is immediately after the ground installation has been installed or modified, six months afterward, and then annually. The security of all bolted or clamped connections and the condition of the wire jumpers exposed to physical damage are two key checks to be made. No–Ox is to be reapplied to all mechanical connections. The tower must also be inspected for corrosion, loosening bolts, etc.

A ground resistivity test is also recommended, as any increase in resistivity from previous readings indicates deterioration of the ground system. If an increase is measured, the problem may be isolated by measuring the various sub–systems of the ground system. This may be easily done if mechanical connections (in test wells if underground) have been implemented between the subsystems. These connections may then be used to disconnect the various sub–systems from each other, in order to measure each one independently of others. These sub–systems include the tower ground ring (and radials), the external ground ring around the building, the internal ground system, and any utility ground systems.

APPENDIX A — *Ground Testing Methods For Cellular Radio Sites*

1. “FALL OF POTENTIAL” METHOD

1.1 EQUIPMENT AND MATERIALS REQUIRED

- Megger Null Balance Earth Tester (Biddle Instruments, Blue Bell, PA).
- Extra test lead wire (2 spools; 500 ft., #12 or #14 AWG insulated wire).
- Test stakes (included with Earth Tester).
- Long tape measure (100 ft. or more).
- Compass (to ensure a straight path along which the P2 probe of the Earth Tester will be placed).
- Two small (1/2 in. diameter) metal hose clamps, or similar device, to fasten extension lead to C2 and P2 probes.

1.2 PROCEDURE

NOTE

Figure 1 (Appendix E) illustrates the following procedure, with a sample graph of the results expected. For sites with very large ground systems or obstructions, please read the paragraphs of **2. The “Asymptote Variation” Of The Fall Of Potential Method** on page16.

Step 1. If a 4–terminal tester is utilized, jumper the C1 and P1 terminals of the Earth Tester together. (These are internally jumpered on the 3–terminal tester.)

Step 2. Connect the short test lead from terminal C1 on the Earth Tester to the approximate electrical center of Ground system Under Test (GUT).

NOTE

The electrical center of the ground system will probably be the vertical lead to the site external ground bar, where the rf transmission line shields will be grounded just prior to entering the building. This is also near the point where the tower ground ring is tied to the building’s external ground system. Other site configurations will require local evaluation.

Step 3. Connect a long test lead, extended by a length (see following note) of #12 or #14 AWG insulated wire, to the C2 terminal of the Earth Tester.

NOTE

The C2 probe will be driven 1.5 to 2 feet into the ground at a point that is at least 5 times the diameter of the site ground system (including the tower ground and grounded fences, guy wire anchors, etc.) from the site. Choose a convenient direction that has no obstacles to the wire or to the insertion of the P2 and C2 probes.

Step 4. Firmly clamp the opposite end of the C2 test lead to the side and near the top of the C2 probe. Leave enough clearance between the top of the probe and the test lead connection to avoid hammer contact and damage to the clamp.

Step 5. With the tape measure, mark a number of points along a straight line (use compass) corresponding to the following percentages of the overall C1 to C2 distance (600 ft. is used in this example):

Point	%	Feet to P2	Ohms
1	20	120	_________
2	30	180	_________
3	40	240	_________
4	50	300	_________
5	55	330	_________
6	62	372	_________
7	70	420	_________
8	80	480	_________

P2length of wire added _________

C2length of wire added _________

Step 6. At each indicated P2 distance (determined in Step 5), insert the P2 probe, its lead extended by a fixed amount of wire as required. (NOTE: do not change length of wire during test.) Record amount and size of the wire used so its resistance can be subtracted.

Step 7. Using the Earth Tester, measure and record apparent ground system resistance at each of the 8 test points.

NOTE

As mentioned in the *Megger* Earth Tester manual, a slightly slower or faster cranking speed of the generator will be required if the meter exhibits instability at a particular speed. This is due to stray, interfering 60 Hz power currents in the ground. Resistances should be measured only to the nearest tenth of an ohm. This precaution does not apply to battery operated versions of the Earth Tester.

Step 8. Plot the accumulated data on linear graph paper. The 62% point will show the true resistance of the ground system when the resistance of the extra wire is subtracted (approximately 1/2 to 1 ohm, depending on exact wire type).

NOTE

If the data point for the 62% measurement is off the general line of the curve, it may have been corrupted by buried pipes, etc. or inaccurate measurements. The curve as plotted will show a good estimate of the true ground system resistance in that case.

2. THE "ASYMPTOTE VARIATION" OF THE FALL OF POTENTIAL METHOD

2.1 INTRODUCTION

Ground tests of cellular infrastructure sites may at times seem to indicate a poor or insufficient ground. While it is certainly possible that the ground plan was inadequate for a particular site, it is important to be aware of the possibility of measurement errors that can result from the choice of an incorrect ground testing method, as opposed to those resulting from mistakes made in the actual reading of the meter itself. A fairly common error is caused by the use of the "Fall of Potential" method (described in paragraphs1 of this appendix) when the C1 to C2 distance is too small as compared to the overall dimensions of the site ground system.

2.2 BACKGROUND

If the site ground system is of large size, the required C1 to C2 distance of 5 times the overall diameter of the ground system can become impractical, particularly as this is actually the minimum distance for reasonable accuracy (a distance of up to 10 times the diameter is preferable). In such a case, a variation of the "Fall of Potential" method, used by NASA and other government departments, can obtain very accurate results at much shorter (and practical) distances.

This technique results in several incorrect ground resistance readings, obtained from a set of three normal "Fall of Potential" tests done as usual, except for the use of C2 positions which are too close to the site. These positions vary from very close to somewhat close. The resultant false ground values (they will be erroneously high) are then plotted on linear graph paper, and a best–fit, falling exponential curve, connecting each series' 62% reading, is extrapolated out to its asymptote, or nearly flat value. This very closely approximates the true value of ground resistance.

The principle involved is that these false readings will tend towards an accurate value as the C1 to C2 distance increases, even though the proper distance is never achieved. The point at which the curve becomes flat (or nearly so) is a close approximation of that true value. An actual example of the results of both methods, performed on the same site and superimposed on the same graph is shown in Figure 9 (Appendix E). It can be seen that the two results closely agree. The method is explained in further detail in the following step–by–step procedure.

2.3 EQUIPMENT AND MATERIALS REQUIRED

Equipment and material requirements are identical to those described in paragraph **1. “Fall Of Potential” Method** (of this appendix).

2.4 DETAILED STEPS FOR USING THE “ASYMPTOTE VARIATION”

Step 1. Choose three C2 points at convenient (but non–trivial) distances, such as 100, 200, and 300 feet from the site center.

Step 2. Choose a direction that is free of obstructions (underground pipes, etc.). All measurements must lie along the same line.

Step 3. Select one of the C1 to C2 distances determined in Step 1 and take a series of readings with the P2 probe, at eight measured intervals representing 30, 40, 50, 55, 62, 65, 70, and 80 percent of each C2 distance. The procedure used for each series of measurements at a given C2 distance is the same as described in paragraph **1. “Fall Of Potential” Method** (of this appendix). Again, all of these measurement points (both within a series, and each C2 point) must be in a straight line. Record the data.

Step 4. Move the C2 rod to the next point, as determined in Step 1, and repeat the test of Step 3. Record the data. Repeat for each of the remaining points.

NOTE

Should additional wire be needed for the furthest measurement, it must be insulated #14 AWG or heavier. Make a clean, solid clamped connection to the C2/P2 test leads on the Earth Tester.

Step 5. The length and gauge of any extension wire should be recorded. The resistance of this wire is then calculated and subtracted from the results.

Step 6. Plot the accumulated data (three curves) in the manner explained previously. Then plot the (curve–fitted) 62% points (the “false ground values”) from each series in an exponential curve. The asymptote, or tangential value toward which this fourth curve tends, is easily seen. This represents the true ground system resistance.

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APPENDIX B — *Document References*

The following references were used in preparing this document, and provide further information on the subject of grounding.

AC Service Grounding Engineering Application, GTE Practices section 795–805–072

Controlling Lightning Damage at Radio Sites, by Richard Little, Principle Staff Engineer, Motorola Radio Telephone Systems Group

Electrical Protection Engineering Fundamentals, GTE Practices section 887–000–050

Electrical Protection Guide for Land–Based Radio Facilities, Josyln Electronic Systems manual by David Boethe

Electrical Protection of Radio Stations, Bell System Practices section 886–030–085

Electrical Considerations Radio Station Protection, GTE Practices section 887–030–085

Fundamental Considerations of Lightning Protection and Grounding, NASA/FAA publication # N79–76935. U.S. Government Printing Office

Getting Down to Earth, Biddle Instruments

Grounding and Bonding, Volume 2–1988 P/O “A Handbook Series on Electromagnetic Interference and Compatibility”, by Interference Control Technologies, Inc.

The “Grounds” for Lightning and EMP Protection, by Roger Block, Polyphasor Corporation

Grounding Cellular Installations, by Richard Little, Principal Staff Engineer, Motorola Radio Telephone Systems Group

Grounding Guidelines for Cellular Radio, by Randy Thompson, Motorola Radio Telephone Systems Group

Grounding Principles and Corrosion Protection, National Marine Electronics Association Technical Papers; Tinton Falls, NJ. Chapters “Planning Marine HF–SSB Systems” and “Selection and Installation of Marine Antenna Systems”, by Karl M. Schulte, Motorola Radio–Telephone Systems Group

Lightning Protection Code, National Fire Protection Association (ANSI/NFPA 78–1989)

National Electrical Code, National Fire Protection Association (ANSI/NFPA 70–1990)

Protective Grounding Systems General Equipment Ground Requirements for Microwave Radio and Auxiliary Stations, Bell System Practices section 802–001–197

Radio and Microwave Towers Bonding and Grounding Network Installation, GTE Practices section 621–800–200

Structural Standards for Steel Antenna Towers and Antenna Supporting Structures, Electronic Industries Association standard number RS222

Telecommunications Engineering and Construction Manual, Section 825 (Situations Requiring Special Protection), and Section 810 (Electrical Protection of Electronic Analog and Digital Central Office Equipment), Rural Electrification Administration.

Western Electric Installation Engineering Handbook 261

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APPENDIX C — *Galvanic Corrosion*

The bonding of two metals may result in Galvanic corrosion. This reaction occurs at the junction of dissimilar metals when exposed to moisture. The degree and rate of corrosion depends on the relative position of the metals in the electromechanical series. Following is a chart depicting this series. The metals at the top of the chart will corrode more easily than those at the bottom. To determine the likelihood of two metals reacting, determine the difference between their listed EMFs. If it is greater than 0.6 volts, the metals are too dissimilar to be bonded. If the difference is 0.6 volts or less, the metals may be safely bonded.

METAL	EMF (Volts)
Magnesium	+2.37
Magnesium Alloys	+0.95
Beryllium	+1.85
Aluminum	+1.66
Zinc	+0.76
Chromium	+0.74
Iron or Steel	+0.44
Cast Iron	*
Cadmium	+0.40
Nickel	+0.25
Tin	+0.14
Stainless Steel	*
Lead	+0.13
Brass	*
Copper	–0.34
Bronze	*
Copper–Nickel Alloys	–0.35
Monel	*
Silver Solder	–0.45
Silver	–0.80
Graphite	–0.50
Platinum	–1.20
Gold	–1.50

* Reliable values N/A

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APPENDIX D – *Grounding Checklists*

The following is contains checklists to be used to facilitate the inspection of site grounding. For additional details, refer to the main body of this document. For unique grounding situations, contact Systems Engineering for consultation.

KEY:

EGB	External Ground Bar	IGR	Isolated Ground Ring
EGR	External Ground Ring	IGZ	Isolated Ground Zone
IGB	Isolated Ground Bar	MGB	Master Ground Bar

GENERAL:
All bends in ground wires are to have a minimal 8–inch bending radius.
AC surge protector to be installed on the load side of the main ac disconnect.
AC to tower lighting to be surge protected.
IGZ cable tray to be isolated from all other cable trays.
IGZ cable tray to be isolated from all casual contacts with ground.
No ground wires in metal conduit unless conduit is bonded to ground at both ends.

Table 1. *External Site Grounding Checklist*

ITEM	✓	DESCRIPTION	CONDUCTOR	CONNECTION
		All Sites (MTSO And Cell) Require:		
		Connections to the EGR (External Ground Ring):		
1		EGB	Note 2	*CADWELD*
2		IGR (each corner and every 16 feet between)	#2 solid	*CADWELD*
3		ground rods (every 16 feet) and under EGB	#2 solid	*CADWELD*
4		MGB	#2 solid	*CADWELD*
		All Cell Sites Require:		
		Connections to the EGR (External Ground Ring):		
1		tower ground ring (2 connections recommended)	#2 solid	mechanical
2		lightning arrestor bracket	#2 solid	*CADWELD*
		Connections to the tower:		
1		from tower ground ring	#2 solid	*CADWELD*
2		top of rf lines	ground kit	mechanical
3		rf lines at exit from tower	ground kit	mechanical
4		guy wire to ground rods (guyed towers only)	#2 stranded	mechanical
		Connections to the tower ring:		
1		from tower leg(s)	#2 solid	*CADWELD*
2		from EGR (2 connections recommended)	#2 solid	*CADWELD*
		Miscellaneous external grounding connections (connect to nearest point of external system):		
1		metal fencing within 7 feet	#2 solid	Note 1
2		metal building parts	#2 solid	Note 1
3		fuel storage tanks	#2 solid	Note 1
4		utility grounding electrode systems	#2 solid	Note 1
5		metal objects more than 2 ft. sq. and within 7 ft.	#2 solid	Note 1
6		reinforcing bar in concrete floor (if accessible)	#2 solid	Note 1
7		building skids or anchors (if accessible)	#2 solid	Note 1
8		exterior cable tray, ice bridge	#2 solid	Note 1
9		generator grounding system (if applicable)	#2 solid	Note 1
10		generator chassis (if not otherwise grounded)	#2 solid	Note 1
		Connections to the EGB (External Ground Bar):		
1		waveguide entry window	#2 stranded	mechanical
2		rf line ground kits at building entry	#2 stranded	mechanical
3		EGR	#2 solid	*CADWELD*

NOTES:
1. All below ground connections must be exothermic. Above ground connections may be mechanical.
2. Either two #2 AWG solid wires or one 2–inch x 1/16–inch copper strap must be used.

Table 2. *Internal Site Grounding Checklist*				
ITEM	**✓**	**DESCRIPTION**	**CONDUCTOR**	**CONNECTION**
		Connections to the MGB (Master Ground Bar):		
1		racks containing rf equipment	#6 stranded	mechanical
2		waveguide entry window	#6 stranded	mechanical
3		RMC (receiver multicoupler)	#6 stranded	mechanical
4		telephone protector grounding terminal	#6 stranded	mechanical
5		generator chassis (if not otherwise grounded)	#6 stranded	mechanical
6		channel bank racks	#6 stranded	mechanical
7		EGR	#2 solid	mechanical
8		metal water utility pipe	#6 stranded	mechanical
9		multi–grounded neutral	#6 stranded	mechanical
10		building steel (if accessible)	#6 stranded	mechanical
11		IGR	#2 stranded	mechanical
12		IGB	#2 stranded	mechanical
13		ground bar of +24 Vdc power system	#6 stranded	mechanical
14		ground bar of –48 Vdc power system	#6 stranded	mechanical
		Connections to the IGR (Internal Ground Ring):		
1		all racks not grounded to MGB or IGB	#6 stranded	mechanical
2		ventilation louvers and ducts	#6 stranded	mechanical
3		cell site cable tray (multiple points)	#6 stranded	mechanical
4		metal door and window frames	#6 stranded	mechanical
5		metal battery racks	#6 stranded	mechanical
6		Halon system	#6 stranded	mechanical
7		transfer switch enclosure	#6 stranded	mechanical
8		miscellaneous significant metal objects	#6 stranded	mechanical
9		EGR (every 16 ft.)	#2 solid	mechanical
10		MGB	#2 stranded	mechanical
		Connections to the IGB (Internal Ground Bar):		
1		MGB	#2 stranded	mechanical
2		cellular switch frame	#6 stranded	mechanical
3		grounds from ac outlets in the IGZ	#6 stranded	mechanical
4		IGZ cable tray (one point only)	#6 stranded	mechanical
5		IGZ distribution frame	#6 stranded	mechanical
6		modem frame	#6 stranded	mechanical
7		other EMX associated frames	#6 stranded	mechanical

APPENDIX E — *Reference Diagrams*

The following is a table of contents for Appendix E.

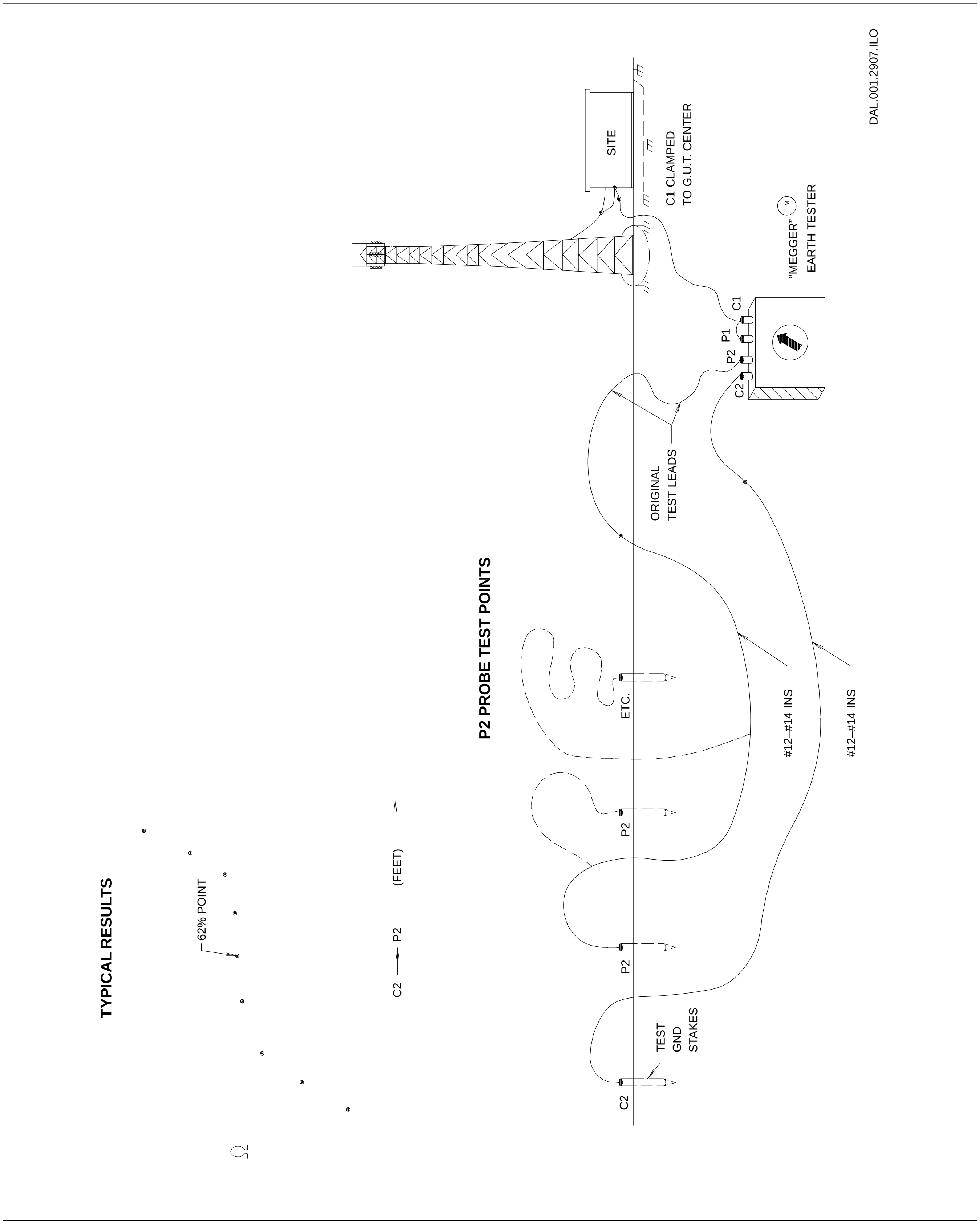

Figure 1. Ground System Testing — "Fall of Potential" Method

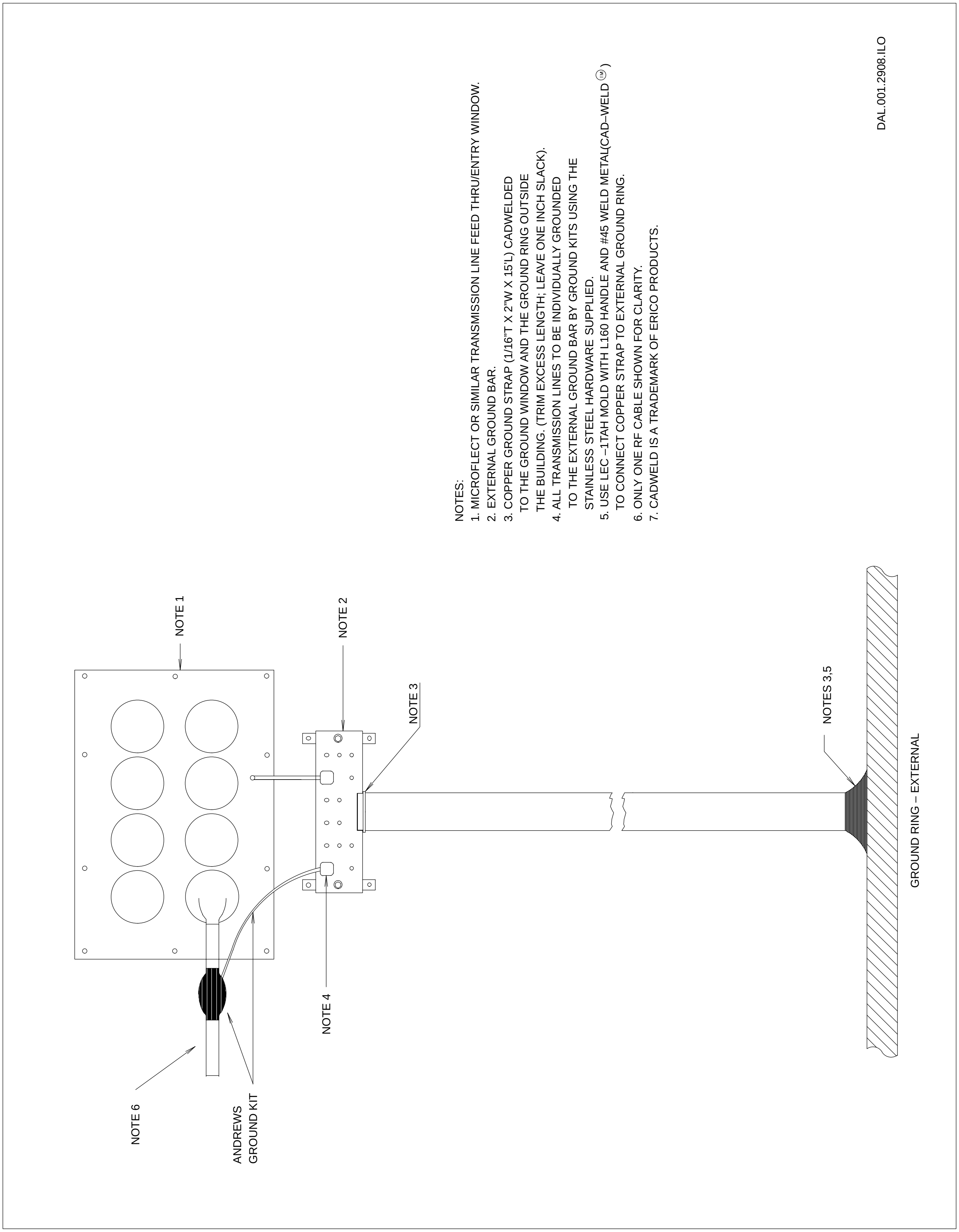

Figure 2. External Ground Window Detail

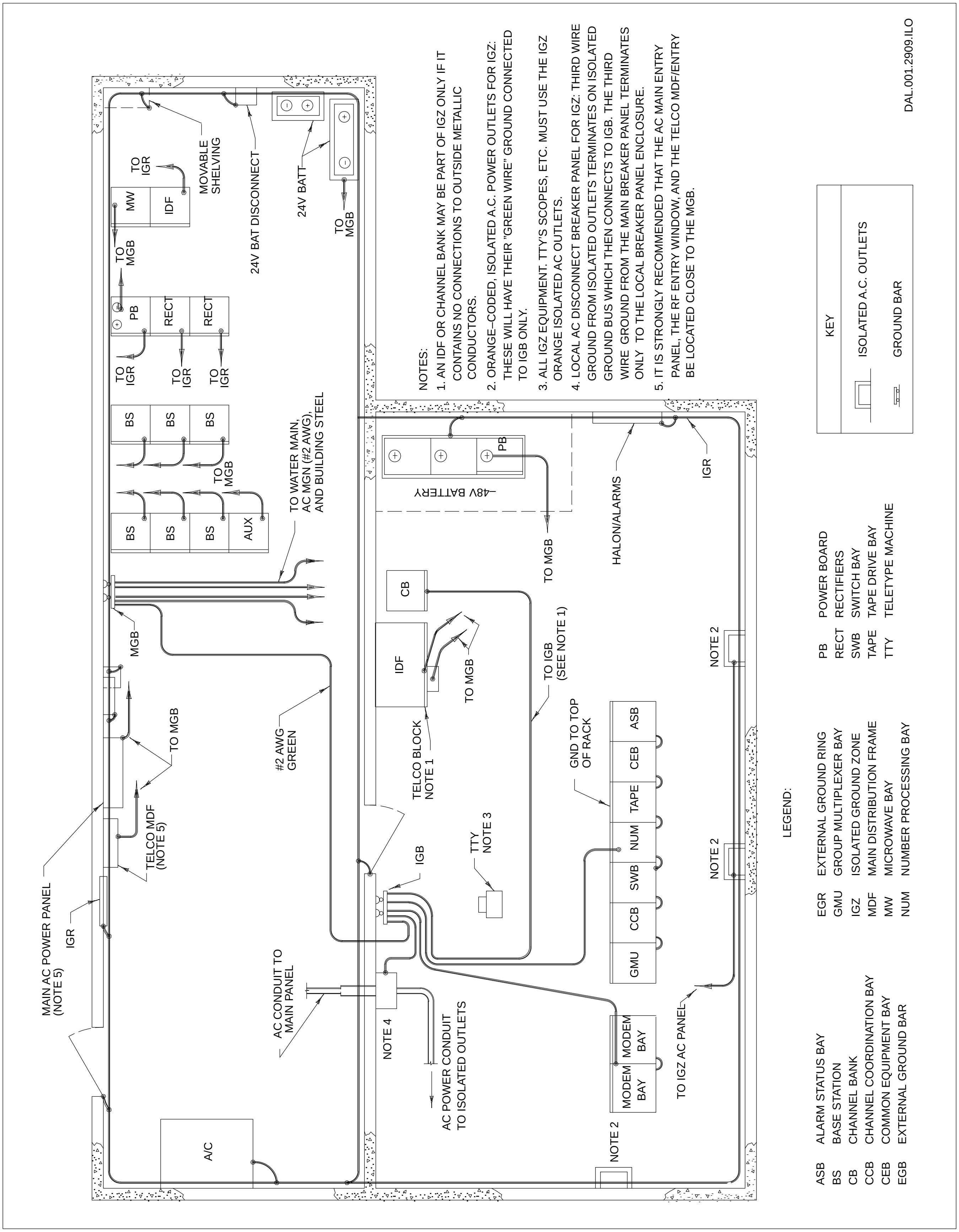

Figure 3. Example of Typical Collocated Cell/MTSO Site Ground Plan

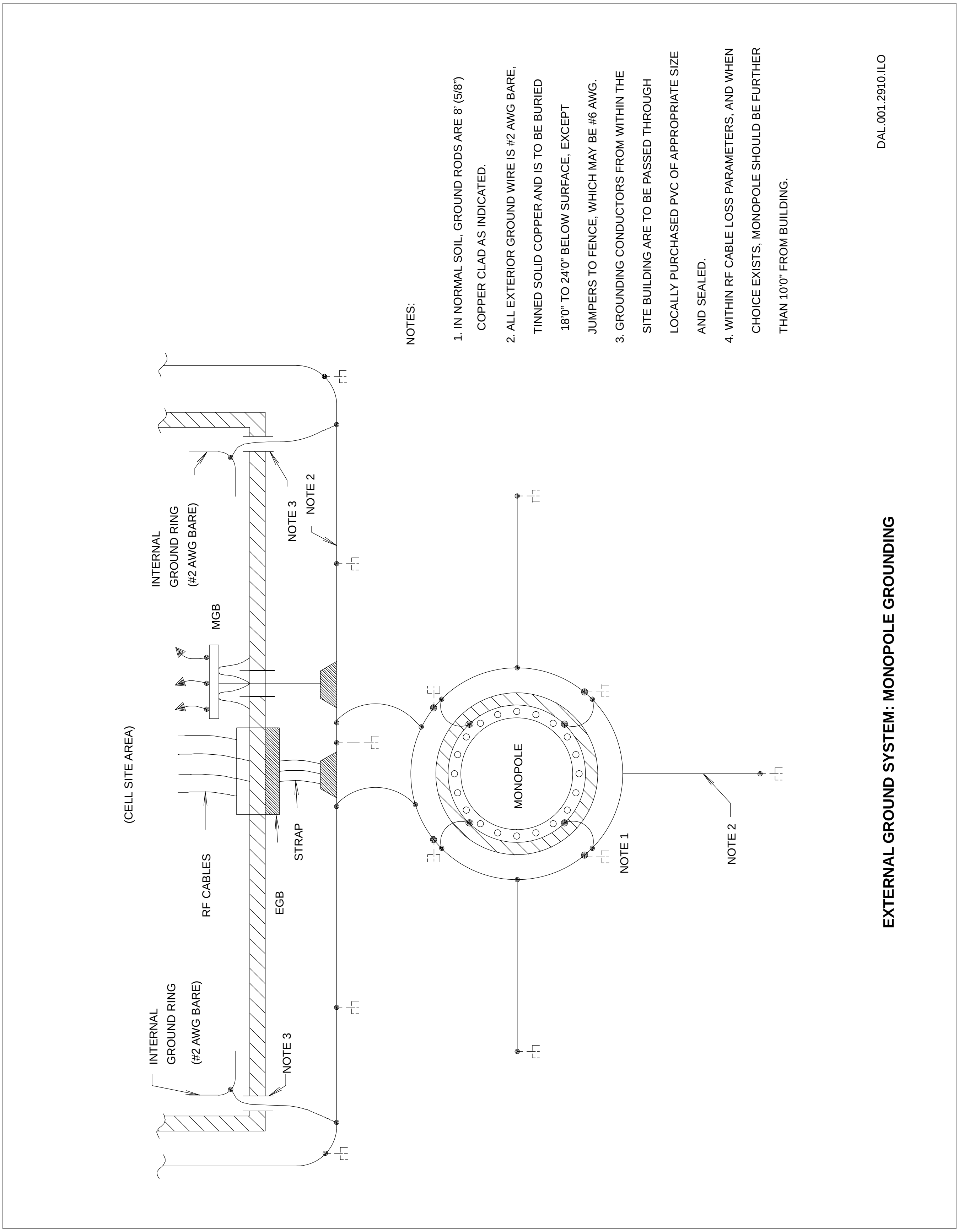

Figure 4. Typical Monopole Grounding

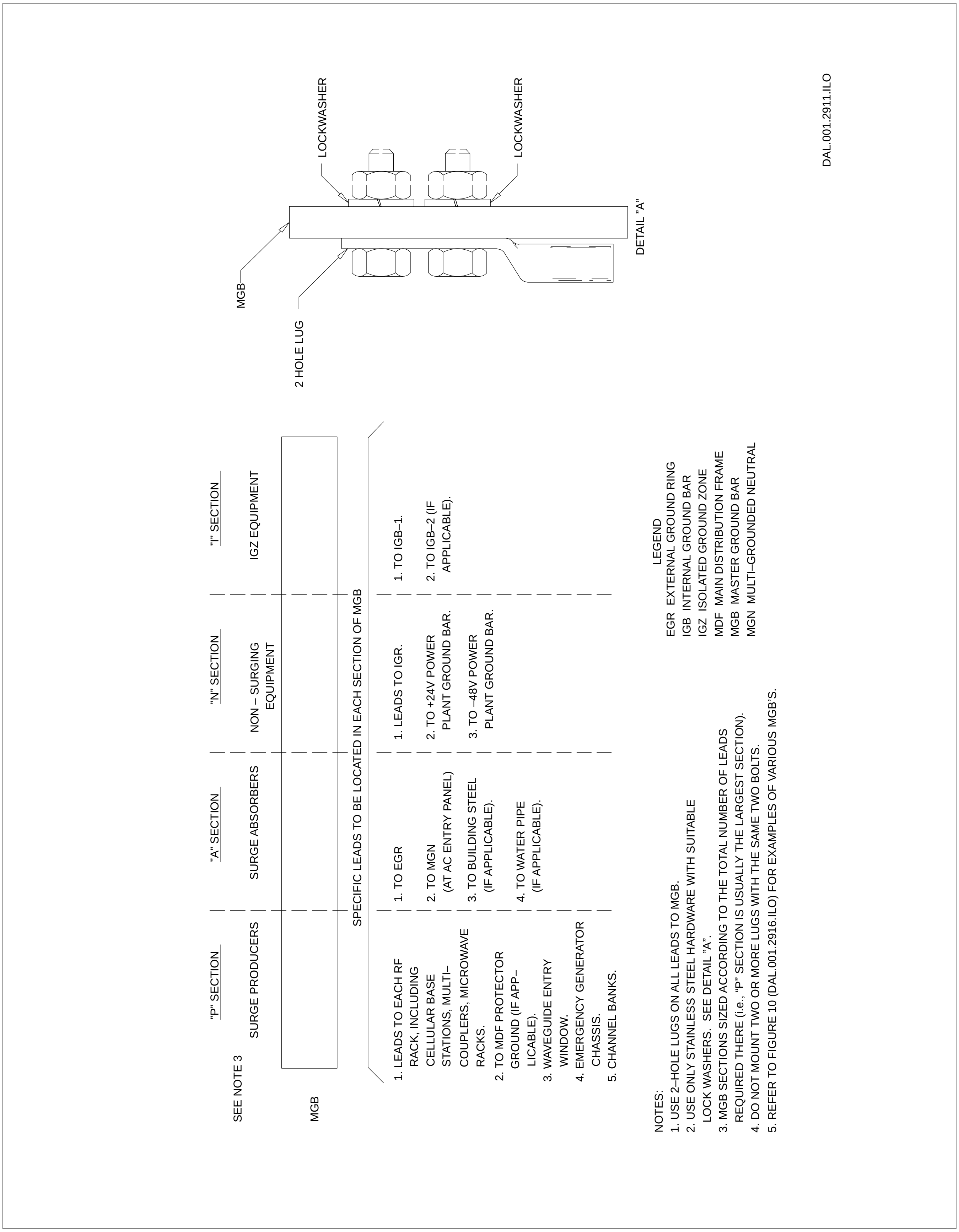

Figure 5. Typical Master Ground Bar Connections (for Smaller Sites)

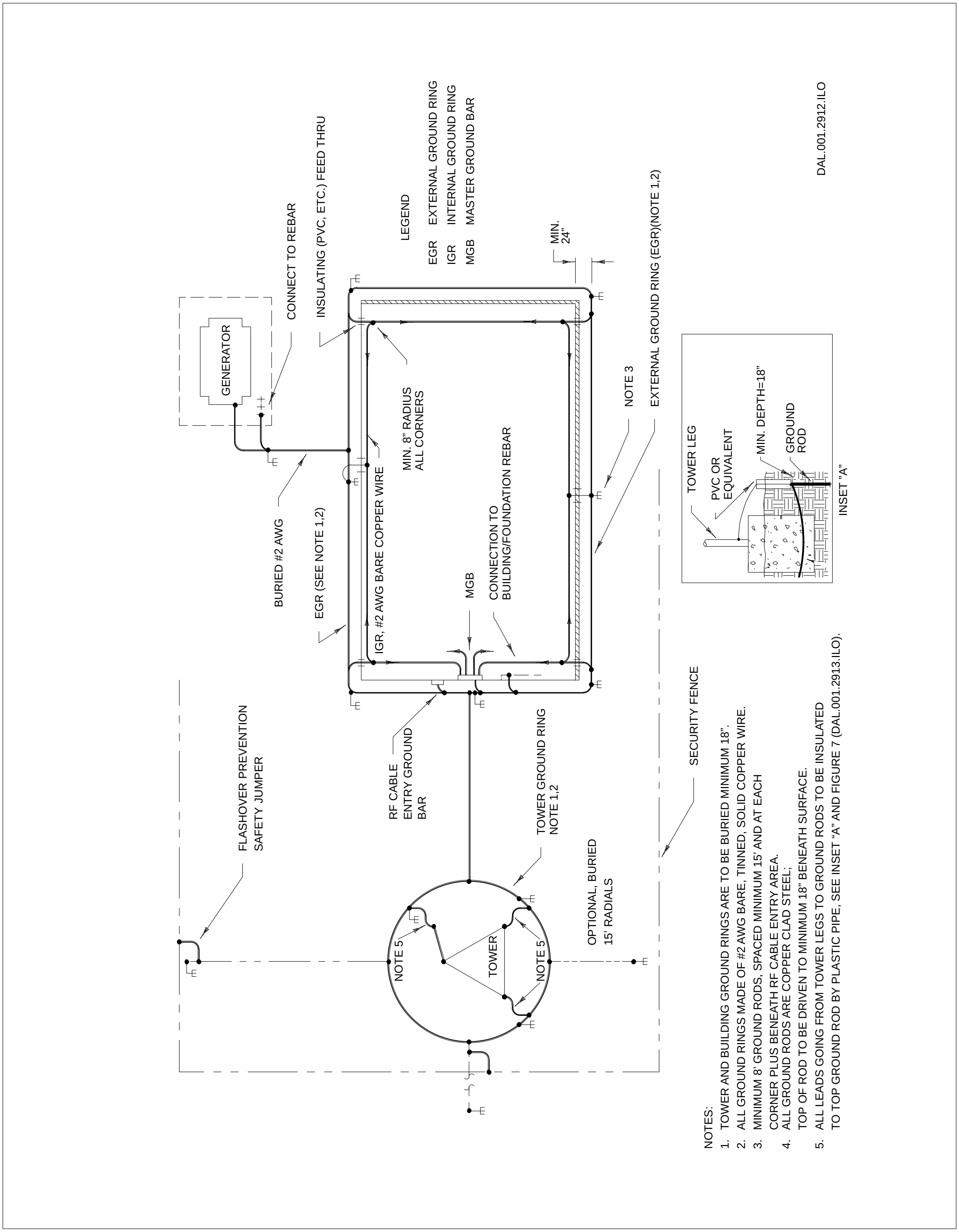

Figure 6. Typical Cell Site Ground Plan

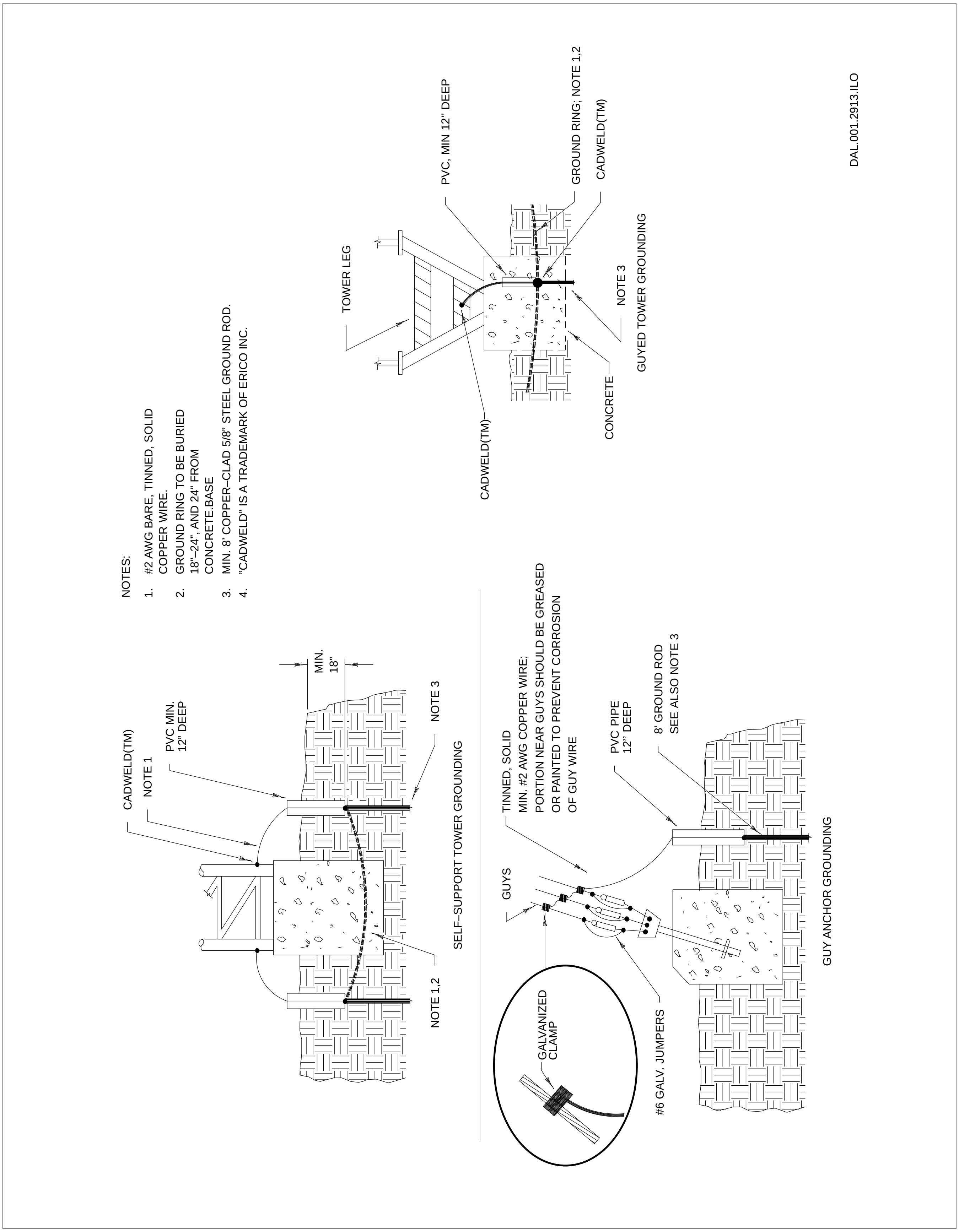

Figure 7. Tower Base and Guy Wire Grounding Detail

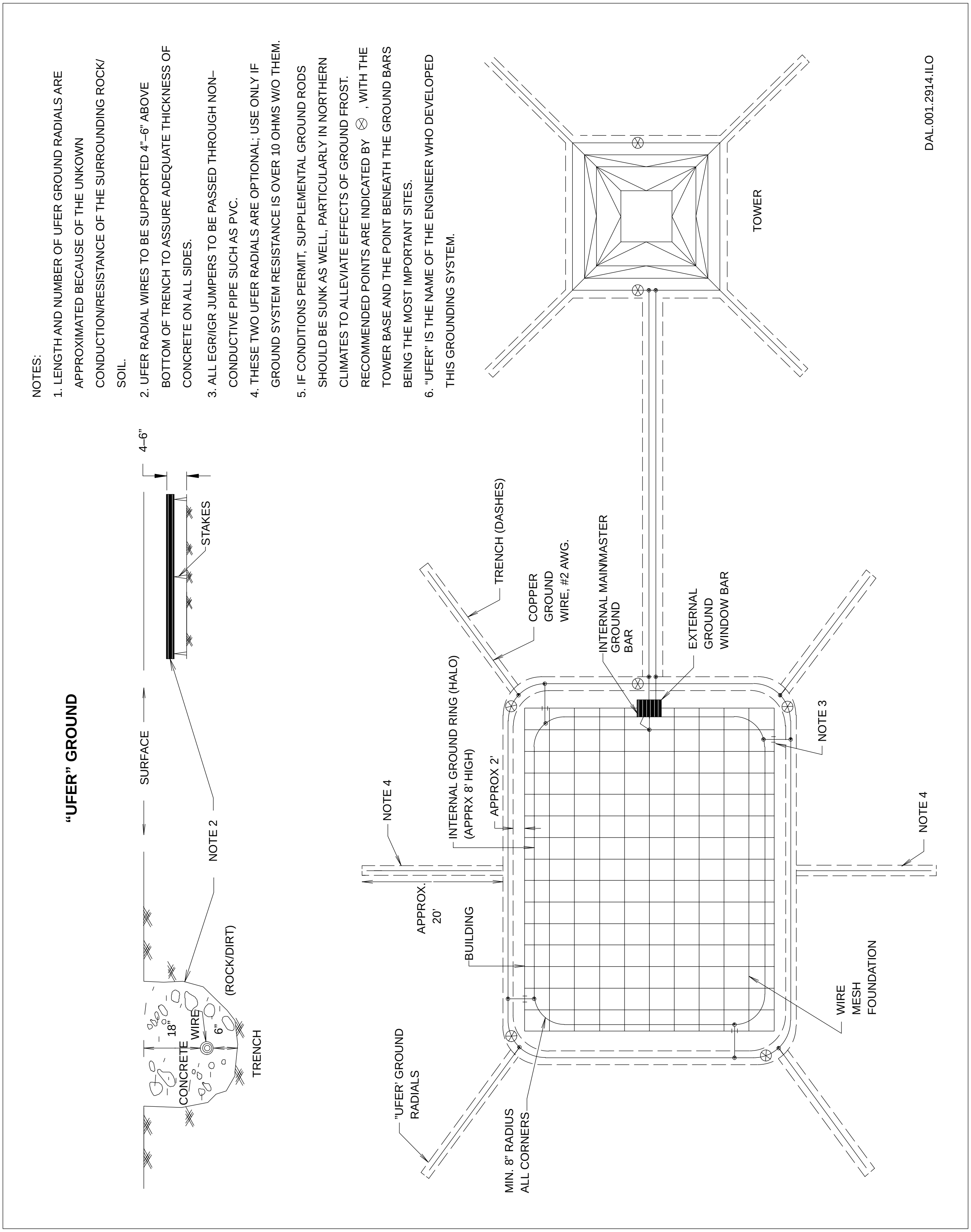

Figure 8. Example of Ufer Grounding Plan

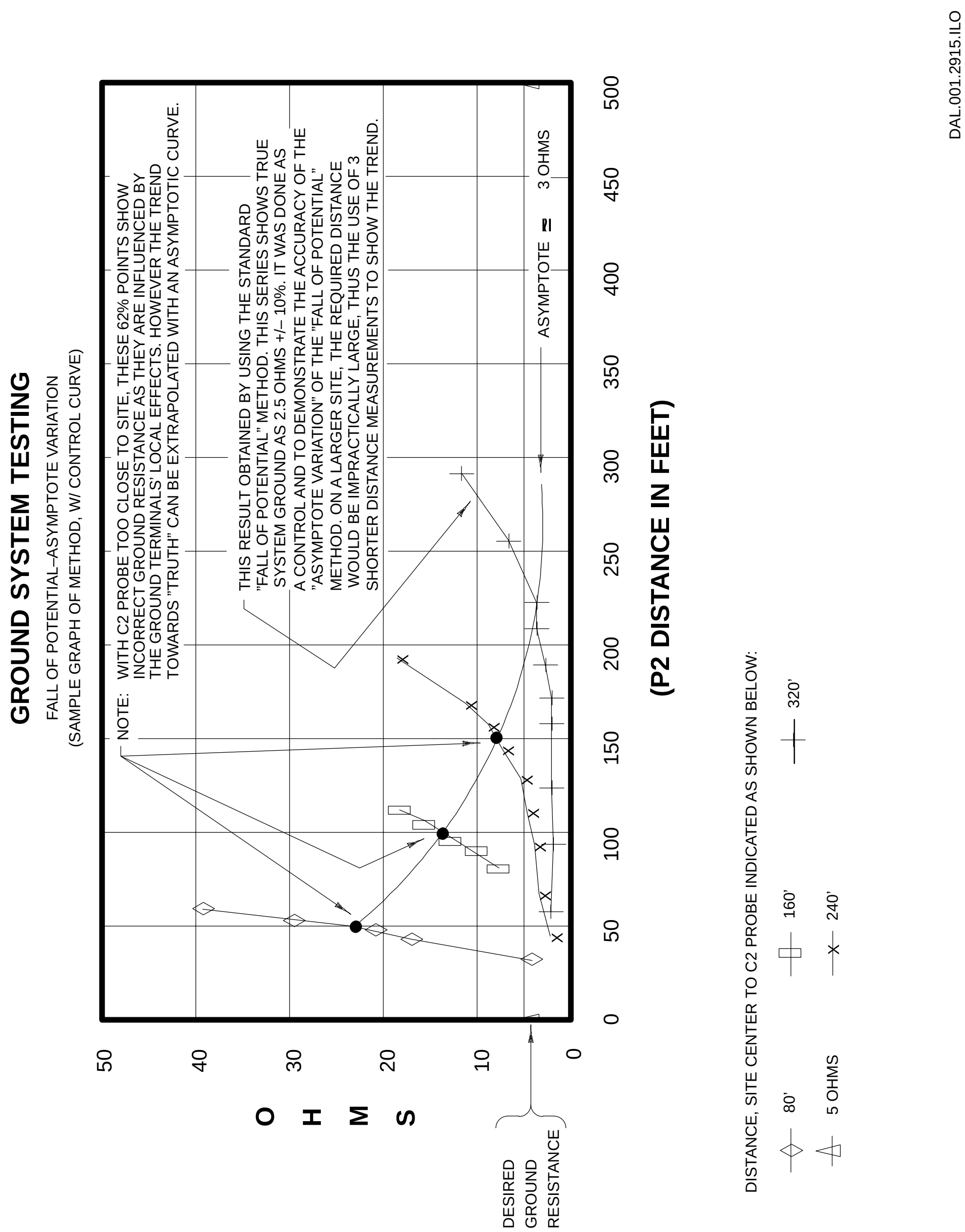

Figure 9. Ground System Testing; Fall of Potential — Asymptote Method

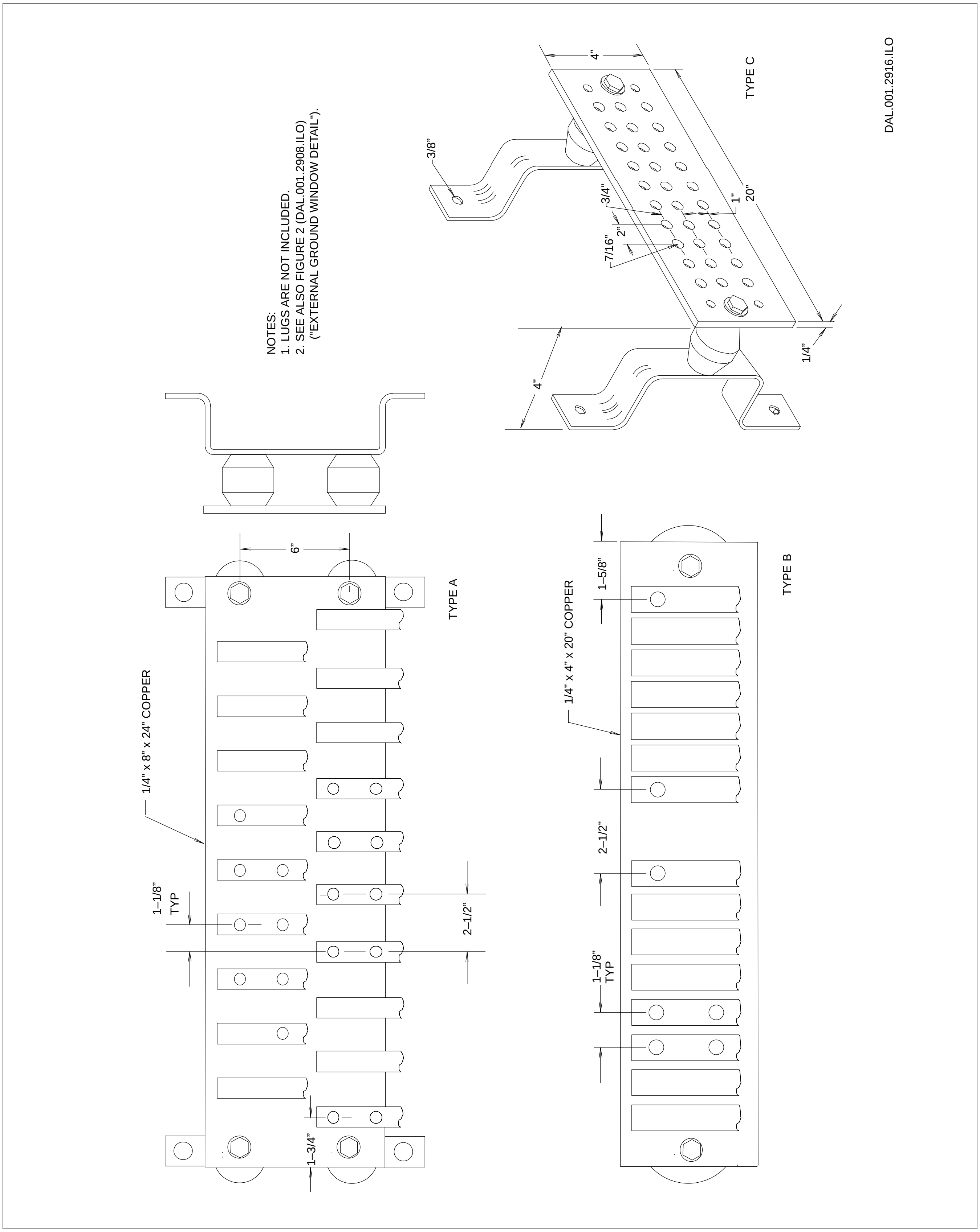

Figure 10. Representative Ground Bars

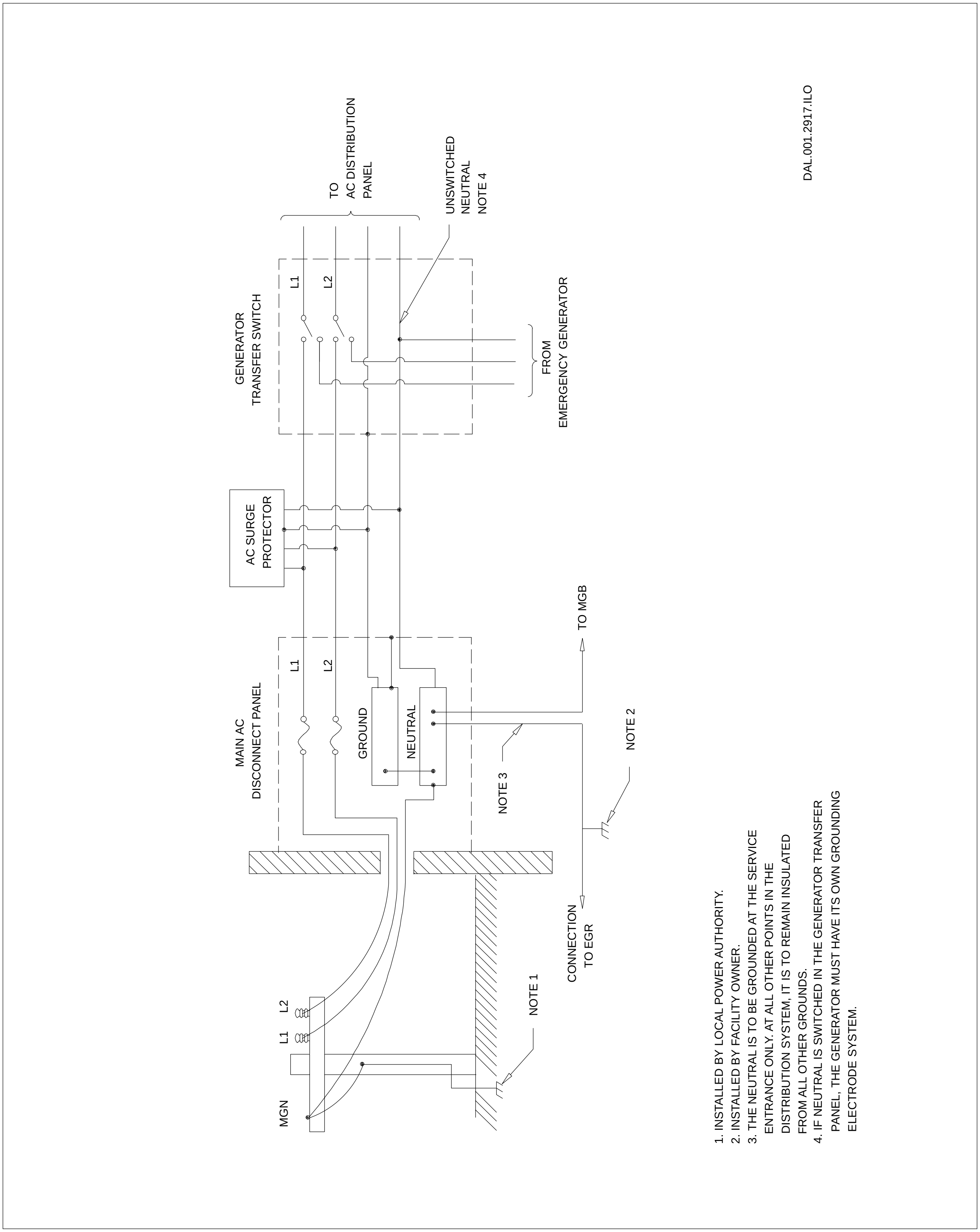

Figure 11. AC Power Utility Grounding

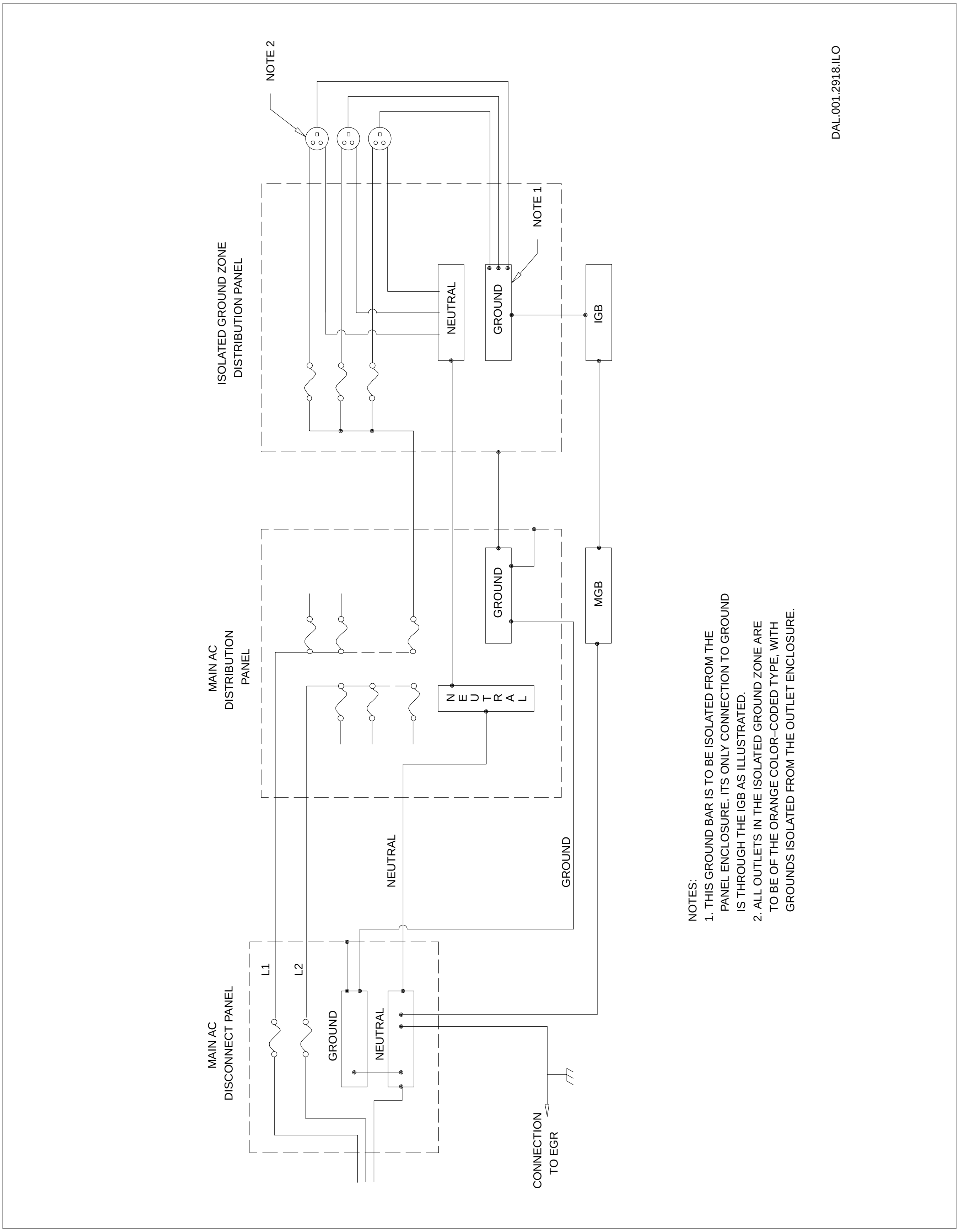

Figure 12. AC Outlet Grounding in the Isolated Ground Zone

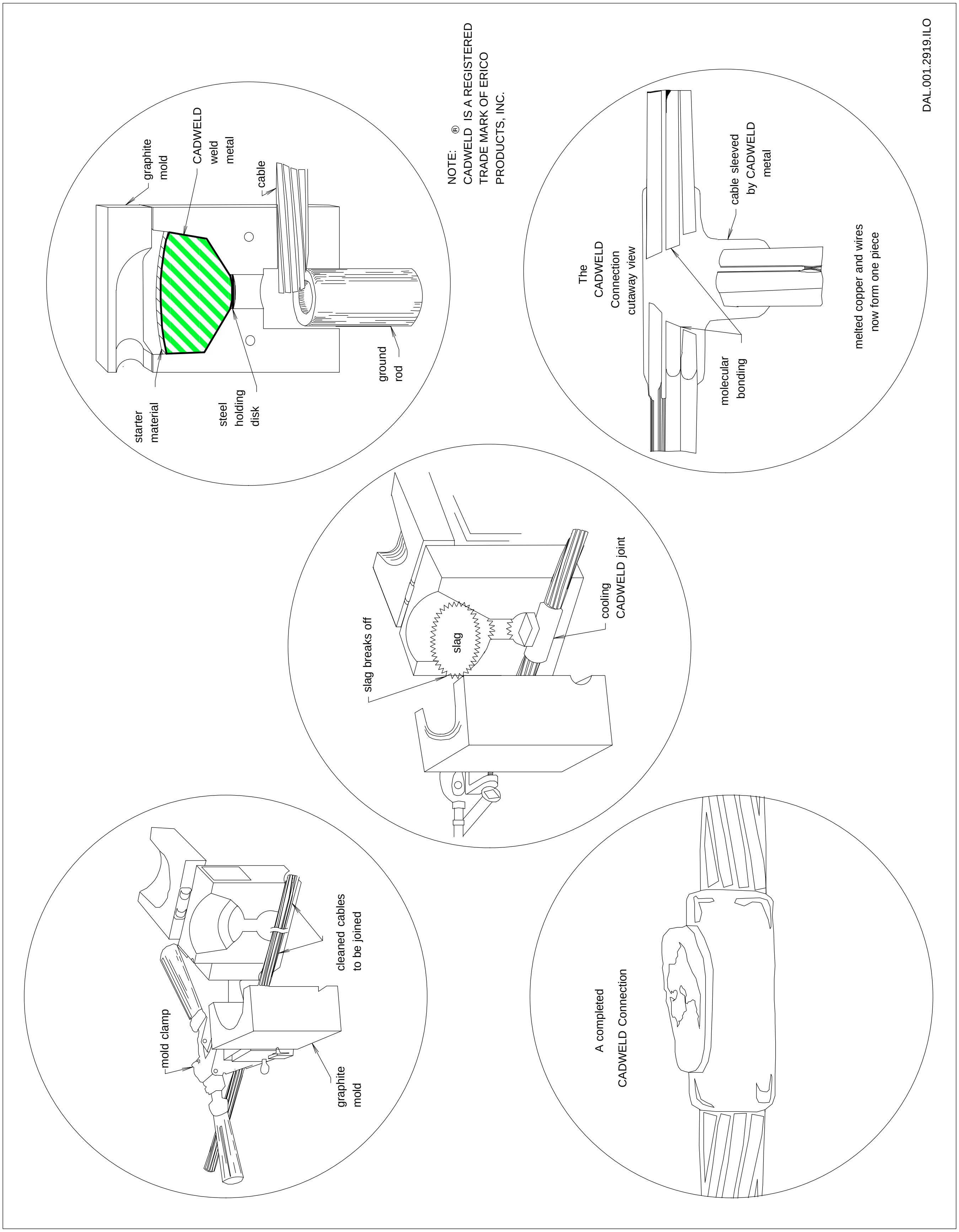

Figure 13. Making CADWELD Connections

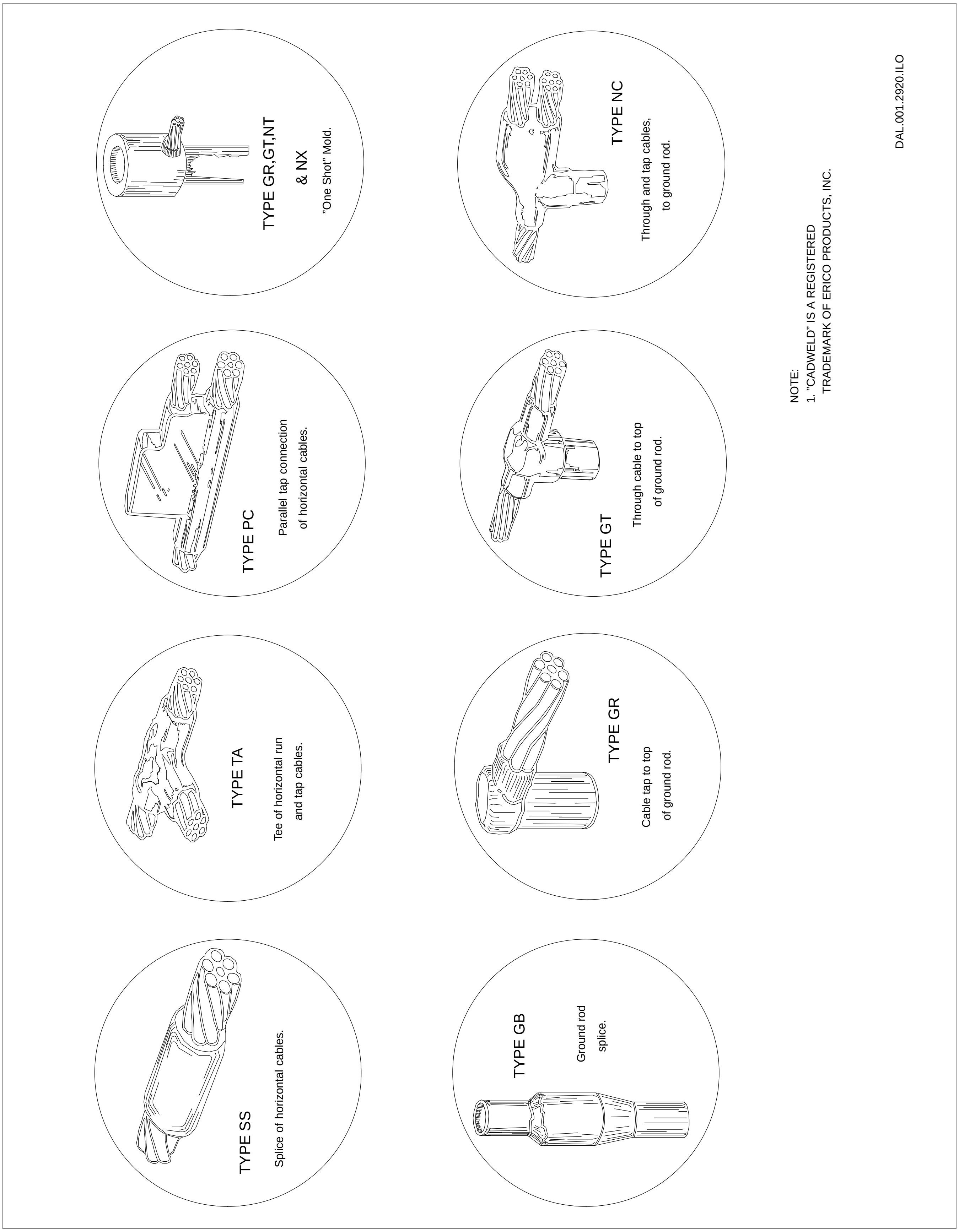

Figure 14. CADWELD Connection Styles: Cable–to–Cable/Cable–to–Rod

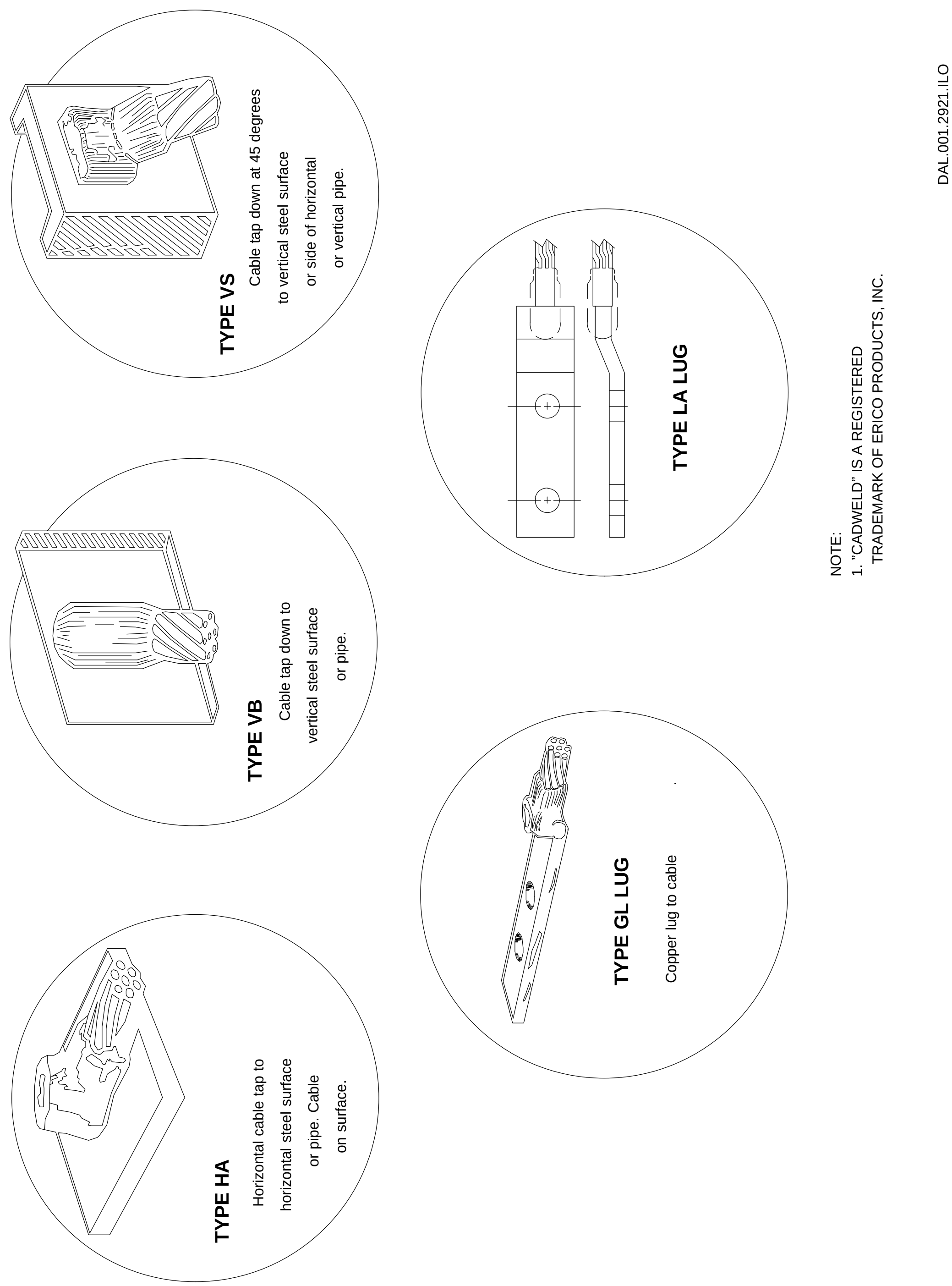

Figure 15. CADWELD Connection Styles: Cable–to–Surface

APPENDIX D

GENERAL CONVERSIONS AND FORMULAS

TABLE D-1 CONVERSION FORMULAS

Conversion Formulas
Linear Measure
miles (statute) = miles (nautical) x 1.1508
mils = in x (1 x 10^3)
ft = in/12
yard = ft/3
miles = ft/5280
Volume
ounce (fluid) = qt x 32
pint = qt x 2
gallon (US) = qt/4
gallon (imperial) = gallon (US)/0.8327
gallon (US) = cu. ft. / 7.477
Avoirdupois Weight
ounce = lb x 16
short ton = lb/2000
long ton (UK) = lb/2240
Temperature
°C = (°F-32)/1.8
°F = (°C·1.8) + 32
°K (Kelvin; Celsius absolute) = °C + 273.18
°R (Rankine; Fahrenheit absolute) = °F + 459.72

TABLE D-1 CONVERSION FORMULAS (CONTINUED)

Conversion Formulas
Angular Measurement
radians = degrees x 0.0145
revolutions = radians x 2π
Sinusoidal Waveform Measurement
rms = average x 1.11
peak = average x 1.57
peak-to-peak = average x 3.14
average = rms x 0.9
peak = rms x 1.414
peak-to-peak = rms x 2.828
average = peak x 0.637
rms = peak x 0.707
peak-to-peak = peak x 2
Power
hp = W / 746
BTU/hr = W / 0.293
Energy
BTU = KWh / (2.9306 x 10^{-4})
Metric Conversion Formulas
Linear Measure
cm = in x 2.54
in = centimeters x 0.3937
in = meters x 39.37
yards = meters x 1.0936
ft = kilometers x 3281
kilometers = miles (statute) x 1.6093
micron = meter / 10^{-6}
millimicron = meter / 10^{-9}

TABLE D-1 CONVERSION FORMULAS (CONTINUED)

Conversion Formulas
Angstrom units = meter / 10^{-10}
Area
cm^2 = sq. in / 0.155
m^2 = sq. ft / 10.76
Liquid Measure
US gallon = liter x 0.2642
fluid ounce = milliliter x 0.0338
Volume
liter = 1000 cm^3 = cu. in / 61.02
Pressure
Pa = N/m^2 = PSF x 47.85
Pa = PSI x 6891
atm = PSF x 2117
Weight
ounce = gram x 0.03527
lb = kilogram x 2.2046
long ton (UK) = metric ton x 1.1023
gram = ounce x 28.35
kilogram = lb x 0.4536
metric ton = long ton (UK) x 0.9072
tonne = ton (US) x 1.102
Torque
N·m = lbf·ft x 1.356
lbf·ft = N·m x 0.7376

TABLE D-2 METRIC EQUIVALENTS OF AMERICAN WIRE GAUGE (AWG)

	Area			Diameter	
AWG	c mils	inches[1]	mm2	mils	mm
28	159.8	0.000126	0.804	12.6	0.320
26	254.1	0.000200	0.128	15.9	0.404
24	404.0	0.000317	0.205	20.1	0.511
22	642.4	0.000505	0.324	25.3	0.643
19	1288	0.001012	0.653	35.9	0.912
18	1624	0.001276	0.823	40.3	1.02
16	2583	0.002028	1.31	50.8	1.29
15	3257	0.002558	1.65	57.1	1.45
14	4107	0.003225	2.08	64.1	1.63
13	5178	0.004067	2.63	72.0	1.83
12	6530	0.005129	3.310	80.0	2.05
11	8234	0.006467	4.17	90.7	2.304
10	10380	0.008155	5.261	101.9	2.588
9	13090	0.01028	6.631	114.4	2.906
8	16510	0.01297	8.367	128.5	3.264
7	20820	0.01635	10.55	144.3	3.665
6	26250	0.02062	13.30	162.0	4.115
5	33100	0.02600	16.77	181.9	4.520
4	41740	0.03278	21.15	204.3	5.189
3	52640	0.04134	26.67	229.4	5.827
2	66370	0.05213	33.62	257.6	6.543
1	83690	0.06573	42.41	289.3	7.346
1/0	10550	0.08289	53.49	324.9	8.252
2/0	13310	0.1045	67.43	364.8	9.266
3/0	167800	0.1318	85.01	409.6	10.40
4/0	211600	0.1662	107.26	460.0	11.68
	250000		126.70	500.0	12.70
	350000		177.39		
	500000		253.35		
	750000		380.13		

1. All conductors are solid except AWG 2 and coarser which are stranded.

TABLE D-3 TEMPERATURE CONVERSION CHART

°C	°F	°C	°F	°C	°F	°C	°F
-60	-76	-25	-13	5	41	45	113
-55	-67	-20	-4	10	50	50	122
-50	-58	-17.8	0	15	59	55	131
-45	-49	-15	5	20	68	60	140
-40	-40	-10	14	30	86	65	149
-35	-31	-5	23	35	95	70	158
-30	-22	0	32	40	104		

NOTE: °C= (°F-32) / 1.8
°F= (°C·1.8) + 32

TABLE D-4 ENGINEERING PREFIXES

Prefix	Symbol	Value	Example
tera	T	1×10^{12}	terahertz (THz)
giga	G	1×10^{9}	gigahertz (GHz)
mega	M	1×10^{6}	megahertz (MHz)
kilo	k	1×10^{3}	kilohertz (kHz)
centi	c	1×10^{-2}	centimeter (cm)
milli	m	1×10^{-3}	millihenry (mH)
micro	µ	1×10^{-6}	microfarad (µF)
nano	n	1×10^{-9}	nanosecond (nsec)
pico	p	1×10^{-12}	picofarad (pF)

TABLE D-5 DECIMAL EQUIVALENT DRILL SIZES

Fractional Drill Size (in.)	Decimal Equivalent (in.)	Metric Equivalent (mm)	Fractional Drill Size (in.)	Decimal Equivalent (in.)	Metric Equivalent (mm)
1/64	0.0156	0.397	33/64	0.5156	13.097
1/32	0.0313	0.794	17/32	0.5313	13.494
3/64	0.0469	1.191	35/64	0.5469	13.891
1/16	0.0625	1.588	**9/16**	0.5625	14.287
5/64	0.0781	1.985	37/64	0.5781	14.684
3/32	0.0938	2.381	19/32	0.5938	15.081
7/64	0.0194	2.778	39/64	0.6094	15.478
1/8	0.125	3.175	**5/8**	0.625	15.875
9/64	0.1406	3.572	41/64	0.6406	16.272
5/32	0.1563	3.969	21/32	0.6563	16.669
11/64	0.1719	4.366	43/64	0.6719	17.067
3/16	0.1875	4.762	**11/16**	0.6875	17.463
13/64	0.2031	5.159	45/64	0.7031	17.86
7/32	0.2188	5.556	23/32	0.7188	18.238
15/64	0.2344	5.953	47/64	0.7344	18.635
1/4	0.25	6.35	**3/4**	0.75	19.049
17/64	0.2656	6.747	49/64	0.7656	19.446
9/32	0.2813	7.144	25/32	0.7813	19.842
19/64	0.2969	7.541	51/64	0.7969	20.239
5/16	0.3125	7.937	**13/16**	0.8125	20.636
21/64	0.3281	8.334	53/64	0.8281	21.033
11/32	0.3438	8.731	27/32	0.8438	21.43
23/64	0.3594	9.128	55/64	0.8594	21.827
3/8	0.375	9.525	**7/8**	0.875	22.224
25/64	0.3906	9.922	57/64	0.8906	22.621
13/32	0.4063	10.319	29/32	0.9063	23.018
27/64	0.4219	10.716	59/64	0.9219	23.415
7/16	0.4375	11.112	15/16	0.9375	23.812
29/64	0.4531	11.509	61/64	0.9531	24.209
15/32	0.4688	11.906	31/32	0.9688	24.606
31/64	0.4844	12.303	63/64	0.9844	25.004
1/2	0.5	12.7	**1**	1.0	25.4

TABLE D-6 POWERS OF 10

Unit	Name
10^{12} = 1 000 000 000 000	1 trillion (US, France) 1 billion (UK, Germany)
10^{9} = 1 000 000 000	1 billion (US) 1 milliard (France and Germany)
10^{6} = 1 000 000	1 million
10^{3} = 1 000	1 thousand
10^{2} = 100	1 hundred
10^{1} = 10	ten
10^{0} = 1	one (unity)
10^{-1} = 0.1	1 tenth
10^{-2} = 0.01	1 hundredth
10^{-3} = 0.001	1 thousandth
10^{-6} = 0.000 001	1 millionth
10^{-9} = 0.000 000 001	1 billionth (US)
10^{-12} = 0.000 000 000 001	1 trillionth (US)

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ELECTROMAGNETIC ENERGY INFORMATION

This appendix discusses the following topics:

E.1 INTRODUCTION

This appendix provides information to assist in understanding the concepts required to comply with FCC guidelines for human exposure to Electromagnetic Energy at antenna sites. This information is **not** intended to replace a structured training program, but is intended to provide basic information and methodology in structuring an Electromagnetic Energy compliance program. The methods presented in this appendix represent one approach for meeting FCC requirement; other methods may also meet FCC guidelines.

In August 1996, the Federal Communication Commission (FCC) adopted new guidelines for evaluating the environmental effects of Radio Frequency (RF) energy from transmitters on wireless communication sites. While there is no scientific evidence that RF emissions from these sites operating within established safety guidelines pose a health risk, fields close to antennas on transmitter sites must be understood and care must be taken to assure safe operation during maintenance. The guidelines adopted by the FCC provide considerable margins of protection from any known health risk.

This text discusses some of the issues involved in analyzing and understanding the Electromagnetic Energy (EME) environment that may exist on a complex communications site. A complex site is not only a site with hundreds of transmitters, antennas, and some broadcast, but any site with more than one RF transmitter. Considerable investigation has been done to understand the levels of exposure associated with such facilities, but little has been written on the implementation of procedures to ensure operating conditions in compliance with the FCC guidelines.

Modern communication sites typically contain many transmitters serving various functions or services, such as cellular, PCS, ESMR, paging, basic two-way radio, broadcast, etc. With each of these services requiring separate transmitters, in the past each service would typically develop its own sites and exist alone. However, with the dramatic growth of these services has come a growing incentive and need for transmitter collocation (the grouping of transmitters for different communications services at a single site). This collocation naturally results in correspondingly greater densities of EME fields about the site.

The drive for collocation comes from the need for more sites to satisfy public demand for more communications services, as well as public reaction to the proliferation and location of those sites. This will create communications sites more dense than has ever been dealt with before. In order to accommodate this natural growth in antenna density, more locations that consolidate communication transmitters are likely.

While collocation is a logical response to the marketplace factors outlined above, it presents challenges to the companies providing these services. As more transmitters are added to a site, the density of RF generators and EME increases. This is not unlike the situation found on a hilltop surrounding a large metropolitan area. The best hilltops have a high density of broadcast and communications sites. Because these are usually located on a common ridge or peak, the RF density may at times approach recognized exposure limits.

This appendix discusses some of the issues that must be considered in the management of a complex communications site. These considerations are important in order to ensure the operation of sites within recognized exposure limits. The RF density increases with the increase in the number of transmitters. However, operating conditions in compliance with the FCC guidelines can help be assured by the use of basic principles discussed here.

E.2 ENVIRONMENTAL EVALUATION

The possible health effects associated with exposure to EME have been studied for more than half a century. Scientists first identified the exposure threshold above which RF energy may cause adverse biological effects. The only established adverse effect of RF energy relates to the heating of tissue. Standard-setting bodies then set recommended exposure limits that are substantially below this threshold by at least a factor of 10 or more. With this substantial built-in margin of protection, these standards constitute reliable science-based guidelines for safe human exposure. Internationally, EME exposure standards exist in many countries. In the United States, one accepted standard comes from the American National Standards Institute C95 committee formed in the late 1950's. This committee has undergone many changes and implemented several standards. In 1988 the Institute of Electrical and Electronics Engineers (IEEE) became the sole sponsor of the C95 Committee, and the committee became the IEEE Standards Coordinating Committee (SCC), SCC28. In 1991 IEEE adopted their current standards as IEEE C95-1991. These standards were subsequently recognized by ANSI (American National Standards Institute) in 1992 as the ANSI/IEEE C95-1992 standard for safety levels of radio frequency exposure. The exposure limits in the ANSI standard are similar in many respects to those set by the National Council on Radiation Protection and Measurements (NCRP), an independent organization chartered by the U.S. Congress.

The Federal Communication Commission recently adopted guidelines which generally followed the recommendations of expert health and safety agencies such as the EPA, FDA, OSHA, NIOSH, and others, to adopt field and power density limits as recommended by the NCRP Report No. 86 and the SAR limits from the ANSI/IEEE C95.1-1992. (For more information review FCC Report and Order (FCC 96-326) and Second Memorandum and Order (FCC 97-303). These can be found on the FCC Office of Engineering and Technology website address: www.fcc.gov/oet/rfsafety)

E.2.1 EXPOSURE STANDARDS AND LIMITS

With the publication of the SCC28 standard as ANSI/IEEE C95.1-1992, a number of new elements were added to prior ANSI standards. These changes included modification of the exposure limits and the classification of exposure environments as Occupational/Controlled and General Population/Uncontrolled. Exposure limits in the new guidelines adopted by the FCC are specified in terms of Maximum Permissible Exposure (MPE) as a function of frequency; MPE's are given in units of electric and magnetic field strength and power densities. For exposure to multiple frequencies, the fraction (or percentage) of the MPE produced by each frequency is determined and these fractions (or percentages) must not exceed unity (or 100 percent).

If the RF fields at a specific location are composed of four frequencies and their fields represent the percentages of the applicable MPE for Occupational/Controlled environments as identified by the FCC are shown below, the resulting exposure can be expressed as 85% of the allowable Occupational/Controlled MPE and continuous exposure would be in compliance with the FCC limits. An example is shown below.

Frequency (MHz)	Measured Power Density	MPE
155.025	0.25 mW/cm^2	25%
465.0125	0.54 mW/cm^2	35%
955.0125	0.48 mW/cm^2	15%
851.0125	0.28 mW/cm^2	10%
	Total Exposure:	**85%**

Different limits apply to different circumstances (see Figure E-1), based on whether a person at or near a specific site knows or is informed and has control of potential RF exposure. Occupational/Controlled Environment limits apply to individuals who should know that there is a potential for exposure as a requirement of employment, or as the incidental result of transient passage through areas that may exceed exposure levels beyond the General Population/Uncontrolled environment MPEs. For example, a maintenance technician who performs work on transmitters should be aware (due to training and the nature of his work) that transmitters produce RF energy. Because of the knowledge and understanding that exposure is possible, this individual would be evaluated against the Occupational/Controlled environment limits. General Population/Uncontrolled Environment limits apply to individuals assumed to have no knowledge of, or control over, their possible exposure to RF energy. If the technician in the example above brought his family to the same area, the situation would change. Since the family members would not be assumed to have knowledge or understanding of the RF environment, their exposures would be judged against the limits for General Population/Uncontrolled environments. The technician, however, would be evaluated against the Occupational/Controlled environment limits. Simple understanding or precautions can assure that RF levels at or near an antenna site do not exceed maximum permitted exposure levels. The MPE exposure levels for General Population/Uncontrolled environments are five times lower than the MPE exposure levels for Occupational/Controlled environments. The technician, in the above example, could be exposed to a power density of 3 mW/cm^2 from a 900 MHz transmitter while the family members could only be exposed to 600 $\mu W/cm^2$.

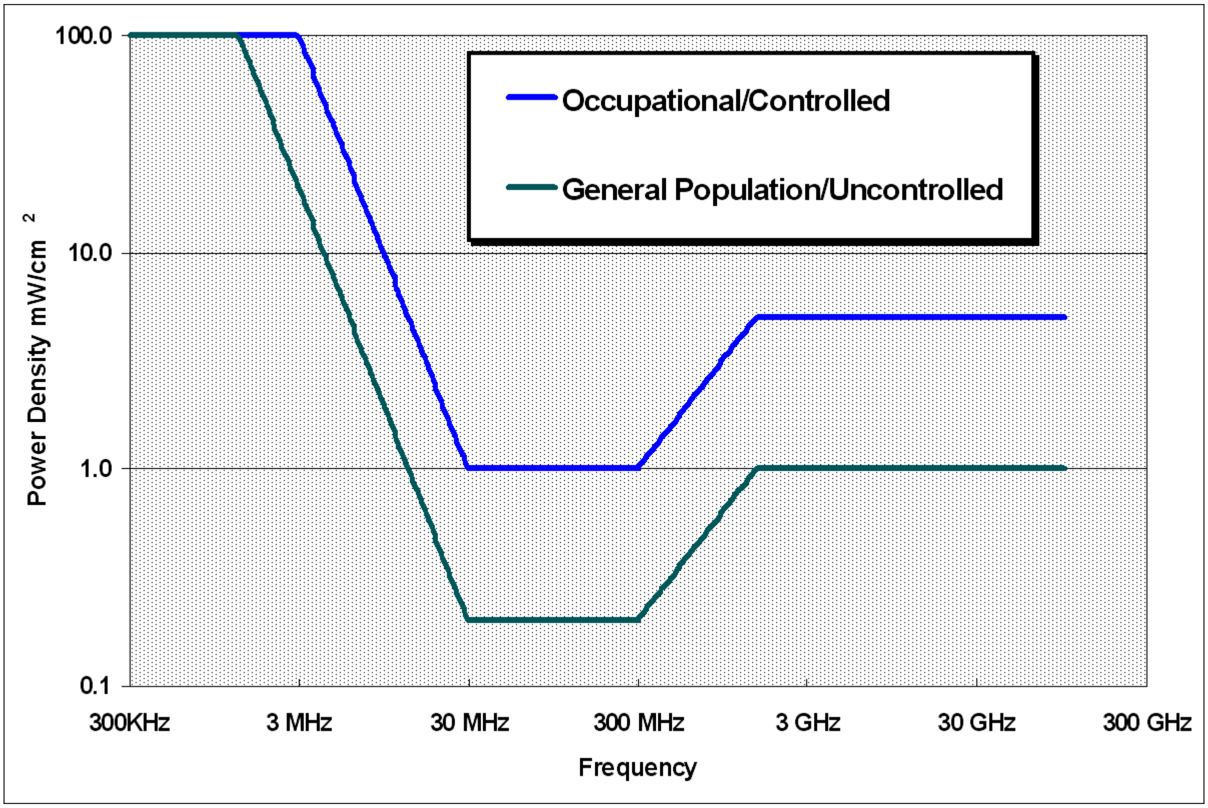


FIGURE E-1 FCC ADOPTED MAXIMUM PERMISSIBLE EXPOSURE LIMITS

E.2.2 COMPLIANCE ANALYSIS

E.2.2.1 SPATIAL-PEAK

The maximum RF energy across the area of the human body (about 1.8 m (6 ft.) high) that an individual can be exposed to, is considered the Whole Body Peak (WBP). This level should be considered as the highest level that is found in the area of interest. If, during the evaluation of an area for exposure, there are no WBP exposures above the MPE being considered, the area is considered below the limits and requires no additional evaluation.

E.2.2.2 SPATIAL-AVERAGING

If, during the evaluation of an area for potential exposure, it is determined that there are areas where peak levels (WBP) will exceed the MPE, then spatial-averaging is required. Spatial-averaging considers the whole area of the human body in the evaluation of exposure. If there is an area that has RF fields above the applicable MPE, additional vertical measurements should be taken to understand the levels between ground level and 1.8 m (6 ft.) high.[1] The average of these vertical measurements is the Spatial-averaged exposure, which is used to evaluate compliance with the MPE.

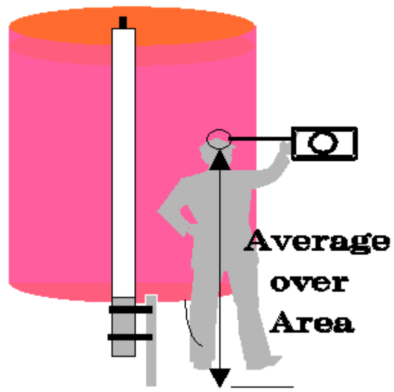


FIGURE E-2 SPATIAL AVERAGING

E.2.2.3 TIME-AVERAGING

MPEs in the guidelines are in terms of a time-averaged exposure, typically either 6-minute for Occupational/Controlled MPE or 30-minutes for General Population/ Uncontrolled MPE. The averaging times are used to regulate the energy absorption rate in an individual exposed to RF fields so that the total energy delivered over the averaging time does not exceed FCC guidelines. This permits short duration exposure to much higher level fields as long as the average value over the prescribed time remains within the MPE.

The FCC MPE is time and spatially averaged. It is therefore permissible to exceed the numeric values of the MPE for brief periods of time and in some locations of space as long as the average exposure does not exceed the limits over the time and space indicated.

1. The ANSI/IEEE C95.1 - 1992 standard uses a height of 2.0 meters.

While time averaging is considered an acceptable mechanism for managing high exposure levels, it requires considerable attention and consideration. There is potential for error and thus, the use of time averaging alone generally should be avoided. If situations are encountered where levels exceed the exposure permitted with spatial-averaging, then other means **shall** be utilized to reduce exposure. There are situations however, where time averaging may prove to be an acceptable method available to control exposure. One of these situations is tower climbing. While on a tower, a climber may move through fields that are in excess of the limits for continuous exposure. If a steady rate of ascent is maintained the time-weighted averaged exposure can be maintained below the limit allowed in the guidelines.

E.2.3 EXPOSURE EVALUATION

Evaluating possible RF exposure levels can be done using both theoretical models and physical testing. Modeling a site allows the tester to be aware of situations and anticipate locations where close physical examination is required.

The maximum exposure allowed by the FCC limits is 100% of the MPE, averaged over both time and body height. To provide a margin of tolerance to ensure compliance, in many cases an additional factor of 3 dB or 50% should be adopted as an action threshold. Any levels above 50% of the applicable MPE **shall** have action procedures to maintain compliance.

E.2.3.1 RF MODELING

Modeling is the theoretical calculation of RF fields based on the situation. With a minimum amount of data, the field strength can be estimated before actual testing begins. To fully apply modeling, the characteristics of the antenna radiating in free space must first be understood. The field radiates from an antenna like a ripple in the water after a pebble is thrown. The closer to the source, the more curved the wave front will be; further from the source the circle becomes very large and the wave front has less curvature. Far from the source, the field appears planar. The field will still be curved but within the limits of observation it appears to occupy a flat plane in space, e.g., plane-wave radiation.

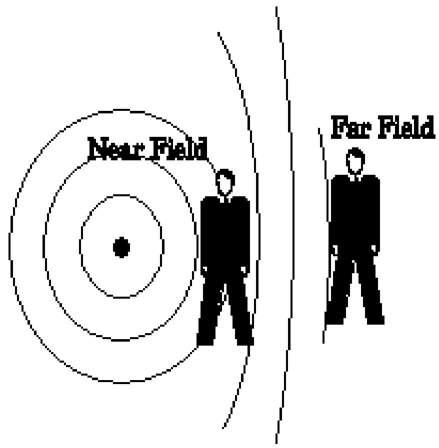


FIGURE E-3 RF MODELING

Close to the antenna is a region referred to as the **near field**. Within this region the spatial characteristics of the RF fields are very complex. The average power density within the near field varies inversely with the distance from the antenna. In other words, as distance from the antenna increases, the power density is reduced inversely with distance, D. This is the so-called **1/D** region.

Further from the antenna is the **far field**. In the far field, the beam has developed and propagates in a behaved manner. In the far field as distance from the antenna increases, the power density decreases inversely with the square of distance. This is the so-called **$1/D^2$** region. This signal intensity characteristic is commonly used to predict coverage. Far field calculation of signal strength is the normal approach for estimating signal strength a mobile receiver will receive.

From the standpoint of anticipating the power density to which a person will be exposed from an antenna, both the near and far fields must be understood. If RF levels are predicted very near an antenna based on the square of the distance (as is indicated in the far field formula), the calculated levels increase faster than what really occurs close to the antenna. There is a point called the crossover point where the two fields meet. Before this point the power density drops off linearly and after this point the signal reduces as an inverse square relationship. If both formulas are considered, there is a point of intersection. This crossover point is defined as the boundary of the near field and far field.

The power density decreases much faster in the far field than the near field. There is a distance from the antenna where the field strength of near field and far field are equal or intersect. The point of intersection (crossover point) is the boundary for the two zones.

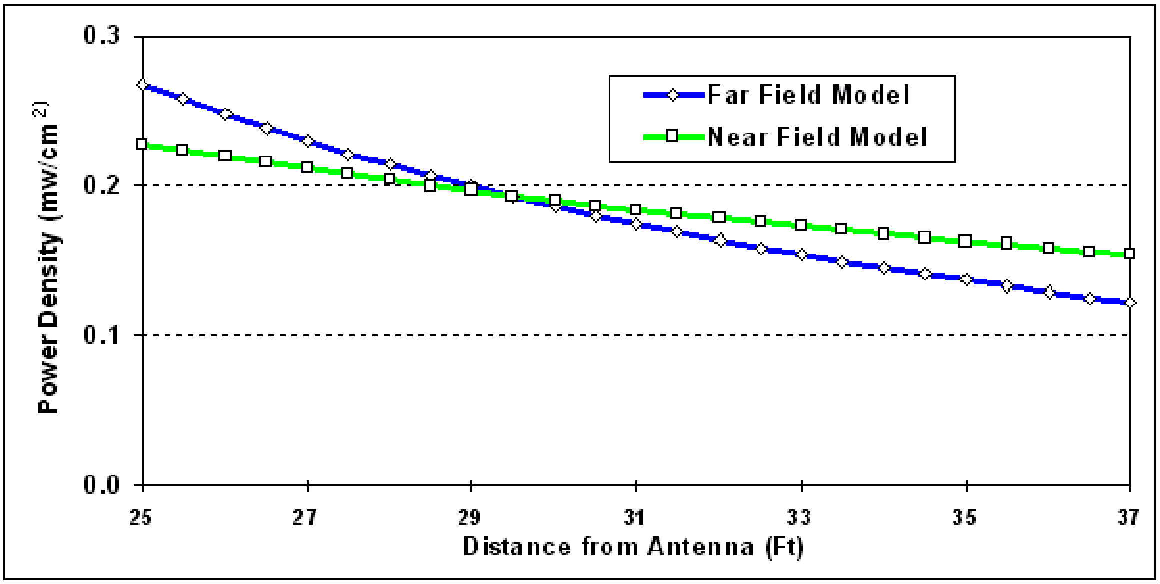
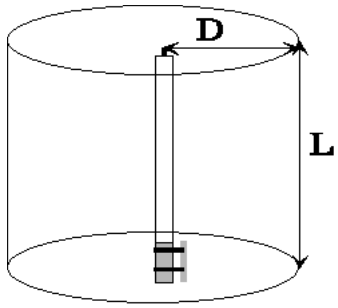


FIGURE E-4 EXAMPLE OF NEAR FIELD/FAR FIELD CROSSOVER

The data in Figure E-4 represent the crossover for a 6 dBd gain omni antenna that is 2.74 m (9 ft.) in length. As the aperture length and gain change, the crossover point will also change greatly. For the example above, the crossover point is approximately 9.14 m (30 ft.). For an antenna with 10 dBd of gain and an aperture length of 3.96 m (13 ft.), the crossover point will be over 30.5 m (100 ft.). A 3 dBd gain antenna with an aperture length of 45.7 cm (1.5 ft.) will have a crossover point of only 91 cm (3 ft.).

E.2.3.1.1 CYLINDRICAL MODEL

For vertical antennas, with omnidirectional horizontal patterns, the power density in the near field can be estimated using the circular radiation pattern and the height of the antenna. The area of a cylinder placed over this antenna is assumed to be uniformly exposed to the power radiated by the antenna; no RF energy emanates from the top or bottom. This power density is approximately the same as the average power density an individual of a specific height would be exposed to when standing next to the antenna. This formula is referred to as the Cylindrical Model since it utilizes a cylinder for the modeling (see Figure E-5).



$$S = \frac{P}{2\pi DL}$$

S = Power Density (mW/cm^2)
P = Total Power into Antenna (mW)
D = Distance from Antenna (cm)
L= Length of Antenna Aperture (cm)

FIGURE E-5 CYLINDRICAL MODEL

Shorter antennas result in higher fields and exposure for a constant power. The greater the power, the higher the EME field. The shorter the aperture, the higher the EME field. The closer to the antenna, the higher the EME field.

E.2.3.1.2 SPHERICAL MODEL

In the far field, the radiation pattern becomes developed and does not change with distance from the antenna. The maximum radiating power density becomes related to the gain of the antenna. In the far field, the power density decreases as the square of the distance. With an isotropic point source (omnidirectional in all directions) the power density can be envisioned as the source power distributed over a sphere having a radius equal to the distance from the antenna. When the antenna has gain, the maximum power density in the far field can be calculated using the formula below:

$$S = \frac{PG}{4\pi D^2}$$

S = Power Density (mW/cm^2)
P = Total Power into Antenna (mW)
G = Gain Ratio of Antenna based on an Isotropic radiator
D = Distance from Antenna (cm)

E.2.3.2 ROOFVIEW™ EME MODELING SOFTWARE

[1]RoofView is a modeling software package that allows a theoretical study of site situations. The software creates a mosaic map of the area showing the EME levels (see Figure E-6). The calculations can use different methods, different standards, antenna heights, and uptime for evaluation. There are two versions:

- **RoofView** is the building version showing EME situations on a single plane.
- **TowerCalc** is used to model towers. This will allow the EME situation on any level of the tower to be understood.

The software runs on Excel 5.0 for Windows 3.1 and NT and Excel 7 for Windows 95. The information needed to create a model and generate a zoning map is:

- Transmitter Power into Antenna
- Frequency
- Antenna mount designation
- Antenna location on roof
- Antenna Characteristics
    - Gain
    - Aperture Length
    - Mounting Height

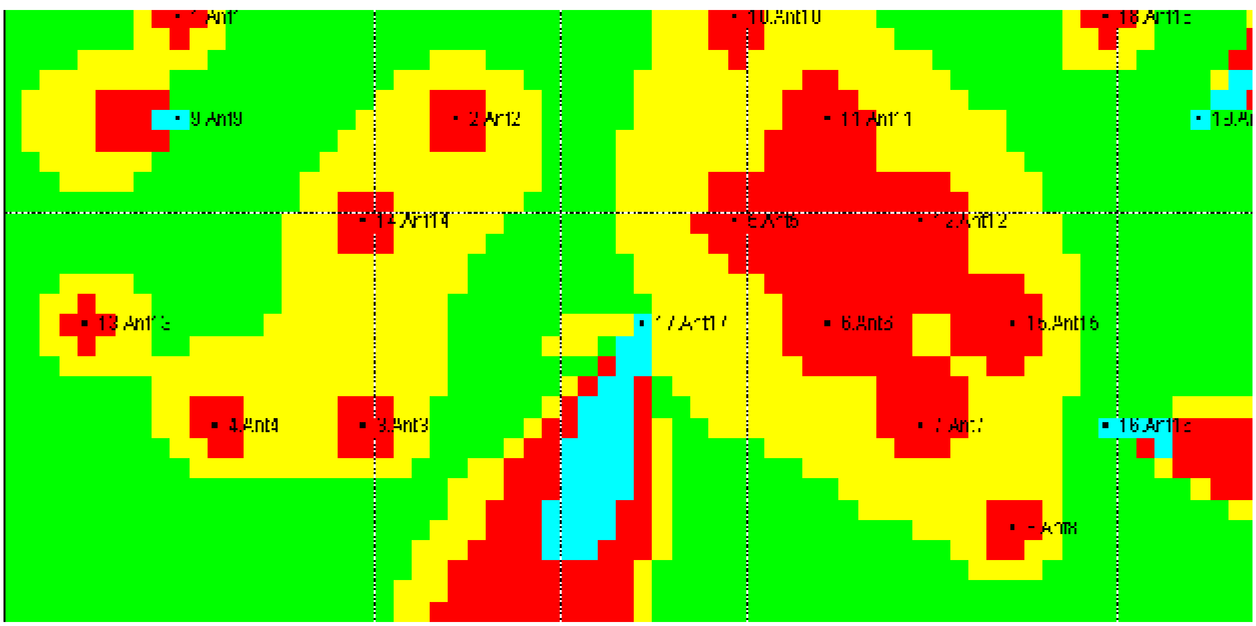


FIGURE E-6 EME ZONE MAP OF A COMPLEX ROOFTOP ANTENNA SITE

1. Trademark RoofView™ and TowerCalc™ are licensed to Richard Tell Associates, Inc., Las Vegas NV. Additional information can be found on Website: www.radhaz.com

RoofView calculates and plots a pictorial representation of EME levels. Antenna fields can be expressed directly as a percentage of user selectable MPEs. This is analogous to running a range prediction coverage map. During RF system design an understanding of coverage is important. During site design EME evaluation is important.

E.2.4 EME ZONING

After the exposure levels are determined an evaluation and classification **shall** be performed. The classifying of the exposure allows site managers to understand the complete situation and develop procedures to ensure exposure to employees and contractors is maintained below the acceptable limits.

Classifying exposure focuses on comparing the levels found against the Occupational/Controlled MPE. As the term indicates, MPE is the maximum permissible exposure an individual should encounter. To further classify areas, a standard color coding can be adopted to clearly show the EME levels.

On a site where RF transmitters and their associated antennas are located, it is usually necessary to restrict the access of the general population. This area frequently is bounded by walls, fences, and other natural or man made structures. Within this area three zones (Green, Yellow, and Red) will be used to determine the requirements for compliance to the FCC guidelines.

E.2.4.1 GREEN ZONE

The green zone is any area where the time (as appropriate) and spatial-average is below 20% of the Occupational/Controlled MPE. The areas so classified afford the highest level of protection for individuals working in RF fields. There is no time limit and no special EME safety practices are required for these areas. Individuals working in this zone may need only basic EME awareness. This can be conveyed with signs, plaques, or awareness videos to provide the information necessary to create an awareness and understanding of the environment.

Green Zones denote the lowest EME levels at the site. This area is usually associated with equipment rooms, ground areas around towers, and other areas significantly removed from transmitting antennas. The green zone is unique because the exposure levels are below the General Population/Uncontrolled environment MPEs. Care and proper consideration in site design **shall** be done to ensure these levels are maintained. On high-density sites annual (or more frequently if required) evaluations **shall** be done to ensure compliance.

Equipment rooms and areas around the base of towers **shall** always be required to have fields low enough to allow a green classification. The verification and certification of this low level may be required on some sites. If locations are discovered in excess of these levels, changes and modifications must be incorporated to maintain green-zone status. Some methods to maintain green-zone levels are:

- Proper maintenance of RF transmitters. This includes ensuring all shields are maintained properly and installed correctly.
- Not allowing transmit antennas inside equipment rooms or near the ground level of sites.
- Ensuring all microwave dishes are directed away from facilities.
- Proper use and installation of transmission lines and connectors. When waveguide carrying high power is used, verification of fitting integrity must be performed to ensure there is no RF leakage.

E.2.4.2 YELLOW ZONE

The yellow zone is any area where the spatial-average is between 20% to 100% of Occupational/Controlled MPE. While the fields in this area are within acceptable limits, caution must be exercised because nearby locations may exceed the limits. Therefore, individuals in these areas should have heightened awareness and understanding of their potential for exposure. Normally, there will never be a yellow zone without another zone of higher level in the vicinity. Personnel without EME awareness training **shall not** frequent this area regularly. Only personnel with the proper knowledge and understanding of EME compliance procedures **shall** be allowed to work in areas designated as yellow zones. Appropriate Caution signs **shall** be posted to inform personnel of the EME situation.

Yellow zones **shall** be posted to ensure all personnel entering understand the area is controlled. The EME levels in a yellow zone are below the MPE for Occupational/ Controlled environments, but not for General Population/Uncontrolled environments. **Only** individuals who have the knowledge and requirement shall be given access.

E.2.4.3 RED ZONE

The red zone is any area where the spatial-averaged levels fall above 100% of Occupational/Controlled MPE. When locations are found to require red zoning, special procedures, engineering, or restricted access must be implemented to ensure compliance. Some procedures that can be implemented are:

- Restrict Access
- Lock-out/Tag-out of transmitters during maintenance of antenna system
- Control of antenna types used for site design
- Re-engineer site to reduce EME fields
- Measure and consider uptime. (“Uptime” is the percentage that a transmitter will likely be keyed. Refer to “Uptime,” on page E-21 for detailed information.)

E.2.5 CHARACTERIZATION ZONING

The level of RF energy to which one is exposed is called Exposure. The quantity of exposure depends on the duration and strength of the field. In most cases, the characteristics of a site will determine the EME exposure potential. Understanding these characteristics will aid in predicting and preventing levels that exceed the FCC Guidelines and allow the site manager to establish the proper procedures for personnel who frequent these areas.

E.2.5.1 BUILDINGS

Building sites are normally in dense, metropolitan cities. The buildings used are normally the highest structures in the city and offer the unique opportunity of height without the need for a long feedline. The facility which houses the radio transmitters is normally close to the antennas which reduces the loss between the antenna and transmitter, allowing maximum power to the antenna. While this maximum power provides extended range, it increases the EME levels around the antennas. The main determinants of EME are frequency, power into the antenna, and aperture height. The greater the power, the higher the EME field. The shorter the aperture, the higher the EME field for a given power.

On buildings, the antennas are generally mounted on the roof. This mounting arrangement is normally laid out on a single plane and distributed in a grid arrangement, within the confines of the roof. The mounting is normally on a pipe structure and the separation can be as close as 91 cm (3 ft.) in some cases. This arrangement provides for maximum mounting density, but it may leave little space for the workers performing maintenance. Any worker attempting to change an antenna, repair a cable, or perform general maintenance may be exposed to high levels of RF energy from other antennas surrounding the work area. Proper engineering design should be used to prevent this situation. By reducing all the fields on a building the potential for high exposure is eliminated and provides the best compliance resolution.

E.2.5.2 TOWERS

Towers are antenna supporting structures that can be found in various locations ranging from central metropolitan, to isolated rural locations. Normally, the towers are designed to elevate the antennas in accordance with the intended coverage area. This can vary from 30.5 m (100 ft.) for cellular to 610 m (2000 ft.) for two-way communications. Regardless of the height of the supporting structure, the characteristics are the same. The application of the antennas that are being supported determine these characteristics. Cellular towers usually have directional antennas mounted on a single face to define a sector. There may be several faces and several directional antennas per face. A two-way tower can have several antennas mounted in a star configuration to maximize the density of antennas at a position on the tower. Additionally there can be several star mounts on a single tower.

With respect to EME, the cellular configuration presents less exposure to people working on the tower than the two-way tower configuration because the RF radiation of the directional antenna is aimed away from the tower. There is a significant power difference between the front and the back side of the antenna. This difference is called front-to-back ratio. While the front-to-back ratio can be as great as 25 dB in the far field it is less well developed in the near field. There is still reduction of the exposure of the worker in the near field behind, as compared to the front of the antenna, but the amount may be considerably less than the advertised far field front-to-back ratio.

The situation on two-way towers is significantly different. As workers climb up the tower they may encounter several antenna mounts at various locations on the tower. These mounting areas can contain various types of transmitters ranging from paging transmitters with hundreds of watts of power to large antennas for transmitters in the 35 MHz frequency range. While the antennas and the resulting mounting arrangement can be considerably different, in some conditions the EME levels may approach or exceed the FCC guidelines. In the case of the paging transmitter, the antenna will normally be an omni configuration with an aperture length of 1.2 m to 4.6 m (4 to 15 ft.). The antenna will be mounted from 1.2 m to 1.8 m (4 to 6 ft.) from the tower. Fields directly adjacent to the aperture will present the highest levels. Because of this, workers **shall** use caution while working or stopping directly in front of these antennas unless the transmitters are deactivated. If the antenna is grouped with other antennas at the same level more than one transmitter may need to be deactivated. Another important characteristic of paging is the duty cycle of the transmitter. The importance of duty cycle will be discussed in detail later.

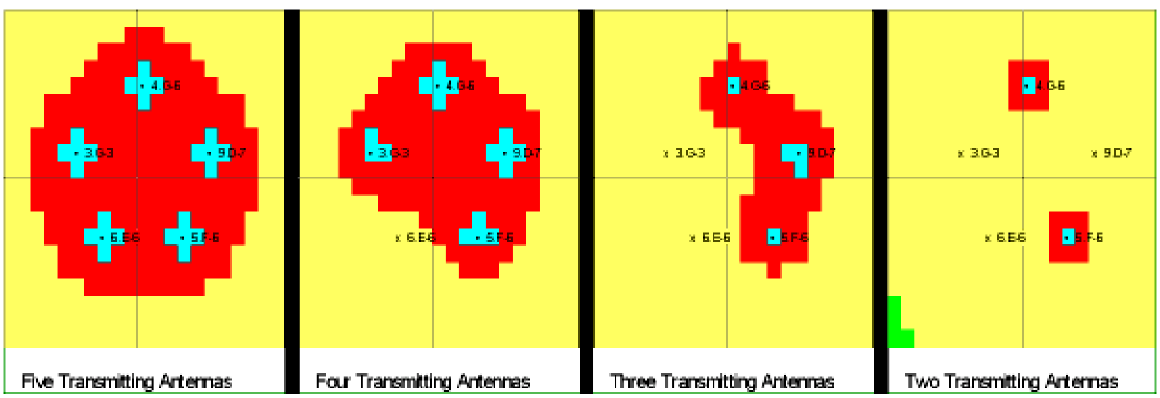


FIGURE E-7 EME ZONE MAP OF A TOWER MOUNTED STAR CLUSTER MOUNT OR CANDELABRA (RESOLUTION 1 SQ. FT.)

Star cluster mounts (see Figure E-7) or candelabras present a significant issue in the management of EME on towers. If there are five to eight antennas mounted in a circle and these antennas are located 1.5 m (5 ft.) from the tower, there is the potential for an EME level in the center that exceeds the limits. Because the center is the tower, workers must ensure they understand the fields while entering this area. Figure E-7 shows the computed effects of several transmitters using the EME modeling program described above. Each square pixel represents 929 cm^2 (1 sq. ft.) of resolution. This simulates the effects of five PD-10017 antennas with 100 W into the antenna at 900 MHz. A worker entering this area may be exposed to EME levels above the applicable MPE and **shall** take appropriate steps, such as moving quickly through the area, to assure compliance with recognized exposure guidelines. What makes this situation difficult to manage is the fact that the field and the resultant high EME levels from all the antenna fields overlap and add. While this situation can exist, the fields are reduced by the cable loss associated with the height of the candelabra, and are therefore more manageable. Most candelabras are mounted on top of a tower.

Because of the cable loss associated with towers, the power into the antenna is significantly lower than buildings and hilltop sites. This loss between the transmitter and antenna reduces the power and ultimately the fields produced. Higher frequencies have higher line loss, which significantly reduces the power at the antenna. This fact is very important and proves to significantly reduce the fields produced on tall towers.

Candelabra and star mounts present unique compliance and maintenance situations due to the additive nature of EME exposure at these locations. Insertion losses of transmission lines reduce the power into the antennas and reduce the likelihood of strong fields on clusters located at high levels on tall towers. For equal transmitter power, the higher the frequency, the higher the insertion loss; thus EME levels are lower on tall towers.

E.3 ENGINEERING CONSIDERATIONS

E.3.1 ANTENNA ELEVATION

One common technique for reducing the RF levels expected on large roof tops is to elevate the antennas above the roof. Elevating the antennas raises the EME fields above the roof and reduces the power density to which an individual at roof level will be exposed. The results of elevating antennas are illustrated in Figure E-8. These data are based on the EME fields produced by an 850 MHz SMR antenna. Ten 150 Watt transmitters through a combiner drive the antenna. The resultant 550 Watts of power is fed into a 3.96 m (13 ft.) omni antenna. This type of antenna configuration is not unusual on rooftops.

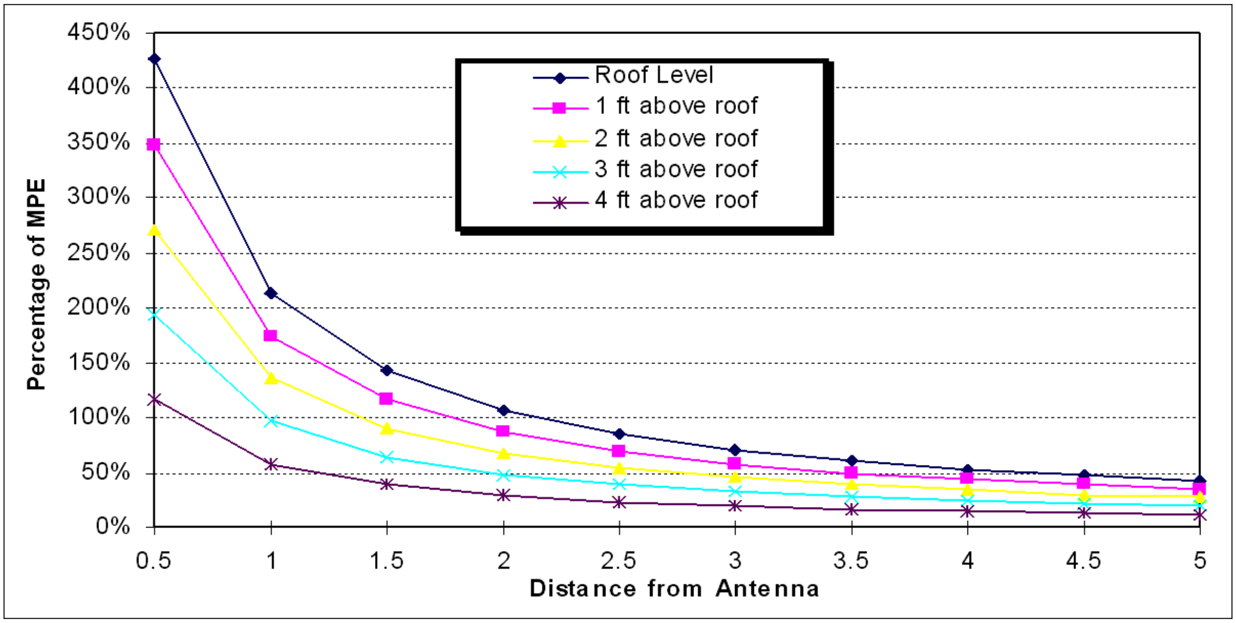


FIGURE E-8 EXPOSURE VS. ANTENNA HEIGHT ABOVE ROOF

The resultant exposure possible can be above the MPE when the antenna is mounted at the roof level. From the chart, fields in excess of 200% of the Occupational/Controlled MPE are encountered within 30.5 cm (1 ft.) of the antenna. While this seems extremely close, a technician walking down the center of an antenna grid with 1.2 m (4 ft.) centers will be 61 cm (2 ft.) from any antenna at any time. At a distance of 61 cm (2 ft.) from this antenna mounted at roof level, it is possible for the exposure to be over 100% of the same MPE. If this situation is compounded with several antennas having the same power density, the levels in this walking area could be above the MPE. For this reason every effort should be given to reducing the fields at the roof level. The most effective technique for reducing the fields on a building, while maintaining constant radiated power, is raising the antenna. Raising the antenna 1.2 m (4 ft.) above the roof reduces the EME field strength at the roof level to about 50% of the MPE at 30.5 cm (1 ft.) from where the antenna was. If the antenna is raised 1.8 m (6 ft.) above the roof the fields are reduced more than 90%.

The most effective technique for reducing EME levels is elevating antennas on buildings and extending antennas away from the tower.

E.3.2 EXTENDING ANTENNAS AWAY FROM TOWERS

Tower contractors climbing the tower must pass through fields created by active antennas on the tower. Antennas mounted on short sidearms or mounted directly to the tower produce high levels of exposure to tower climbers. It is a good engineering practice to mount omnidirectional antennas a minimum of 1.52 m (5 ft.) from the tower.

E.3.3 COLLOCATED BROADCAST TRANSMITTERS

Areas with broadcast transmitters can have fields created by grating lobes from the antenna or fields developed directly by the main radiating beam. On broadcast-only sites these are the only field that must be considered in EME analysis. On collocated sites, the EME fields are a combination of the fields generated by two-way transmitters and broadcast stations. If the exposure from each contributor is considered independently and then added, the total MPE situation can be evaluated. The fields from the broadcast transmitter act like a blanket covering the area. If the fields from a preexisting broadcast station create a level of 15% Occupational/Controlled MPE there is only 85% of the MPE budget remaining. This requires the levels from the two-way transmitters to be lower than what otherwise would be required to maintain compliance. In some conditions extra cooperation between the broadcasters and two-way licensees may be necessary to ensure site compliance. In the areas that receive grating lobes from the broadcast transmitters, careful measurements must be done before compliance can be analyzed.

Consideration must be given to anyone working on antenna systems. If a person must climb into the fields of the broadcast antenna, coordination ahead of time must be done to reduce the transmitter power. Special consideration and care **shall** be utilized when a person is required to climb through a field known to exceed 100% Occupational/ Controlled MPE. On some sites the broadcast towers are mounted adjacent to the two-way tower. In this situation the fields from the broadcast transmitter will be very intense on the two-way tower. Maintenance activities must be coordinated when the broadcast station is collocated. The FCC requires broadcasters to cooperate during maintenance situations; however, they may elect special times to conduct maintenance.

E.3.4 LOCATION OF DIRECTIONAL ANTENNAS

Directional antennas in the horizontal plane present a focused pattern for maximum coverage into a specific area. Even in the near field the levels in the beam of the antenna can be significantly higher than behind or on either side. Consideration must be given to the area and location the antenna is directed. Directional high-powered transmitting antennas should be located where the energy in excess of the Occupation/Control MPE is directed away from any area frequented by workers. Additionally directional antennas **shall not** be installed where they can produce fields higher than the General Population/Uncontrolled MPE in uncontrolled areas.

E.3.5 ANTENNA SELECTION

Antenna selection is important because it is directly linked to EME levels. The requirement for more antennas within a given horizontal space has created new designs of antennas. Within one radome several antennas can now be stacked on top of each other. The standard configurations are double (two), triple (three) and Quad (four) co-linear arrays. Aperture length directly affects the power density created. In the near field, a 4.6 m (15 ft.) antenna driven with 500 Watts will have one-third the power density of an antenna 1.52 m (5 ft.) long. Remember that near the antenna, the power density is related to the surface area of a cylinder placed over the antenna. A cylinder having one-third the height will have one-third the surface area and, hence will result in three times the power density. This is complicated even more when the 1.52 m (5 ft.) antenna is placed with other antennas in a common radome. This allows the power density, created by each antenna, to combine and increase the potential exposure of an individual. The technique of using triple and quad antennas is becoming increasingly popular as the space on hilltops and towers becomes scarcer. Paging transmitters, sectored antenna systems, and digital networks represent only a few of the services requiring individual antennas. There is a finite antenna density that can be accomplished within a given area. Creative methods of combining or increasing the antenna structures must be developed. Consideration should be given to connecting lower power transmitters to the bottom portion of triple and quad radome antennas.

E.3.6 MOUNTING DENSITY OF ANTENNAS

While the RF fields from one antenna may be below the MPE allowed, the combination of fields from several antennas can produce levels exceeding the Occupation/Control MPE. This can be easily seen in Figure E-9 and Figure E-10 which show the fields produced by one antenna and the fields produced by five antennas mounted at roof level with all transmitters keyed simultaneously.

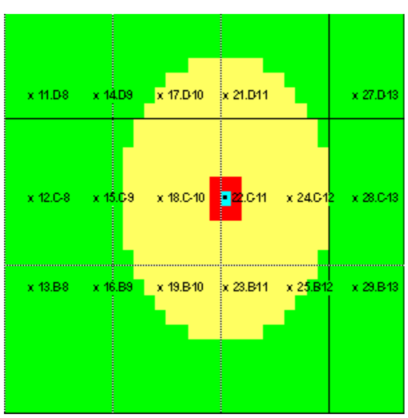


FIGURE E-9 COMPOSITE RF FIELDS WITH ONE ANTENNA TRANSMITTING

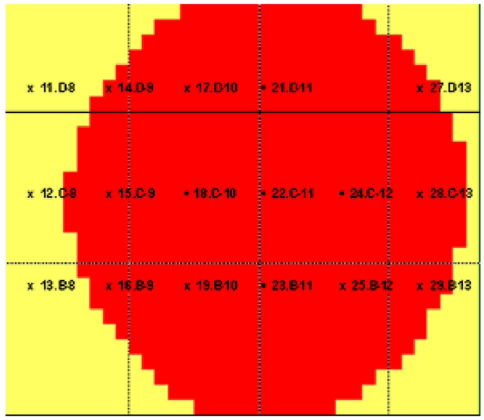


FIGURE E-10 COMPOSITE RF FIELDS WITH FIVE ANTENNAS TRANSMITTING

The combined fields produce levels exceeding the MPE allowed in all areas surrounding the antennas. In these situations, some means of controlling exposure must be used. These techniques may include RF protective clothing, re-engineering the antenna system, or power shutdown or reduction when working in the area. While power shutdown or reduction may appear to be an effective technique, either may be impractical for wireless communications services. It is normally reserved for broadcast transmitters. One preferred method of addressing this is to elevate the antennas above the roof area.

E.3.7 UPTIME

Complex antenna sites have a "personality" that makes them unique. The personality of the site is not only determined by the RF power, frequency, and manufacturer of the equipment, but by the operational characteristics. The RF level and frequency can be determined by understanding the equipment specifications, but operational characteristics can only be quantified by monitoring the usage. Because of the high number of pagers, paging transmitters will have a very high transmitter duty cycle. Trunking (SMR) transmitter activity will depend on customer loading density. This can range from transmitters rarely transmitting, to transmitters rarely not transmitting. Private customer equipment will have a very diverse usage characteristic that can not be predicted. The important point in understanding the characteristics of different services is that they can seldom be predicted.

Additionally, characteristics for transmitters will change due to cultural elements. Transmitters located in Las Vegas will have considerably different uptime characteristics than transmitters located in San Antonio, Texas or New York City. Tests have shown that a site will vary significantly from one time period to another. Sample measurements on a roof of a large building showed a variation in transmitter activity of over 30% between 11:00 a.m. and 2:00 p.m.

Uptime relates to all of the transmitter activity of a site. Uptime can seldom be predicted or characterized precisely, and thus usually must be measured. The amount of Uptime directly affects the EME exposure levels on a site.

In the consideration of site activity, there is an upper level of 100% uptime, or when all transmitters are keyed and actually energized. Actual usage would be the most accurate consideration, but least practical to implement. Actual usage varies greatly over time and antenna. Each antenna has an uptime characteristic based on density of combining, transmitter usage, and activity.

While the use of Uptime could provide a better approach to predicting the actual levels that could be encountered, it proves to be impractical. Determining the Uptime characteristics can be very complex and change with time. Only by constantly monitoring and adjusting the model can uptime be used. Uptime cannot be theoretically calculated, it must be measured. Measurement of uptime involves high speed scanning of frequencies over a long period of time. Only after thousands of activity observations taken over days of monitoring will the worst case, actual, and instantaneous uptime be understood. This complex procedure creates uncertainty. Practically, the uptime that should be used in the analysis of complex sites usually is 100% or total uptime.

E.3.8 ANTENNA SITE DOCUMENTATION

Any evaluation is only as accurate as the data used to make the evaluation. Antenna site documentation is important and **shall** be done in a standardized manner. For the analysis of EME fields, there are two methods of documentation. One proves to be considerably more exact but both allow an engineer to understand the EME situation and apply the proper compliance procedures, if necessary.

E.3.8.1 ACTUAL DOCUMENTATION

Actual documentation provides an accurate picture of the site situation. Actual documentation can be used by engineers for purposes other than EME analysis. Proper documentation requires a detailed description of transmitters, cable, antennas, and location on the tower. Specifically, the following information is required:

- Transmitter frequency by antenna mount
- Power out of transmitter
- Network loss between transmitter and antenna
- Antenna characteristics and specifications
- Antenna location and standoff
- Uptime characteristics
- Areas frequented by personnel
- Layout of antenna field (roof or tower)

E.3.8.2 CATEGORIZATION DOCUMENTATION

Determining which transmitter is connected to which antenna on a site via which coaxial cable can be very expensive and in many cases is not necessary. Categorization documentation evolves determining the lowest loss coax and the highest-powered transmitter in any particular band. It is then assumed that all antennas for that band have this combination attached. By understanding the frequency, spacing, height and antenna characteristics of all antennas on the tower an approximation of the worst case EME situation can be determined. If this preliminary investigation proves to be compliant, then the actual situation will be compliant. Thus, this worst case scenario evaluation will assist in determining if a more detailed evaluation is required. This method of EME analysis requires a trained site auditor to only determine the components affecting EME compliance. This procedure will not provide the exact levels of the fields, but can be used to determine sites that require additional investigation using actual documentation.

Understanding the EME environment for a given site requires that an inventory of all generators of RF energy and the EME exposure potential be maintained for all facilities. This requires standardized documentation practices and regular updating.

E.4 WORK PRACTICES

The way an antenna site is managed, controlled, and operated directly relates to the quality of the site. All of the customers on a site not only have physical investments, but also rely on uninterrupted service. The requirements placed on all contractors, customers, and employees determine the quality of a site.

E.4.1 TRAINING AND QUALIFICATION VERIFICATION

A very specific part of worker contracting is verification of qualification and training. All contractors **shall** have a basic understanding of EME awareness and show an understanding of site standards. All contractors are expected to be experts in their field and to be fully aware of changes in governmental regulations. Without regular training a contractor cannot expect to be fully aware of changing hardware, technology, and government regulations.

E.4.2 PHYSICAL ACCESS CONTROL

Antenna sites must have physical access control. The minimum requirement is locked gates to prevent vehicular access, and locks on the facility. In most situations towers should have specific access control. Access to the site **shall not** allow access to the tower. Tower climbing prevention **shall** be accomplished with fencing around the tower, climb prevention on the tower, or locking barriers on the tower. Unauthorized climbing must be prevented to ensure individuals climbing a tower understands the EME situation, are qualified, and possess the correct climbing equipment. The facility should be equipped with card access, where appropriate, to provide a direct history of traffic at the site. Card access will provide specific information on who comes and goes from the site.

E.4.3 POLICING

Any policy controlling site administration must be enforced before compliance can be assured. Every effort **shall** be given to ensuring all contractors understand, comply and support the policies of the site. Violation of policy **shall** be grounds for disqualification of a contractor. It is a privilege to work on a site and the policies must be followed.

E.4.4 CHAIN OF AUTHORITY AND REPORTING REQUIREMENTS

There should be site books or a site folder located at each facility. These documents will outline the policies and procedures for the site including a contact roster for emergencies and notifications. Additionally, any specific site situations or policies can also be contained in the site book.

E.4.5 UNDERSTANDING SITE RESPONSIBILITIES UNDER SHARED CONDITIONS

There are situations where occupancy and management of a site involves other agencies or entities. This may be a situation where a site is located on a building, collocated with broadcast companies, shared hilltop, etc. In each of these situations, others can make decisions that can affect the safety and operation of the site. Every effort should be given to developing consolidated procedures that require the compliance of all parties. This protects their interests and safety as well as contractors and employees using the site. Control measures **shall** be coordinated to allow safe tower maintenance. When other transmitters are involved, power reduction, lock-out/tag-out, or restricted time for maintenance may have to be used to assure RF exposure is controlled.

E.4.6 GENERAL PROCEDURES

General procedures relate to normal practices that are common to all sites. These can be found posted at all sites on the “Guidelines for working in radio frequency environments” placard. These guidelines are:

- **All personnel shall have electromagnetic energy (EME) awareness training**

  All workers entering a RF controlled area **shall** understand their potential exposure and steps they can take to reduce their EME exposure. Awareness is a requirement of all workers. This includes not only field engineers, maintenance technicians and site designers, but also others such as site acquisition personnel, building management, and service oriented personnel (such as electrical, telephone, elevator and air conditioning mechanics as well as roof repair, painting and window washing crews). The FCC report and Order specifically indicates the requirement to make personnel at a transmitter site “fully aware” of their risk of exposure. Awareness training increases worker sensitivity to potential exposure, thereby assisting proper compliance regarding exposure limits. Awareness can be given in different formats, some may be video, formal classroom, and informal discussions.

- **All personnel entering this site must be authorized**

  Only personnel who have been trained and understand the EME situation and other safety requirements associated with site work shall be allowed access without escorts. When untrained individuals access the sites, trained escorts are required.

- **Obey all posted signs**

  This guideline emphasizes the importance of observing and understanding the instructions on posted signs at the transmitter site. All safety signs play an important role in any safety program and just as any of these signs convey a specific message related directly to safe work in a particular environment, postings at transmitter sites are no different. For example, certain areas may be designated “NO ACCESS” unless certain antennas are shut down. It is important that these signs be understood and obeyed, to assure EME exposure below the FCC guidelines. The requirement for RF protective clothing for workers is another precaution that could be identified on signs designating areas of potential exposure in excess of FCC limits.

- **Assume all antennas are active**

  Because most telecommunications transmissions are intermittent, the status of many transmitters that may be operating at a particular site will be unknown. It is important to assume that all antennas may be energized and to maintain a safe working distance from each of them. Only with special instruments to detect the presence of RF energy can it be determined a particular antenna is not energized at any given moment. While EME measurement surveys may have been performed on the site, these surveys do not assure that a specific antenna is not active at a given time.

- **Before working on antennas, notify owners and disable appropriate transmitters**

  Before working on an antenna, workers must ensure that all attached transmitters are deactivated. Most antennas at a transmitter site are being used for important communications. They may be used for emergency and safety purposes like fire protection, rescue dispatch and police communications. Although all attached transmitters must be turned off before touching and working on an antenna, in any case touching or working on an antenna **shall not** be attempted before contacting the owners or operators. Coordinating with the individuals responsible for use of the transmitter will make sure that turning off the equipment will not cause a serious disruption of the service. Sometimes, this coordination may mean that the work will have to be performed at night or in the early hours of the morning. Lockout/Tagout tags should be used to make sure someone else does not inadvertently turn on the transmitter while work on the antenna is being performed.

- **Maintain minimum 92 cm (3 ft.) clearance from all antennas**

  Studies have shown that the EME fields close to two-way radio transmitting antennas can be strong enough to exceed the limits specified by the FCC guidelines. A 92 cm (3 ft.) clearance is a practical approach to assure that exposure remains within FCC limits. This ensures a distance is always maintained unless work is required on an antenna. Work on a **specific** antenna **shall only** be accomplished after the attached transmitters have been turned off. A small increase in distance from an antenna can have a substantial effect on reducing the EME exposure. This is particularly important when working near other active antennas. This also applies when doing work on roof or tower mounted equipment like air conditioners, tower lights or window washing rigs.

- **Do not stop in front of antennas**

  When moving about at the transmitter site workers **shall** avoid stopping near any antenna; they should continue on until they reach an area that is removed from their immediate vicinity. If they are going to take a break from work, or have lunch, they should select a place on the roof that will provide as much distance between them and the nearest antennas as practical. When climbing a tower, workers should select rest points away from antennas. Workers should always try to keep below or behind antennas to minimize their exposure to the main beam of the antenna. By continuing to move past high EME fields the average exposure will be minimized.

- **Use personal RF monitors while working near antennas**

  Special care must be exercised when working on or very near antennas. Although the EME fields cannot be sensed directly, transmitter activity can be detected close to an antenna with a personal RF monitor. Wearing such a monitor will allow workers to ensure that all connected transmitters have been turned off before they begin maintenance. As they approach an antenna, if the monitor alarms, they **shall** get away from the antenna, determine which transmitters are still on and disable them.

- **Never operate transmitters without shields during normal operation**

  Some work at antenna sites involves troubleshooting and repair of the radio transmitters. The shields within transmitter power amplifiers are there to prevent strong RF fields from radiating out of the transmitter cabinet. Operating the transmitter without shields could cause interference and exposure of the technician performing the service to EME levels in excess of the FCC guidelines. While shields must be removed for many maintenance tasks, they **shall** always be properly reinstalled before returning the transmitter to normal operation.

- **Do not operate base station antennas in equipment room**

  At any time, transmitting antennas **shall not** be operated inside the equipment rooms, even for short term testing. This includes mobile magnet mount antennas attached to the top of transmitter cabinets as temporary installations. Using transmit antennas inside equipment rooms can increase the exposure to EME levels above FCC guidelines and create undesirable radio frequency interference.

E.4.7 SITE SPECIFIC PROCEDURES

Site specific procedures that are unique to a particular site may need to be available to assure compliance to the FCC Guidelines. These can include:

- Special access
- Potential high EME exposure situations
- Special maintenance procedures for antenna repair
- Maintenance procedures unique to the site
- Special security procedures
- Special reporting procedures related to other tenants and owners

E.4.8 OPERATING PROCEDURES

The conduct of contractors should be controlled and coordinated by the antenna site manager. All contractors, whether customer controlled or contracted directly with the management, must follow specific procedures. These procedures relate to safe operations that will be followed during installation and maintenance of antenna systems. Site procedures will prevail over contractor accepted practices and standards. Contractors must follow the guidelines for the site.

E.5 SIGNAGE

Various signs may be required on antenna sites. The minimum requirement is to post an EME caution and/or warning signs, as appropriate, wherever EME levels can exceed those associated with a green zone. This sign **shall** be posted in a location that can be easily viewed by individuals that enter the areas of concern. Some areas that may be effected are building tops, towers, areas around broadcast, etc. This assures notice and understanding that the area has active RF transmitters. The sign **shall** conform to the ANSI standards.

Posting of signs provides a convenient method to convey to individuals important information. While signs can be effective if used properly, they can convey the wrong message and create undue alarm if used incorrectly. For this reason different signs are recommended for specific applications. These signs represent the best methodology available in conveying important information.

The standards used in creating these signs are:

Signal word- This word designates the degree of safety alerting, e.g. Warning, Caution, and Notice.

Symbol - The advisory symbol for identifying incident electromagnetic energy consists of black wavefronts radiating from a stylized point source. This symbol is defined in NEMA/ANSI Z535.3-1991.

Text Message - The text message **shall** convey three things:

- What the safety issue is
- What action should be considered
- What authority the issue is based upon

These are used to designate the possible issues that can be encountered at an antenna site. These signs have specific implementation guidelines as outlined below. Improper implementation could result in inaccurate information being conveyed or unnecessary alarm being created.

Examples of signs that have been implemented in the United States are shown below.

- **Site Guidelines**

  The site guidelines are posted inside the equipment room to make all workers aware of the normal requirements for site operation. The major intent is to ensure that compliance is maintained at the site. Having the sign visually available informs and reminds all personnel and others who have proper access of the rules for the site. This also qualifies as awareness information.

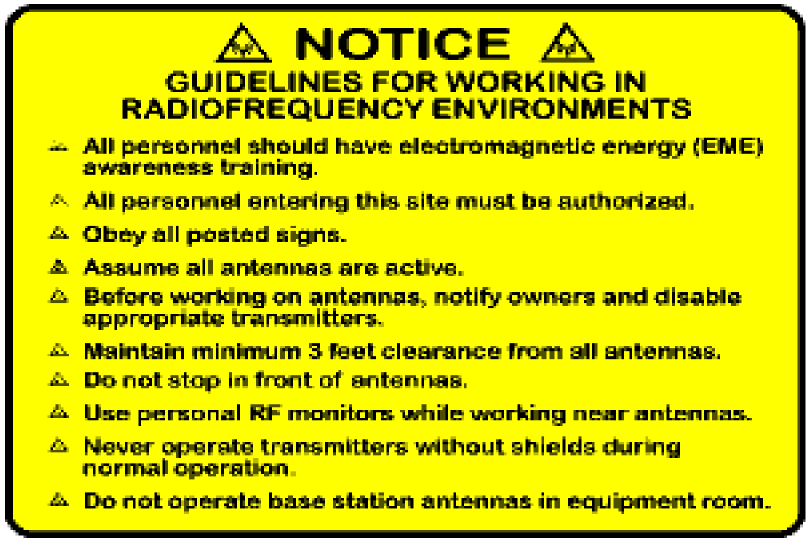


FIGURE E-11 SITE GUIDELINES PLACARD

- **Notice**

  The notice sign is used to distinguish the boundary between the General Population/Uncontrolled and the Occupational/Controlled areas. This boundary will usually be the fence for the property, gate entrance, or roof door to the equipment room. The limits associated with this notification must be less than the Occupational/Controlled MPE. All sites have standard guidelines posted that must be obeyed and understood by all workers. These guidelines will ensure the area is maintained below Occupational/Controlled MPE. EME awareness training is recommended for all workers.

FIGURE E-12 NOTICE SIGN

- **Caution**

  The caution sign identifies RF controlled areas where RF exposure can exceed the Occupational/Controlled MPE. Generic guidelines apply in all situations and will be posted at all sites; however, site specific guidelines may be associated with some areas to ensure work is always performed in compliance with the FCC guidelines. Such site specific guidelines may require reduction of RF power before work begins or the use of RF protective clothing. In all cases workers **shall not** enter and work in these areas without understanding and obeying the necessary procedures. All authorized workers for RF controlled areas must have EME awareness training.

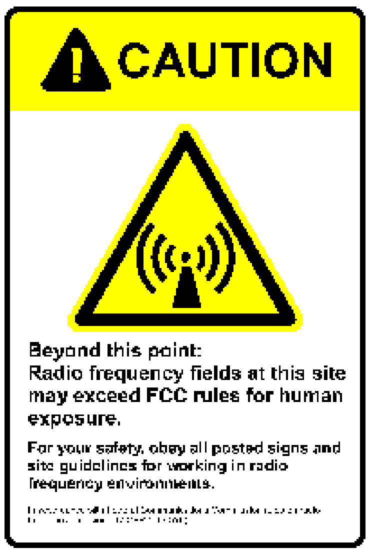


FIGURE E-13 CAUTION SIGN

- **Warning**

  The warning sign denotes the boundary of areas with RF levels substantially above the FCC limits, normally defined as those greater than ten (10) times the Occupational/Controlled MPE.

  Telecommunication contractors and employees **shall not** enter these areas unless special procedures are followed. These situations typically are associated with broadcast transmitters operating at high power. If work is required in these areas, the broadcast transmitter must be shut down for the duration of the maintenance. Engineering evaluation must be performed to determine the proper special procedures required before this area can be entered.

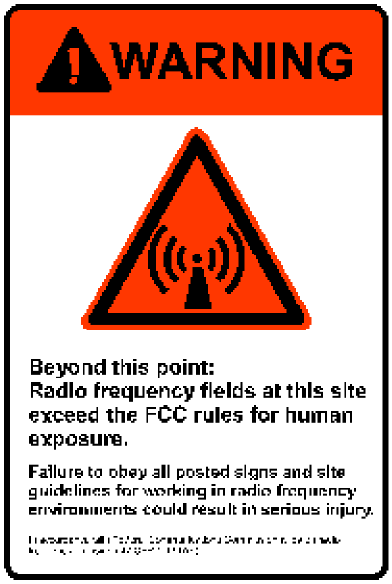


FIGURE E-14 WARNING SIGN

E.6 PERSONAL PROTECTIVE EQUIPMENT (PPE)

E.6.1 PROTECTIVE CLOTHING

There may be situations where field analysis shows areas that are not in compliance with the Occupational/Controlled MPE. After all options are considered and if the situation cannot be controlled with engineering or work practice solutions, implementation of Personal Protective Equipment (PPE) may be the only solution. An example of this type of situation may be a rooftop that has collocated broadcast in the vicinity of a heavily congested antenna field. In certain situations where building architectural concerns are a priority there may be no simple solution available to reduce the fields. The only solution may be the use of RF protective clothing as a means to reduce EME exposure.

RF protective clothing was introduced into the United States several years ago by a German manufacturer (NSP)[1] and sold under the name Naptex™. The suit consists of work coveralls with an integral hood for head protection. The suit is constructed of a polyester yarn, which is wound coaxially around stainless steel fibers. This provides uniform consistency of material and attenuating metal. Tests[2,3] have shown that the suit can effectively provide between 10 dB and 12 dB of reduction in EME absorption within the body at virtually any frequency over the telecommunications spectrum. This would indicate that use of the suit could compensate for exposure to EME fields as great as 1000% above the FCC Occupational/Controlled MPE values. Additional testing has shown the use of the suit without the hood in fields under 300% of the Occupational/Controlled MPE values at 900 MHz provides compliance with the peak SAR limits of 8 W/kg. The acceptable levels that the hoodless suit can be safely used increase as the frequency is reduced. Contractors **shall** be notified if RF Protective Clothing or the hood is required for compliance.

E.6.2 PERSONAL MONITORS

Work on specific antennas **shall only** be accomplished after the appropriate transmitters have been turned off and locked out. This prevents anyone from accidentally activating the transmitters while others are performing maintenance. However, with the large number of transmitters combined into single antennas it becomes considerably more difficult to confirm that all transmitters are deactivated. The ideal method would be to have a RF light on the top of the antenna. The light would be off to confirm that there was no RF activity. A more practical approach would be to use a personal monitor. A personal monitor is an RF threshold detector that alarms when RF exceeds the threshold of the device, normally 50% Occupational/ Controlled MPE. These devices are designed to detect a wide range of frequencies and can be used in most environments. When approaching an antenna that requires maintenance, the monitor **shall** be placed near the antenna for a period of time, about 30 seconds should suffice. If the antenna is still active the monitor will alarm. This will show that there are still transmitters active, or if an alarm does not sounds, will confirm that all transmitters were deactivated. This provides a positive confirmation and allows the worker to ensure they are working on inactive antennas.

Some manufactures of personal monitors propose they can be worn to indicate compliance. This use should be considered carefully because, when the device is used in accordance with its instructions, compliance is only confirmed at the location of the monitor. If, for example, the monitor is worn on the belt of a tower climber, the possibility of entering high fields without the monitor being activated exists. When climbing the head and shoulders can enter high fields without the monitor mounted on the belt alarming. This could provide a false indication of safety.

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1. See NSP World Wide Web site: www.nspworldwide.com
2. Tell, R. A. (1995). *Engineering Services for Measurement and Analysis of Radio frequency (RF) Fields*. Technical report for the Federal Communication Commission, Office of Engineering and Technology, Washington, DC, FCC/OET RTA 95-01 [NTIS order no. PB95-253829].
3. Tell, R. A. (1996). *SAR Evaluation of the Naptex suit for use in VHF and UHF bands*. Presented at the International RF Safety Workshop, Schwangau, Germany, September 25-26.

E.7 EME ACTION THRESHOLDS SUMMARY

As a summary, Figure E-15 describes the actions needed to be taken at the various EME thresholds.

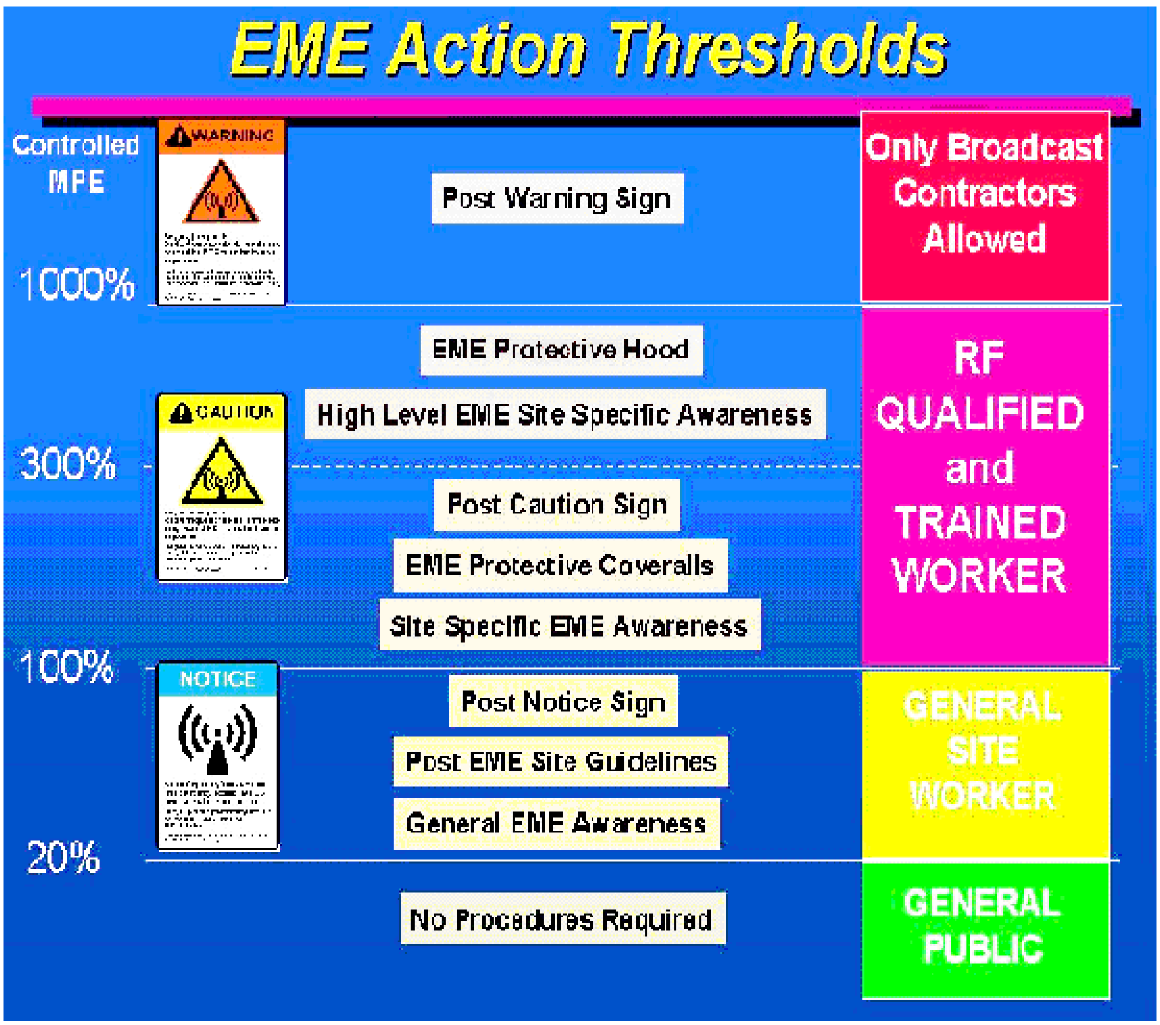

FIGURE E-15 EME ACTION THRESHOLDS

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R56 COMPLIANCE AUDIT

F.1 PURPOSE

The purpose of the R56 compliance audit is to provide an audit form based on the Motorola Standards and Guidelines for Communication Sites manual (R56) requirements, to ensure the overall performance of individuals and contractors performing or supervising installations.

F.2 SCOPE

It is the Motorola policy that all contracted installations shall either conform to or exceed the minimum guidelines established in the “Motorola Standards and Guidelines for Communication Sites” manual (R56). As new equipment is developed and requirements are strengthened, the installation procedures are updated in an effort to provide the customer with a fault-free communication system. These checklists will enable management personnel to better understand deficiencies associated with the installation affording them the opportunity to take corrective action.

Motorola provides this audit and the opinions solely for the purpose of assisting in the compliance to Motorola installation standards. No opinions or recommendations expressed in this audit shall result in liability to Motorola for any losses, damages, expenses, claims, causes of action incurred or sustained by the customer for any reasons whatsoever. Any work resulting from this audit process involving electrical systems, panels, automatic transfer switches, conduits or outlets must be completed by a suitably qualified and licensed electrician. All work must be performed by properly trained, licensed and qualified contractors.

F.3 AUDIT CHECKLIST PROCEDURES

This paragraph provides an overview of the procedures for use with the R56 Compliance Audit form. The audit form should be used as a guide to ensure compliance with the Motorola Standards and Guidelines for Communications Sites (R56) manual. The purpose of the audit is to identify and help resolve Motorola or customer deficiencies prior to releasing the subcontractors. One audit form set will be generated for each site in the system. A copy of the final audit **shall** be kept with the project file for future reference.

F.3.1 PREREQUISITES

- Based on our contractual obligations (scope of work) with the customer, any requirements that are not specified as a Motorola responsibility will automatically be considered as a customer responsibility.
- If one or more items within a group of items, which are being inspected, do not meet the auditing requirements for the specific audit point, then that audit point must show failed.

F.3.2 INSTRUCTIONS FOR R56 COMPLIANCE AUDIT COVER SHEET

Page F-5 is a cover sheet used to summarize audit results. The cover sheet, and a copy of the completed audit form, **shall** be supplied to the Project Manager when the site audit has been completed. It is the responsibility of the Project Manager to address any reported deficiencies with the appropriate parties and obtain resolution that is acceptable to Motorola and the customer.

1. At the top of page F-5, fill in the required information for the audited site. After this is completed, proceed to the site/system description.

2. **Site / System Description**

   In this area, write a brief description of the system. Describe the installed components and list the party responsible for their installation. Also supply the names of the site owner/manager and the prime user of the equipment. After this is completed, proceed to the specific deficiencies/reasons.

   Example:

   This system is an 800 MHz SmartZone™ Voice Trunking System with five voice channels. The control center has Centracom Gold Elite™ Consoles. The trunked equipment was installed by YYYYY, Inc. The grounding was Motorola's responsibility and was subcontracted to ZZZZZ Electric Co. The buildings at the site are of modular construction purchased from SSSSSSS. The site is owned and managed by ZXZXZXZX. The prime user of the equipment is XYZ Properties.

3. **Specific Deficiencies / Reasons**

   In this area, identify and explain any specific deficiencies that were observed at the site. After this is completed, proceed to the explanation of N/A entries.

   Example:

   2.b: Cable runway system does not meet ceiling separation requirements. A separation of 10 cm (4 in.) was measured.

4. **Explanation of N/A Entries**

   In this area, identify and explain any not applicable (N/A) audit points that were identified. After this is completed, send the cover sheet and a copy of the R56 Compliance Audit to the Project Manager.

   Example:

   3.o.15: There are no security bars or metallic window frames at this location.

F.3.3 R56 COMPLIANCE AUDIT

The R56 Compliance Audit starts on page F-7. Begin by filling in all the required information at the top of the page. Once this has been completed, proceed with the audit.

The Reference column on the audit form provides references to the applicable Motorola requirements within the “Motorola Standards and Guidelines for Communication Sites” (R56) manual.

The remainder of the audit is divided into five separate segments for marking as follows:

1. **Motorola Responsibility**

   - **Passed** - Based on our contractual obligations with the customer, if Motorola or its subcontractor is responsible for performing a procedure and it meets or exceeds the R56 installation requirements for the audit point, place an "X" in this column.
   - **Failed** - Based on our contractual obligations with the customer, if Motorola or its subcontractor is responsible for performing a procedure and it does not meet the R56 installation requirements for the audit point, place a "X" in this column.

2. **Customer Responsibility**

   - **Passed** - Based on our contractual obligations with the customer, if Motorola or its subcontractor is not responsible for performing a procedure and it meets or exceeds the R56 installation requirements for the audit point, place an "X" in this column.
   - **Failed** - Based on our contractual obligations with the customer, if Motorola or its subcontractor is not responsible for performing a procedure and it does not meet the R56 installation requirements for the audit point, place an "X" in this column.

3. **N/A**

   - This column is used to denote a not applicable (N/A) audit point. If for any reason an "X" cannot be placed in either the Motorola or Customer Responsibility columns, the audit point should be considered as N/A and an "X" should be placed in this column.
   - Specific installation audit points cannot, and should not, be ignored. For this reason, all N/A audit points must be identified and explained on the audit cover sheet (page F-5).

4. **Motorola Failure Date Corrected**

   - If Motorola or its sub-contractor receives a failing mark for the R56 installation requirement, this column will be left blank for a future correction date.
   - If Motorola or its subcontractor receives a passing mark for the R56 installation requirement, place an "X" in this column since no correction date is necessary.
   - If Motorola or its subcontractor is not responsible for the R56 installation requirement, place an "X" in this column since no correction date is necessary.

5. **Customer Failure Date Corrected**

   - If the customer received a failing mark for the R56 installation requirement, this column will be left blank for a future correction date.
   - If the customer receives a passing mark for the R56 installation requirement, place an "X" in this column since no correction date is necessary.
   - If customer is not responsible for the R56 installation requirement, place an "X" in this column since no correction date is necessary.

R56 Compliance Audit Cover Sheet

Customer Name:____

Equipment Location: ____

Inspector's Name ____

Inspection Results: Motorola_____% Customer:______% Date:______________

Site/system Description:

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Specific Deficiencies/reasons:

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Explanation of N/A Entries:

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R56 Compliance Audit

Customer Name:	**Project Name:**
Project Manager:	**Project #:**
Inspector's Name:	**Audit Date:**
Site Name:	

	DESCRIPTION	**Motorola Responsibility**		**Customer Responsibility**			Motorola Failure	Customer Failure	Reference
		Passed	Failed	Passed	Failed	N/A	Date Corrected	Date Corrected	
1	**GENERAL**								
a.	A copy of the Project Manager's Compliance Sheet has been completed, certified and supplied for attachment to this audit.								
b.	Project Manager's Compliance Sheet shows that all appropriate requirements have been met.								
	TOTALS FOR SECTION								
2	**BUILDING DESIGN AND INSTALLATION**								
a.	The ceiling height is sufficient to meet requirements for equipment installation.								Paragraph 5.6.1
b.	Cable runway system meets the proper installation requirements.								Paragraph 5.10
c.	The floor is sealed as required.								Paragraph 5.6.2
d.	Transmission line entry ports, holes or openings which penetrate the outer surface of the building have been properly sealed.								Paragraph 5.7
e.	Adequate lighting requirements have been met.								Paragraph 5.11
f.	Minimum required fire suppression equipment is properly installed.								Paragraph 5.12
g.	A first aid kit is available and meets requirements.								Paragraph 5.12.6.1
h.	Required personal protective safety items are available for servicing batteries which require such items.								Paragraph 5.12.6.2
i.	A telephone, microwave link, or cellular phone has been made available.								Paragraph 5.12.8
j.	Phone numbers of importance are posted at the site.								Paragraph 5.12.8
k.	The minimum required signage is posted at the site.								Paragraph 5.13
	TOTALS FOR SECTION								

R56 Compliance Audit

	DESCRIPTION	Motorola Responsibility		Customer Responsibility			Motorola Failure	Customer Failure	Reference
		Passed	Failed	Passed	Failed	N/A	Date Corrected	Date Corrected	
3	**EXTERNAL GROUNDING**								
a.	An External Ground Bus bar (EGB) of suitably sized material is properly installed at the transmission line entry point.								Paragraph 6.3.3
b.	The EGB grounding electrode conductor has been properly installed.								Paragraph 6.3.3
c.	When a tower ground bus bar (TGB) is used, it meets the proper installation and bonding requirements.								Paragraph 6.3.4
d.	Each transmission line outer shield is properly bonded to the tower or TGB at the transition of the vertical transmission line run with a weather sealed transmission line grounding kit.								Paragraph 6.4.6
e.	Each transmission line outer shield is properly bonded to the EGB with a weather sealed transmission line grounding kit.								Paragraph 6.4.6
f.	The tower is properly bonded with the required number of B48grounding conductors.								Paragraph 6.4.5
g.	Ice bridges / cable supports have been properly bonded to the EGB.								Paragraph 6.4.3
h.	Each ice bridge / cable support post has been properly bonded to the grounding electrode system.								Paragraph 6.4.3
i.	Ice bridges / cable supports have been properly isolated from the tower.								Paragraph 6.4.3
j.	Guy wires are properly bonded and their grounding conductor maintains a continuous vertical drop to the grounding electrode.								Paragraph 6.4.5
k.	Fencing has been properly bonded to a ground system as required.								Paragraph 6.4.2
l.	Each fence gate is properly bonded to its supporting fence post as required.								Paragraph 6.4.2
m.	Gate supporting fence posts are properly bonded as required.								Paragraph 6.4.2
n.	Generator and support skids have been properly bonded as required.								Paragraph 6.4.1
o.	Items listed below are properly bonded to the grounding electrode system as required.								Paragraph 6.4.1
o.1	Metallic entry ports								Paragraph 6.4.1

R56 Compliance Audit

	DESCRIPTION	Motorola Responsibility		Customer Responsibility			Motorola Failure	Customer Failure	Reference
		Passed	Failed	Passed	Failed	N/A	Date Corrected	Date Corrected	
o.2	Cable conduits or raceways								Paragraph 6.4.1
o.3	Metallic piping (water, gas, electrical conduits, etc.)								Paragraph 6.4.1
o.4	Air conditioner units								Paragraph 6.4.1
o.5	Metal siding and/or roofing on buildings								Paragraph 6.4.1
o.6	Vent covers and grates								Paragraph 6.4.1
o.7	Metal fuel storage tanks (above or below ground)								Paragraph 6.4.1
o.8	Building skid or pier foundations								Paragraph 6.4.1
o.9	Anchors on prefabricated buildings								Paragraph 6.4.1
o.10	Metallic structures for antenna supports, light fixtures, etc.								Paragraph 6.4.1
o.11	Satellite dish supports								Paragraph 6.4.1
o.12	GPS antenna supports								Paragraph 6.4.1
o.13	Hand and safety rails								Paragraph 6.4.1
o.14	Ladders and safety cages								Paragraph 6.4.1
o.15	Security bars and window frames								Paragraph 6.4.1
o.16	Main electrical ground								Paragraph 6.4.1
o.17	Main telco ground								Paragraph 6.4.1
p.	Approved bonding techniques have been used for the connection of dissimilar metals.								Paragraph 6.5.2
q.	Approved methods have been used for conductor connection and termination.								Paragraph 6.5
r.	Bonding surfaces for lugs and clamps are free of paint and corrosion and a conductive anti-oxidant compound has been applied.								Paragraph 6.5
s.	All painted or galvanized bonding surfaces for exothermic welds were cleaned and painted to inhibit rusting.								Paragraph 6.5
t.	All grounding conductors have been routed towards the EGB, TGB or the grounding electrode system and the minimum bending radius has been observed.								Paragraph 6.3.2+K84
u.	Grounding conductors are routed as straight as possible and protected from physical damage as required.								Paragraph 6.3.2
v.	Grounding conductors maintain the minimum required separation from other cable groups.								Paragraph 6.3.2.3

R56 Compliance Audit

	DESCRIPTION	Motorola Responsibility Passed	Motorola Responsibility Failed	Customer Responsibility Passed	Customer Responsibility Failed	N/A	Motorola Failure Date Corrected	Customer Failure Date Corrected	Reference
w.	Grounding conductors are securely fastened as required.								Paragraph 6.4.9
x.	Grounding conductors meet or exceed the conductor size requirements.								Paragraph 6.3.2.3
y.	Braided grounding conductors are not used anywhere in the external ground system.								Paragraph 6.3.2.1
	TOTALS FOR SECTION								

4	**INTERNAL GROUNDING**								
a.	A properly sized Master Ground Bus Bar (MGB) is installed as required.								Paragraph 7.2
b.	The MGB grounding electrode conductor has been properly bonded and routed towards the grounding electrode system.								Paragraph 7.2
c.	All conductor connections to the MGB follow approved connection methods.								Paragraphs 7.4
d.	Where required a Sub System Ground Bus Bar (SSGB) has been properly installed.								Paragraph 7.2.2
e.	The SSGB has been bonded back to the MGB as required.								Paragraph 7.2.2
f.	All conductor connections to the SSGB follow the approved connection methods.								Paragraphs 7.4
g.	Where required an Internal Perimeter Ground Bus (IPGB) is properly installed.								Paragraph 7.3.2
h.	Only ancillary equipment is bonded to the IPGB.								Paragraph 7.3.5.3
i.	Each ancillary support apparatus is properly bonded to the IPGB, MGB, or SSGB.								Paragraph 7.3
j.	Items listed below are properly bonded to the MGB, SSGB, or IPGB using approved connection methods.								Paragraph 7.3.2
j.1	Piping systems								Paragraph 7.3.2.4
j.2	Steel roof trusses								Paragraph 7.3.2.4
j.3	Exposed support beams or columns								Paragraph 7.3.2.4
j.4	Ceiling grids								Paragraph 7.3.2.4
j.5	Raised equipment floor support structure at the proper intervals.								Paragraph 7.3.2.4
j.6	Any exposed metallic building materials (metal siding)								Paragraph 7.3.2.4

R56 Compliance Audit

	DESCRIPTION	Motorola Responsibility		Customer Responsibility			Motorola Failure	Customer Failure	Reference
		Passed	Failed	Passed	Failed	N/A	Date Corrected	Date Corrected	
k.	Surge Suppression Device (SPD) metal housings are bonded to the MGB, SSGB or IPGB as required.								Paragraph 7.3.5.8
l.	Separately derived AC electrical systems are bonded to the MGB or SSGB as required.								Paragraph 7.3
m.	Primary telephone, control, and data network circuit SPDs are properly installed and bonded to the MGB or SSGB as required.								Paragraph 7.3.5.6
n.	RF transmission line SPDs are bonded to the MGB or a separate equipment area SSGB as required.								Paragraph 7.3.5.5
o.	Cable runways are bonded to the MGB or SSGB as required.								Paragraph 7.3.3.4
p.	Each cable runway section is bonded to the adjoining section as required.								Paragraph 7.3.4
q.	Ground bus conductors and their extensions are sized as required.								Paragraph 7.3.1.2
r.	All ground bus conductors, ground bus extensions and equipment grounding conductors are routed towards the MGB or SSGB as required.								Paragraph 7.3.1
s.	Bonding connections to a ground bus or its extensions have been properly insulated as required.								Paragraph 7.3.1.3
t.	Cabinets have been properly bonded back to the MGB, SSGB or ground bus by approved methods.								Paragraph 7.2.2.4
u.	Racks have been properly bonded back to the MGB, SSGB or ground bus by approved methods.								Paragraph 7.2.2.4
v.	Any RGB located within a cabinet or rack is properly bonded back to the MGB, SSGB or ground bus as required.								Paragraph 7.2.2.4
w.	Individual system component chassis equipment is properly bonded as required.								Paragraph 7.2.2+K117.4
x.	Secondary telephone, control, and data network circuit SPDs are properly installed and bonded back to MGB or SSGB as required.								Paragraph 7.3.5.6
y.	All required control center and dispatch equipment is properly bonded back to the MGB, SSGB, or ground bus conductor as required.								Paragraph 7.6
	TOTALS FOR SECTION								

R56 Compliance Audit

DESCRIPTION		Motorola Responsibility		Customer Responsibility			Motorola Failure	Customer Failure	Reference
		Passed	Failed	Passed	Failed	N/A	Date Corrected	Date Corrected	
5	**POWER SOURCES**								
a.	Circuit breakers are labeled to identify the receptacle outlet they are protecting.								Paragraph 8.3.4
b.	Proper clearance requirements are being observed for power panels.								Paragraph 8.3.3
c.	Outlet boxes are permanently marked to identify their assigned circuit breakers and panels.								Paragraph 8.3.10
d.	Power receptacle outlets are mounted securely to the supporting structure.								Paragraph 8.3.9
e.	Adequate service receptacle outlets are provided for the technician.								Paragraph 8.2
f.	Each critical piece of equipment has a dedicated branch circuit and dedicated simplex receptacle.								Paragraph 8.3.10
g.	Power receptacles are installed by the equipment load as required.								Paragraph 8.3.10
h.	Extension cords including temporary outlet strips are **not** used in the final installation.								Paragraph 8.4
i.	Exterior receptacle outlets and circuits are GFCI protected as required.								Paragraph 8.3.5
j.	AC power receptacle outlets and strips are of the proper type and securely mounted as required.								Paragraph 8.4
k.	Appropriate clearance is being observed for safe servicing of UPS and battery banks.								Paragraph 8.6
l.	The neutral - ground bonding conductor has been properly installed in the main service disconnect as required.								Paragraph 8.3.7
m.	Equipment grounding conductors have been installed as required.								Paragraph 7.3.3
n.	Solar panels have been located away from objects that could damage or block sunlight to the panel.								Paragraph 8.7.2
o.	Proper mounting practices are being observed for solar panels or wind generators.								Paragraph 8.7.2
p.	Battery racks are bolted to the floor or wall.								Paragraph 8.8.8

R56 Compliance Audit

	DESCRIPTION	Motorola Responsibility Passed	Motorola Responsibility Failed	Customer Responsibility Passed	Customer Responsibility Failed	N/A	Motorola Failure Date Corrected	Customer Failure Date Corrected	Reference
q.	Battery conductors are enclosed in PVC, metallic conduit or raceways.								Paragraph 8.8.8
r.	A battery disconnect and suitable circuit protection device has been installed as required.								Paragraph 8.8.8
s.	When a standby power generator has been installed, it meets the proper installation requirements.								Paragraph 8.9.2
t.	Standby generators are located in areas only accessible by authorized personnel.								Paragraph 8.9.2
u.	Standby generators have an adequate area provided for servicing.								Paragraph 8.9.2
v.	Fuel storage tanks for standby generators are located within a secured area.								Paragraph 8.9.3
w.	A dedicated electrical circuit has been provided at the generator.								Paragraph 8.9.5
x.	A transfer switch of the proper ampacity rating has been installed to perform the switching between commercial power and standby generator power.								Paragraph 8.9.4
y.	A main service disconnect has been installed as required.								Paragraph 8.9.4
z.	Electrical panelboard ampacity ratings are properly coordinated.								Paragraph 8.9.4
	TOTALS FOR SECTION								

6	**TRANSIENT VOLTAGE SURGE SUPPRESSION**								
a.	A Type 1 SAD/MOV surge protection device (SPD) is installed as required.								Paragraph 9.4.2.2
b.	A Type 2 MOV surge protection device (SPD) is installed as required.								Paragraph 9.4.2.3
c.	Primary SPDs for telephone circuits are installed as required.								Paragraph 9.5.1
d.	Secondary SPDs for telephone circuits are installed as required.								Paragraph 9.5.2
e.	Primary SPDs for control circuits are installed as required.								Paragraph 9.5
f.	Secondary SPDs for control circuits installed as required.								Paragraph 9.5

R56 Compliance Audit

	DESCRIPTION	Motorola Responsibility Passed	Motorola Responsibility Failed	Customer Responsibility Passed	Customer Responsibility Failed	N/A	Motorola Failure Date Corrected	Customer Failure Date Corrected	Reference
g.	Primary SPDs for data network circuits are installed as required.								Paragraph 9.5
h.	Secondary SPDs for data network circuits are installed as required.								Paragraph 9.5
i.	All RF transmission lines, including unused spares, have coaxial RF type SPDs properly installed as required.								Paragraph 9.6
j.	Where a tower top amplifier has been installed, the sample port and its control cables have SPDs installed as required.								Paragraph 9.8
k.	Tower lighting system AC power and data/alarm circuits have SPDs properly installed as required.								Paragraph 9.8
	TOTALS FOR SECTION								

7	**EQUIPMENT INSTALLATION**								
a.	Equipment spacing and aisle widths conform to guidelines.								Paragraph 11.3.1
b.	Equipment is level and plumb.								Paragraph 11.4.5
c.	Equipment is square with surrounding equipment and walls.								Paragraph 11.4.5
d.	Where applicable, seismic installation practices have been observed.								Paragraph 11.4.1
e.	Cabinets and racks are secured as required.								Paragraph 11.6
f.	Cables and cable groups of different function maintain minimum separation of 5 cm (2 in.) as required.								Paragraph 11.8.1
g.	RF cables meet or exceed minimum bending radius requirements.								Paragraph 11.8.9
h.	Plenum-rated cables are installed as required.								Paragraph 11.8.2
i.	Proper cable lengths are used.								Paragraph 11.8.1.2
j.	Cables are properly secured at the required intervals.								Paragraph 11.8.1.1
k.	AC power conductors installed on cable runway systems meet installation requirements.								Paragraph 11.8.4+K178
l.	Cables are properly identified with a standard, double-ended system.								Paragraph 11.8.13

R56 Compliance Audit

	DESCRIPTION	Motorola Responsibility		Customer Responsibility			Motorola Failure	Customer Failure	Reference
		Passed	Failed	Passed	Failed	N/A	Date Corrected	Date Corrected	
m.	Distribution frame wiring conforms to the proper punch-down or wire-wrap techniques.								Paragraph 11.8.12
n.	CAT-5 cables maintain the proper separation from AC power cables.								Paragraph 11.8.7.4
o.	CAT-5 cables do not have any sharp bends.								Paragraph 11.8.7.4
p.	CAT-5 cables meet all other installation requirements.								Paragraph 11.8.7
q.	Cables installed below raised flooring systems are properly installed.								Paragraph 11.8.7
r.	Cables installed above suspended ceilings are properly installed.								Paragraph 11.8.2
s.	Electrostatic discharge practices are observed as required.								Paragraph 11.9
	TOTALS FOR SECTION								

AUDIT TOTALS	**MOTOROLA**		**CUSTOMER**			
	Number of Passed	Number of Failed	Number of Passed	Number of Failed	Total N/A	

APPENDIX G

FOLDOUT DIAGRAMS

This Appendix contains all overside diagrams referenced throughout the manual. Foldout pages are numbered with the prefix "FO."

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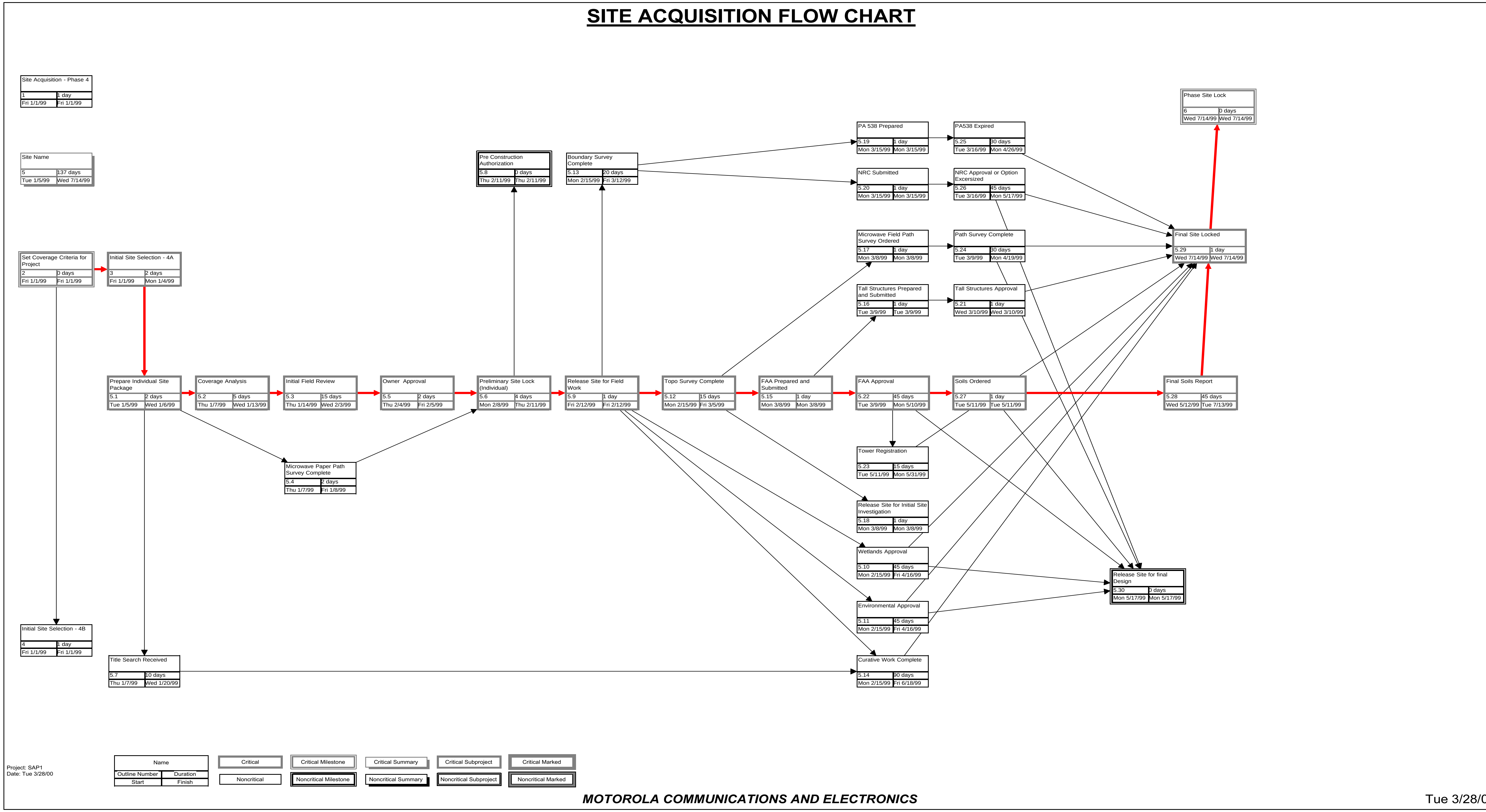


FIGURE G-1 EXAMPLE OF SITE ACQUISITION FLOW CHART

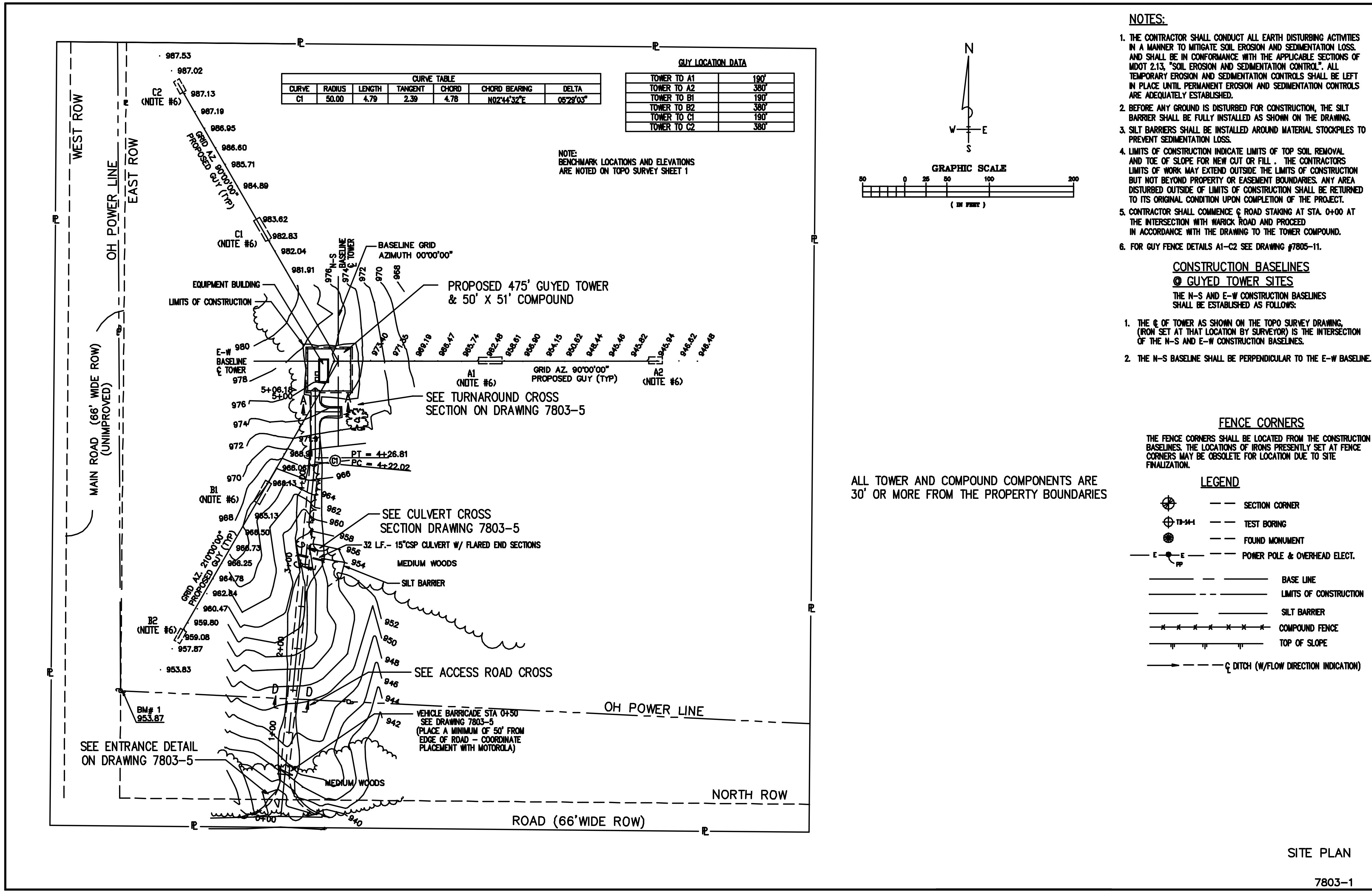


FIGURE G-2 EXAMPLE OF SITE PLAN

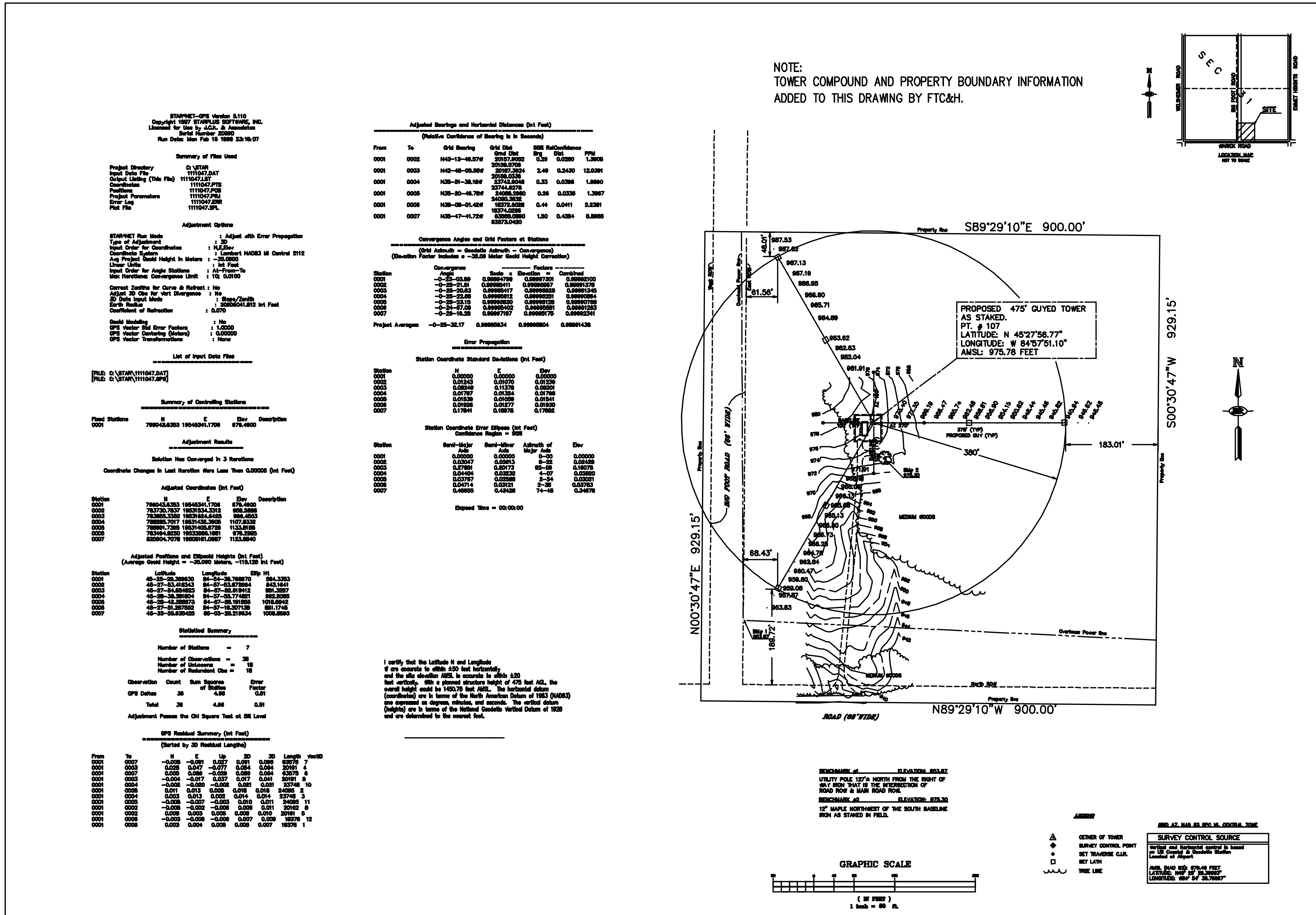


FIGURE G-3 EXAMPLE OF TOPOGRAPHIC SURVEY

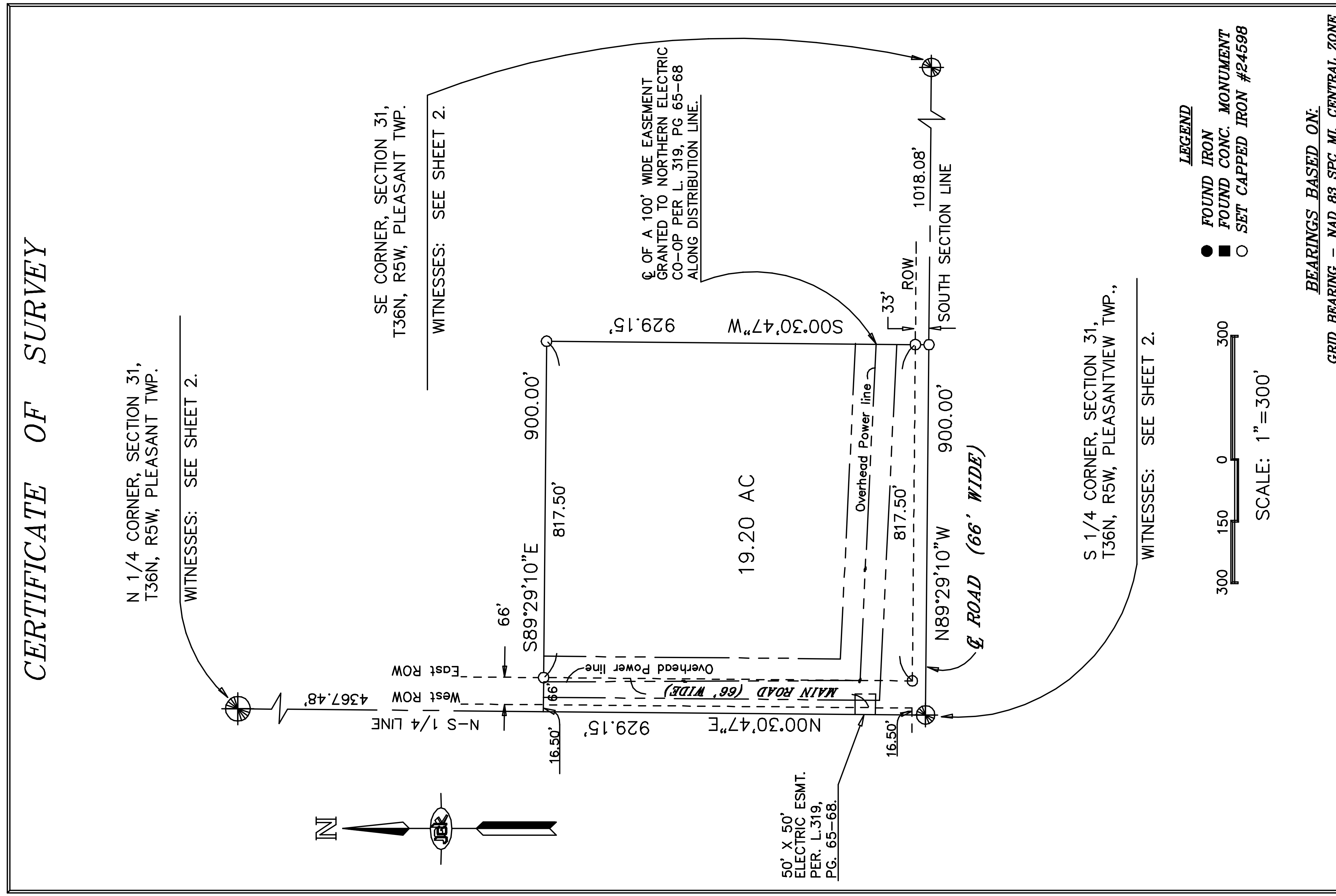
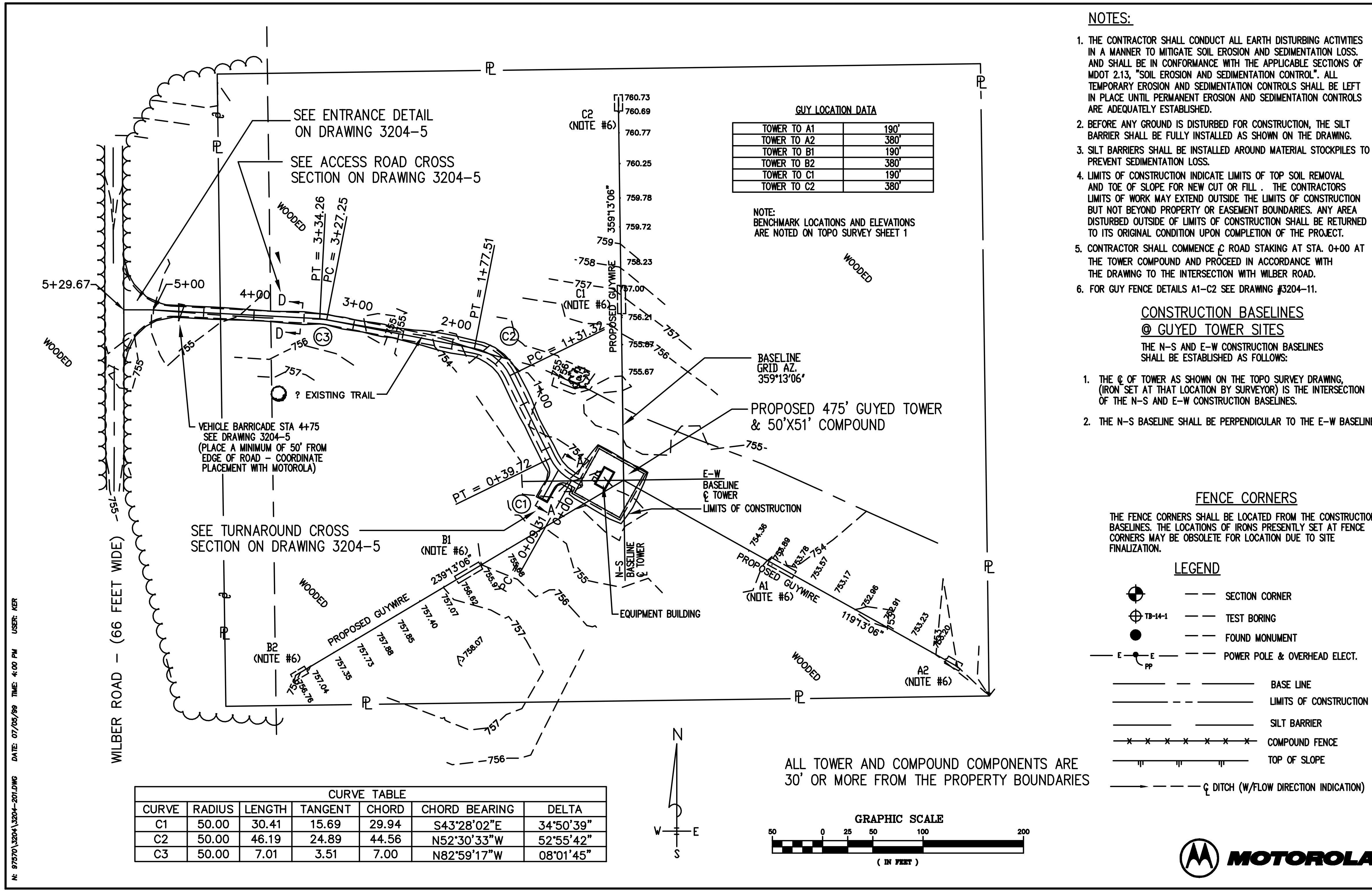


FIGURE G-4 EXAMPLE OF BOUNDARY SURVEY



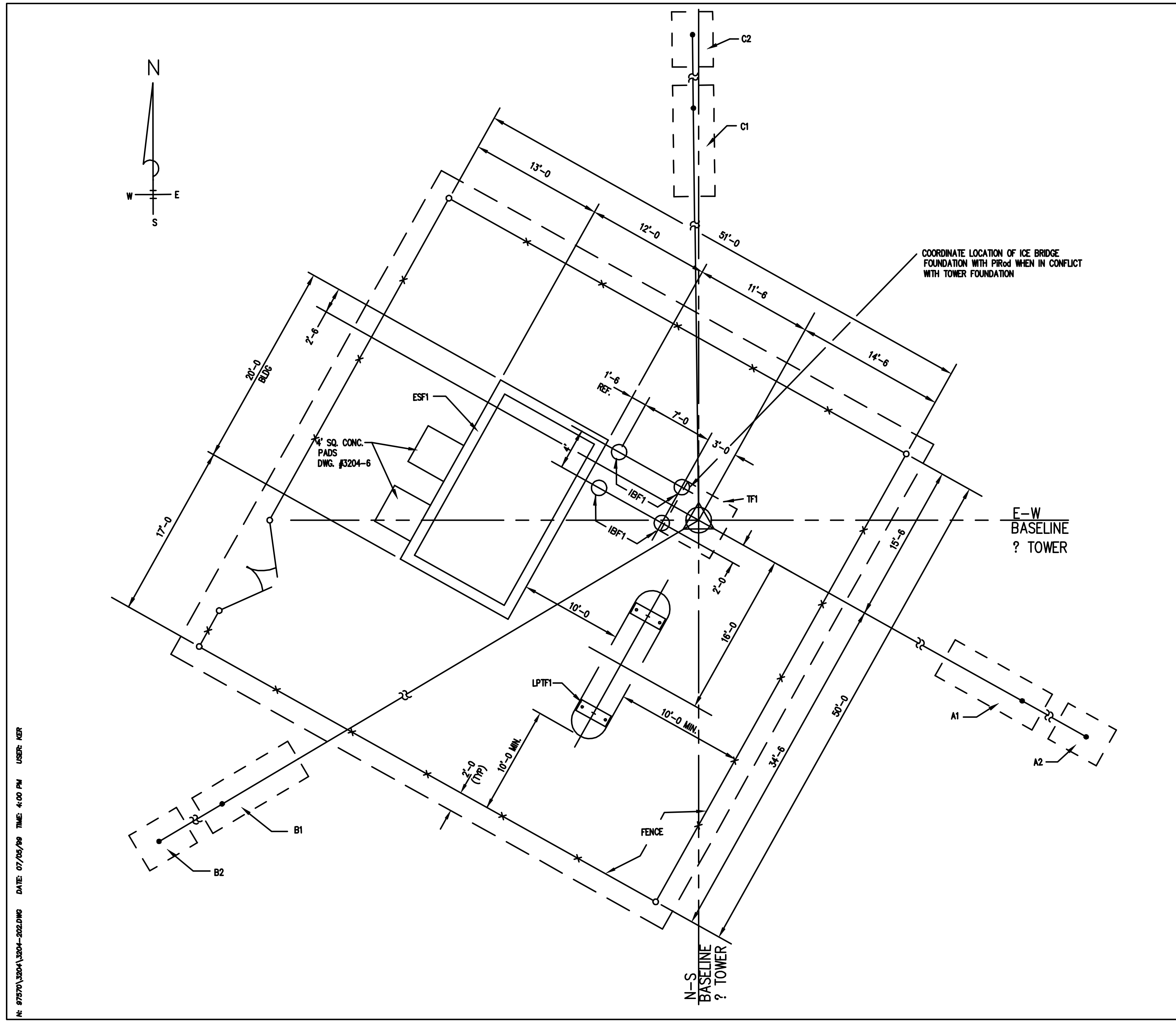
GUY LOCATION DATA

TOWER TO A1	190'
TOWER TO A2	380'
TOWER TO B1	190'
TOWER TO B2	380'
TOWER TO C1	190'
TOWER TO C2	380'

CURVE TABLE

CURVE	RADIUS	LENGTH	TANGENT	CHORD	CHORD BEARING	DELTA
C1	50.00	30.41	15.69	29.94	S43°28'02"E	34°50'39"
C2	50.00	46.19	24.89	44.56	N52°30'33"W	52°55'42"
C3	50.00	7.01	3.51	7.00	N82°59'17"W	08°01'45"

FIGURE G-5 SAMPLE GUYED TOWER SITE DRAWING PACKAGE CONSTRUCTION BASELINES



FOUNDATION SCHEDULE

Mark	Elevation Top/Fdn.	Description	Location and Type
A1, B1 & C1	–	GUY ANCHOR FOUNDATION	PIROD INC. DESIGN DRAWINGS
A2, B2 & C2	–	GUY ANCHOR FOUNDATION	PIROD INC. DESIGN DRAWINGS
TF1	756.0	TOWER FOUNDATION	PIROD INC. DESIGN DRAWINGS
IBF1	–	ICE BRIDGE FOUNDATION	MOTOROLA DRAWING #3204-4
LPTF1	756.0	1000 GAL. L.P. TANK FDN.	MOTOROLA DRAWING #3204-6
ESF1	756.0	12'X 20' EQUIP. SHELTER FDN.	MOTOROLA DRAWING #3204-6

NOTES:

1. ALL FOUNDATIONS SHALL BE LOCATED FROM THE E-W & N-S BASELINES. REFERENCE (REF) DIMENSIONS SHOWN ARE FOR INFORMATION ONLY.

CONSTRUCTION BASELINES
@ GUYED TOWER SITE

THE N-S AND E-W CONSTRUCTION BASELINES SHALL BE ESTABLISHED AS FOLLOWS:

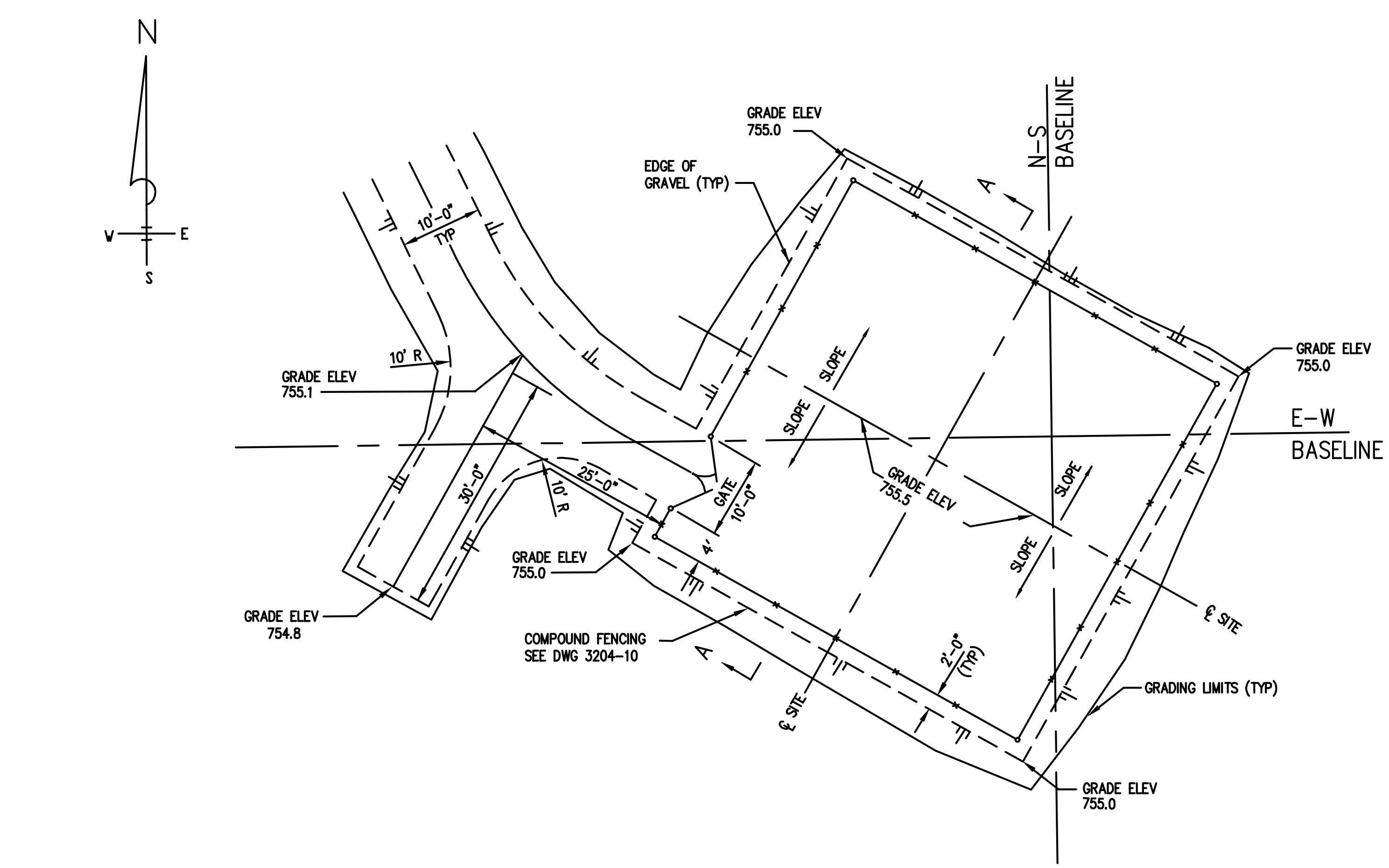
1. THE ℄ OF TOWER AS SHOWN ON THE TOPO SURVEY DRAWING, (IRON SET AT THAT LOCATION BY SURVEYOR) IS THE INTERSECTION OF THE N-S AND E-W CONSTRUCTION BASELINES.
2. THE N-S BASELINE SHALL BE PERPENDICULAR TO THE E-W BASELINE.

FENCE CORNERS

THE FINAL FENCE CORNERS SHALL BE LOCATED FROM THE CONSTRUCTION BASELINES.

MOTOROLA

FIGURE G-6 SAMPLE GUYED SITE DRAWING PACKAGE FOUNDATIONS



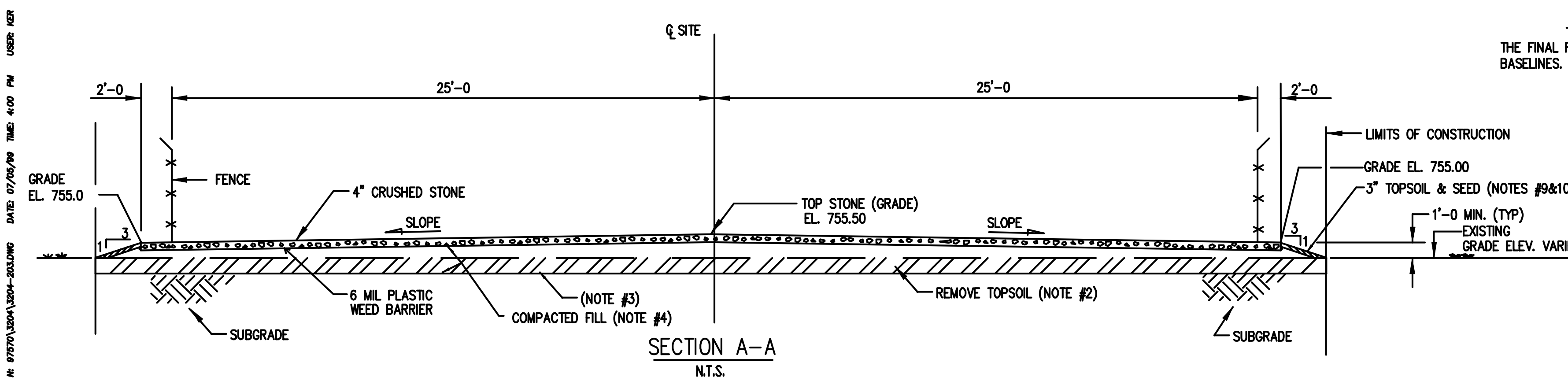
NOTES:

1. CLEAR, GRUB, CUT, FILL & COMPACT SITE COMPOUND AND ACCESS ROAD. FILL, IF REQUIRED, SHALL NOT BE ACQUIRED FROM THE SITE. SPOIL MATERIALS SHALL BE REMOVED FROM THE SITE AND DISPOSED OF PROPERLY.
2. REMOVE ALL TOP SOIL (APPROX. 6") FROM LIMITS OF CONSTRUCTION AS SHOWN ON SITE PLAN.
3. BACKFILL AND UNDERCUT AREAS FOR ALL STRUCTURAL APPLICATIONS ARE TO BE COMPACTED TO 95% OF ITS MODIFIED PROCTOR MAXIMUM DRY DENSITY AS PER ASTM D1557.
4. BACKFILL AND UNDERCUT AREAS FOR NON–STRUCTURAL APPLICATIONS (SUCH AS AROUND PREFABRICATED SHELTER FOUNDATIONS AND ABOVE GROUND LP TANK FOUNDATIONS) ARE TO BE COMPACTED TO 90% OF THE MAXIMUM DRY DENSITY VALUE DETERMINED BY THE STANDARD PROCTOR COMPACTION TEST AS PER ASTM D698.
5. EARTHWORK SHALL BE PERFORMED IN A MANNER CONSISTENT WITH APPLICABLE FLOOD CONTROL AND SEDIMENT CONTROL REGULATIONS.
6. ALL CLEARED DEBRIS AND RUBBISH SHALL IMMEDIATELY BE REMOVED FROM THE SITE. BURNING OF DEBRIS ON THE SITE IS NOT ALLOWED. DEPOSIT OF DEBRIS AND RUBBISH IN THE STATE'S RECEPTACLES IS PROHIBITED.
7. PROVIDE TEMPORARY EROSION CONTROLS, DRAINAGE AND DRAINAGE STRUCTURES TO INCLUDE CULVERTS SUCH THAT WATER SHALL NOT ACCUMULATE IN SUCH A MANNER AS TO PROHIBIT OR RESTRICT ACCESS TO THE SITE OR TO CAUSE DANGER TO INSTALLED EQUIPMENT.
8. ALL DISTURBED AREAS SHALL BE GRADED AS TO HAVE FINISHED SLOPES OF LESS THAN A 2 HORIZONTAL TO 1 VERTICAL RATIO UNLESS SITE CONDITIONS NECESSITATE A STEEPER SLOPE.
9. TOPSOIL IS TO BE STOCKPILED AND REDISTRIBUTED TO DISTURBED AREAS NOT RECEIVING AGGREGATE SURFACING.
10. ALL SLOPES AND DISTURBED AREAS NOT RECEIVING AGGREGATE SURFACING ARE TO BE PREPARED AND BROADCAST SEEDED AND FERTILIZED FOR EROSION PROTECTION. SEEDING FOR AREAS DISTURBED SHALL BE ESTABLISHED SEASONALLY AS INDICATED. THE FOLLOWING SEED MIXTURE RATIOS APPLY FOR EACH 1000 S.F. OF AREA. MULCH SHALL BE APPLIED AT 1 TON/ACRE.

SUMMER (MARCH–AUGUST)	WINTER (SEPTEMBER–FEBRUARY)
6 LBS. BROWN MILLET	8 LBS. ANNUAL RYEGRASS
8 LBS. 16–16–16 FERTILIZER	8 LBS. 16–16–16 FERTILIZER

FENCE CORNERS

THE FINAL FENCE CORNERS SHALL BE LOCATED FROM THE CONSTRUCTION BASELINES.



MOTOROLA

FIGURE G-7 SAMPLE GUYED SITE DRAWING PACKAGE
GRADING AND BACKFILLING PLAN

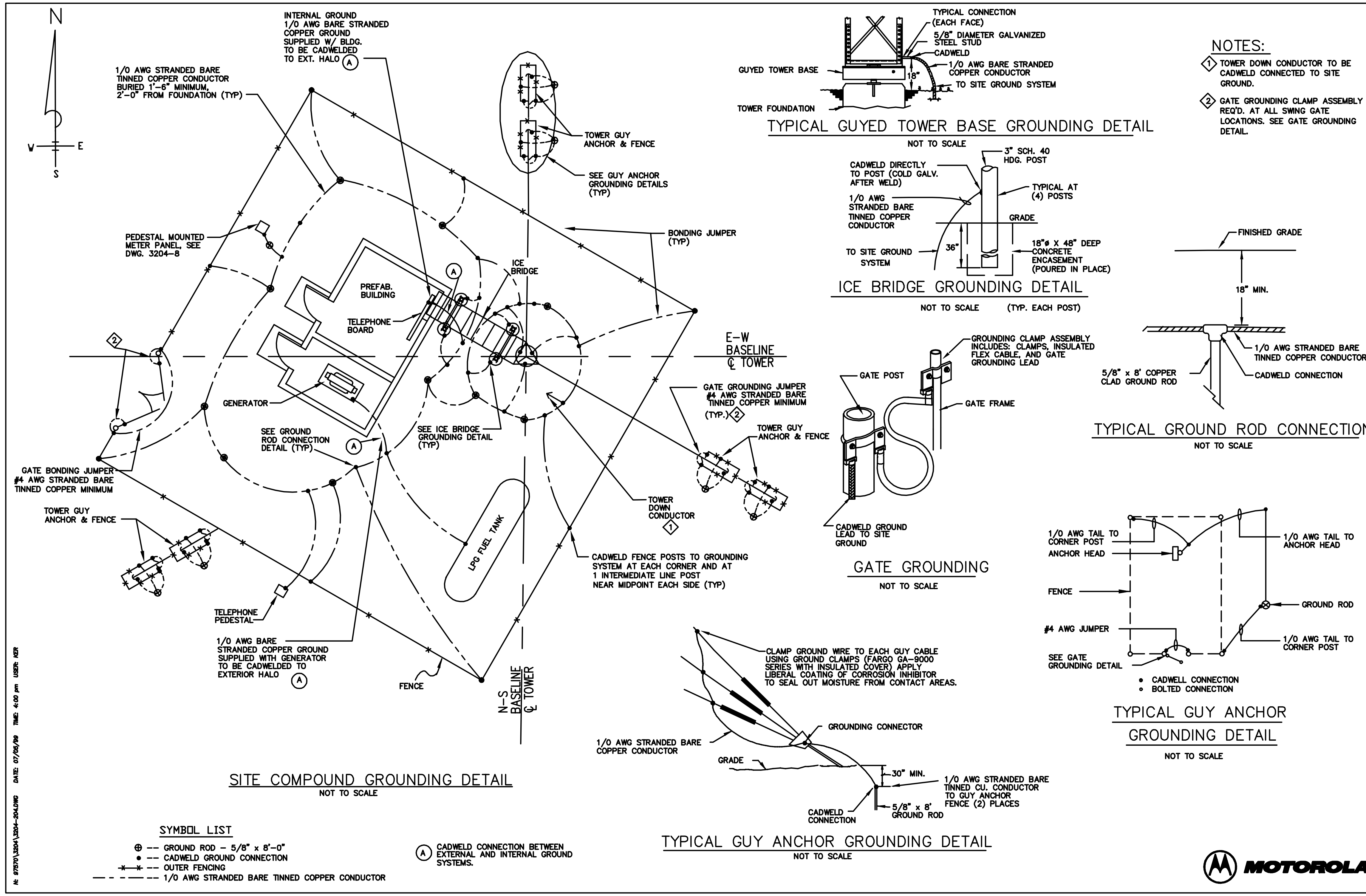


FIGURE G-8 SAMPLE GUYED SITE DRAWING PACKAGE
EXTERNAL GROUND SYSTEM

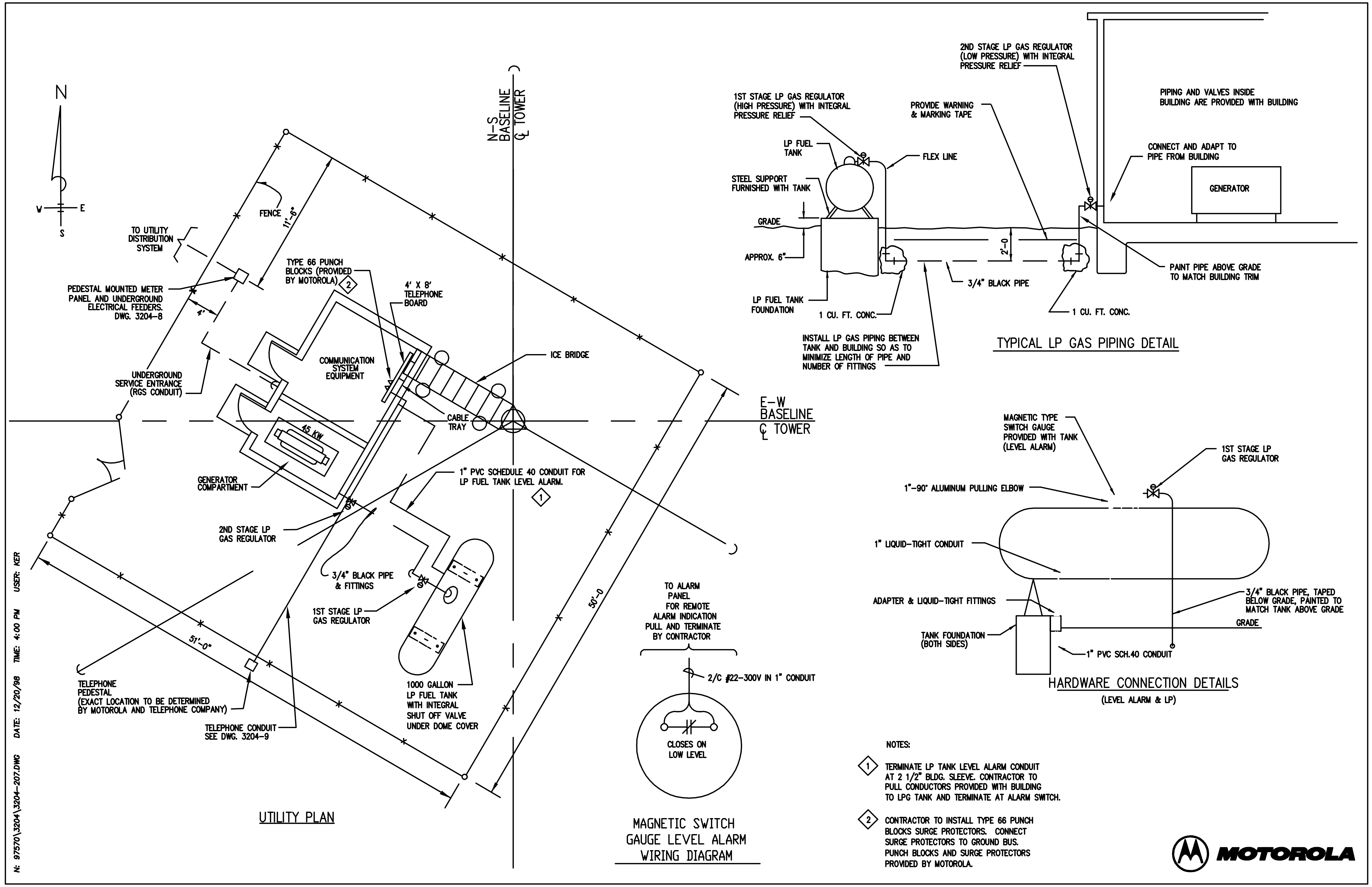


FIGURE G-9 SAMPLE GUYED SITE DRAWING PACKAGE
FUEL TANK DETAILS

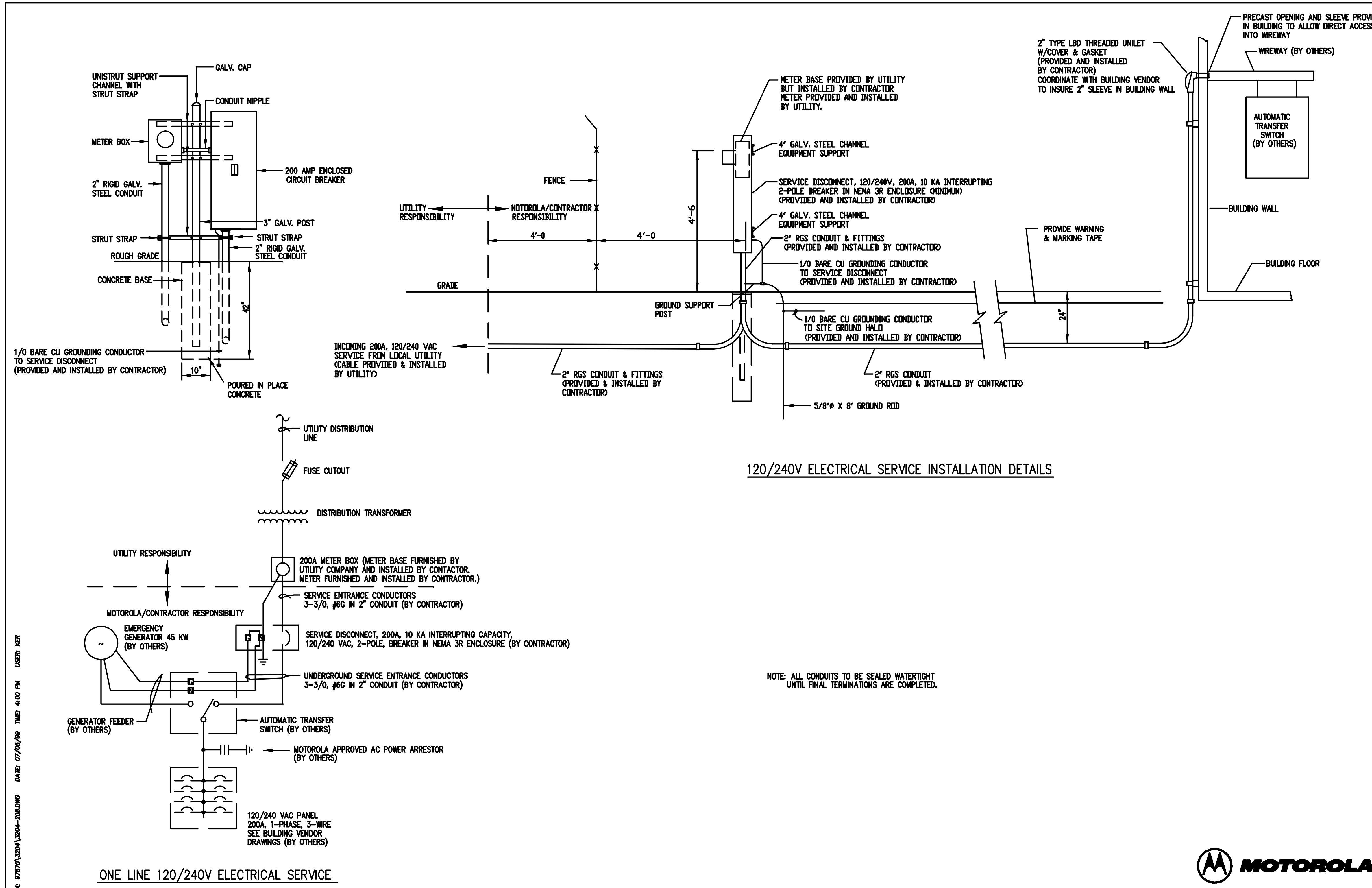


FIGURE G-10 SAMPLE GUYED SITE DRAWING PACKAGE ELECTRICAL SERVICE

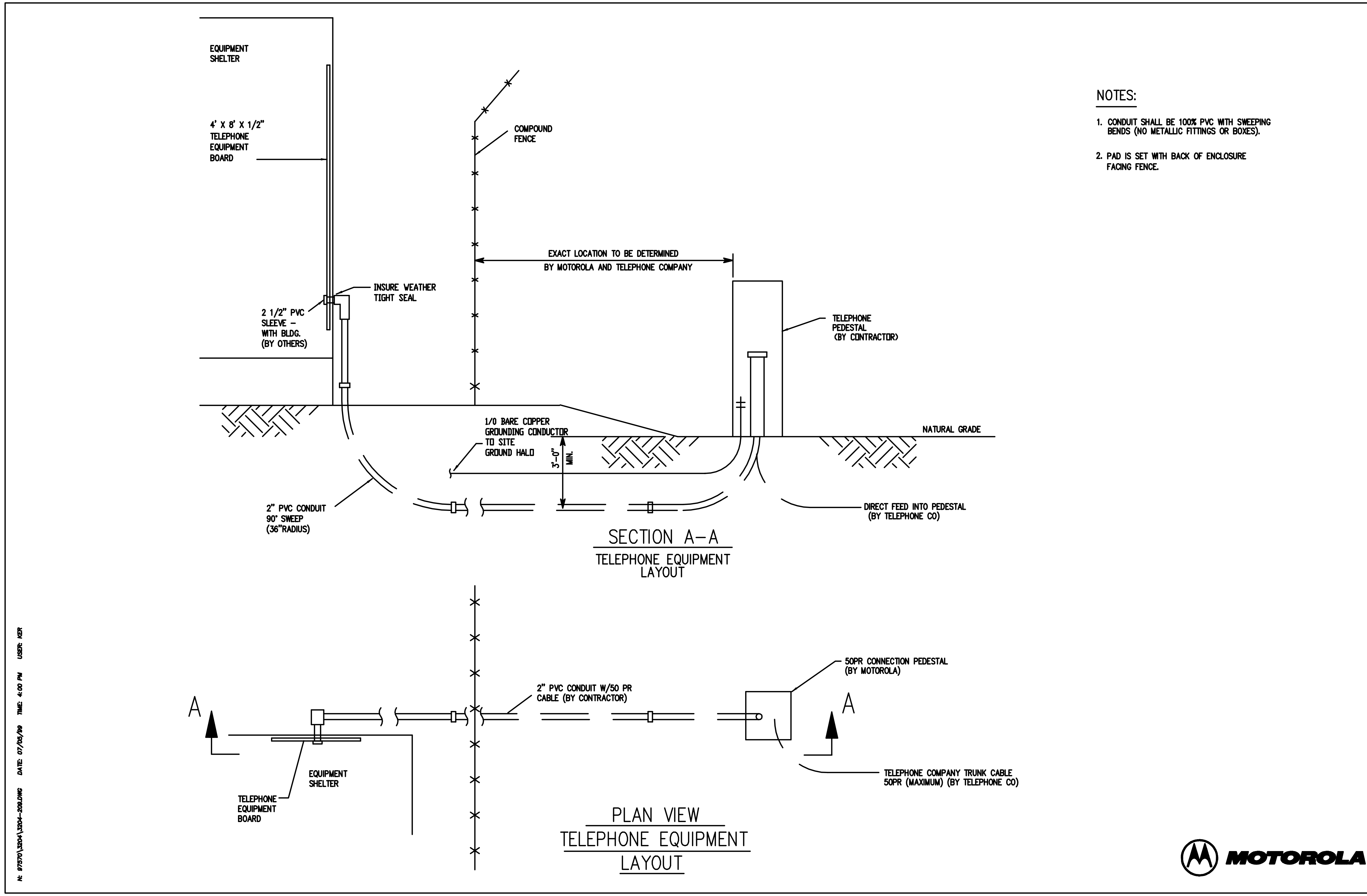
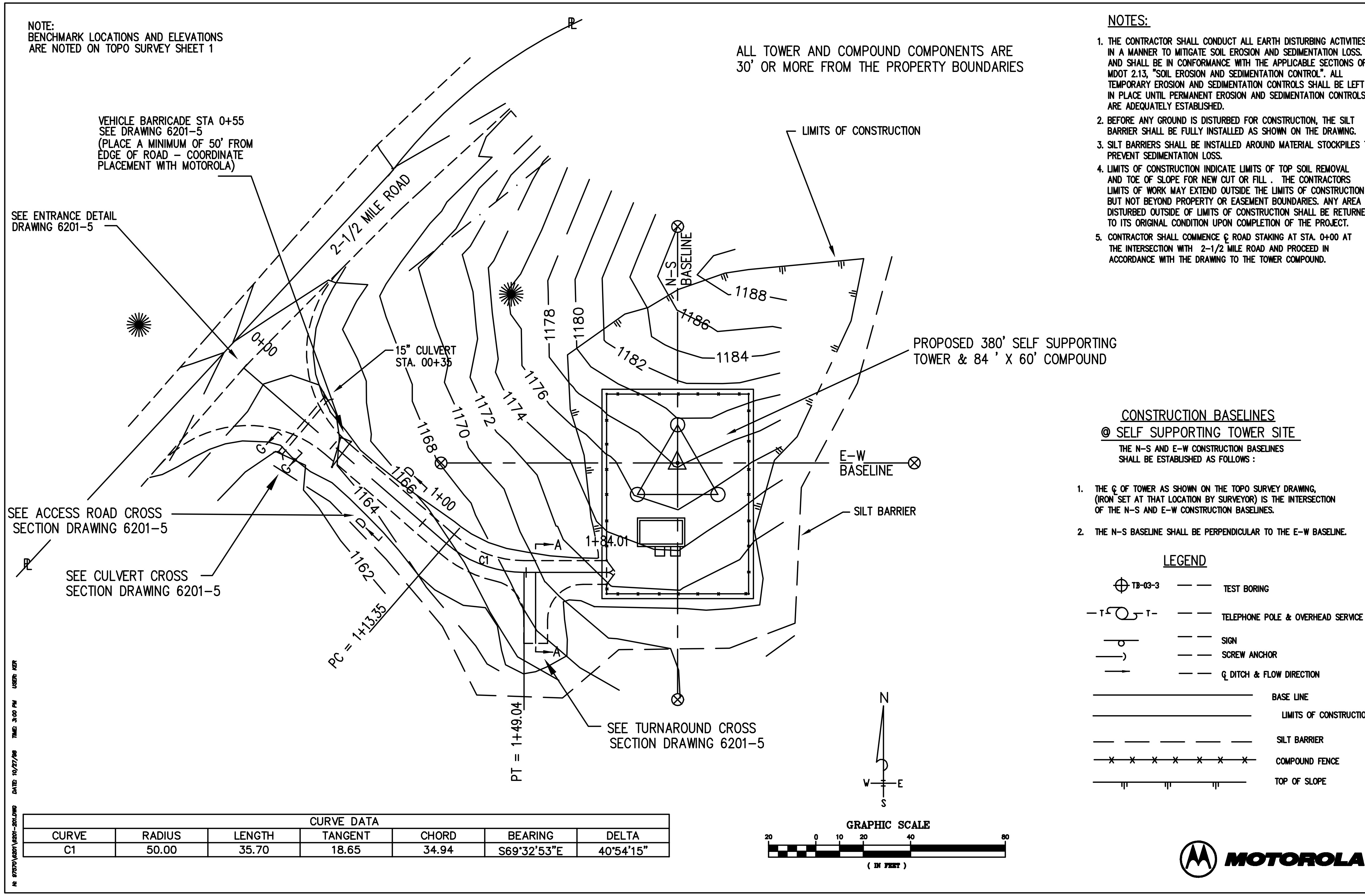


FIGURE G-11 SAMPLE GUYED SITE DRAWING PACKAGE
TELEPHONE SERVICE



CURVE DATA						
CURVE	RADIUS	LENGTH	TANGENT	CHORD	BEARING	DELTA
C1	50.00	35.70	18.65	34.94	S69°32'53"E	40°54'15"

FIGURE G-12 SAMPLE SELF-SUPPORTING TOWER SITE DRAWING PACKAGE - CONSTRUCTION BASELINES

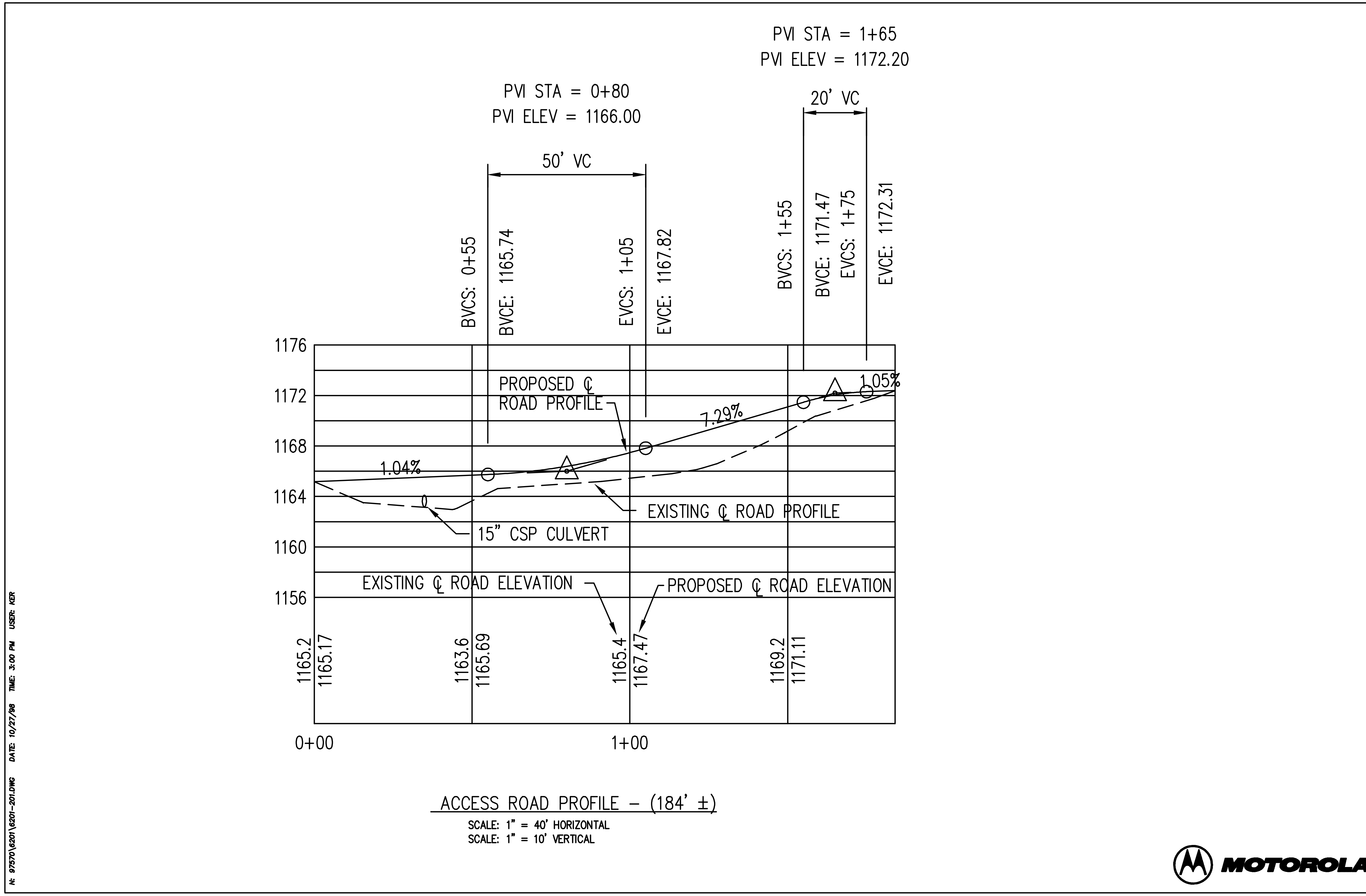
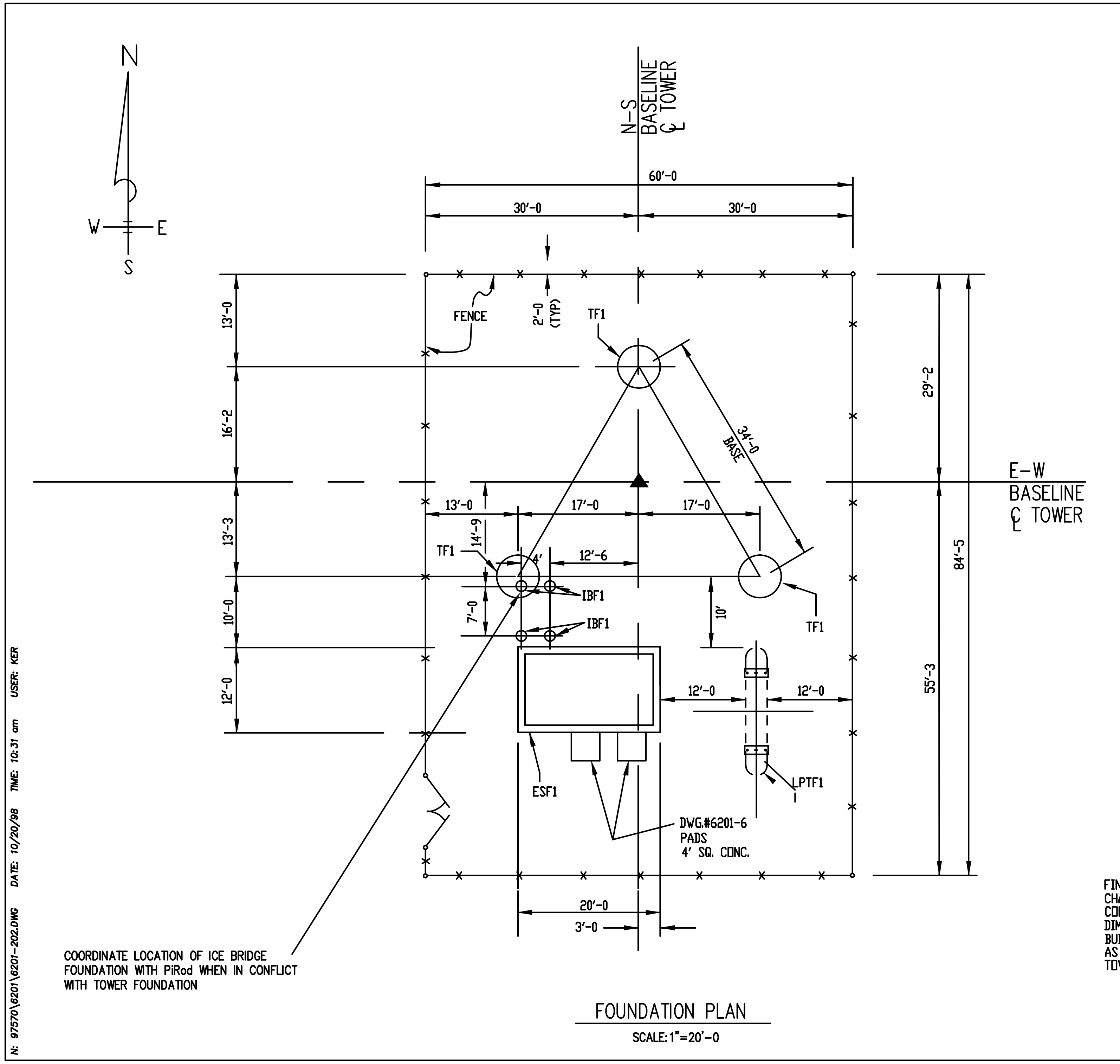


Figure G-13 Sample Self-Supporting Tower Site Drawing Package — Access Road Profile



FOUNDATION SCHEDULE

Mark	Elevation Top/Fdn.	Description	Location and Type
TF1	1173.3	TOWER FOUNDATION	PIROD INC. DESIGN DRAWINGS
IBF1	–	ICE BRIDGE FOUNDATION	MOTOROLA DRAWING #6201-4
LPTF1	1173.3	1000 GAL. L.P. TANK FDN.	MOTOROLA DRAWING #6201-6
ESF1	1173.3	12' X 20' EQUIP. SHELTER FDN.	MOTOROLA DRAWING #6201-6

NOTES:

1. ALL FOUNDATIONS SHALL BE LOCATED FROM THE E-W & N-S BASELINES. REFERENCE (REF) DIMENSIONS SHOWN ARE FOR INFORMATION ONLY.

CONSTRUCTION BASELINES @ SELF SUPPORTING TOWER SITE

THE N-S AND E-W CONSTRUCTION BASELINES SHALL BE ESTABLISHED AS FOLLOWS :

1. THE ℄ OF TOWER AS SHOWN ON THE TOPO SURVEY DRAWING, (IRON SET AT THAT LOCATION BY SURVEYOR) IS THE INTERSECTION OF THE N-S AND E-W CONSTRUCTION BASELINES.
2. THE N-S BASELINE SHALL BE PERPENDICULAR TO THE E-W BASELINE.

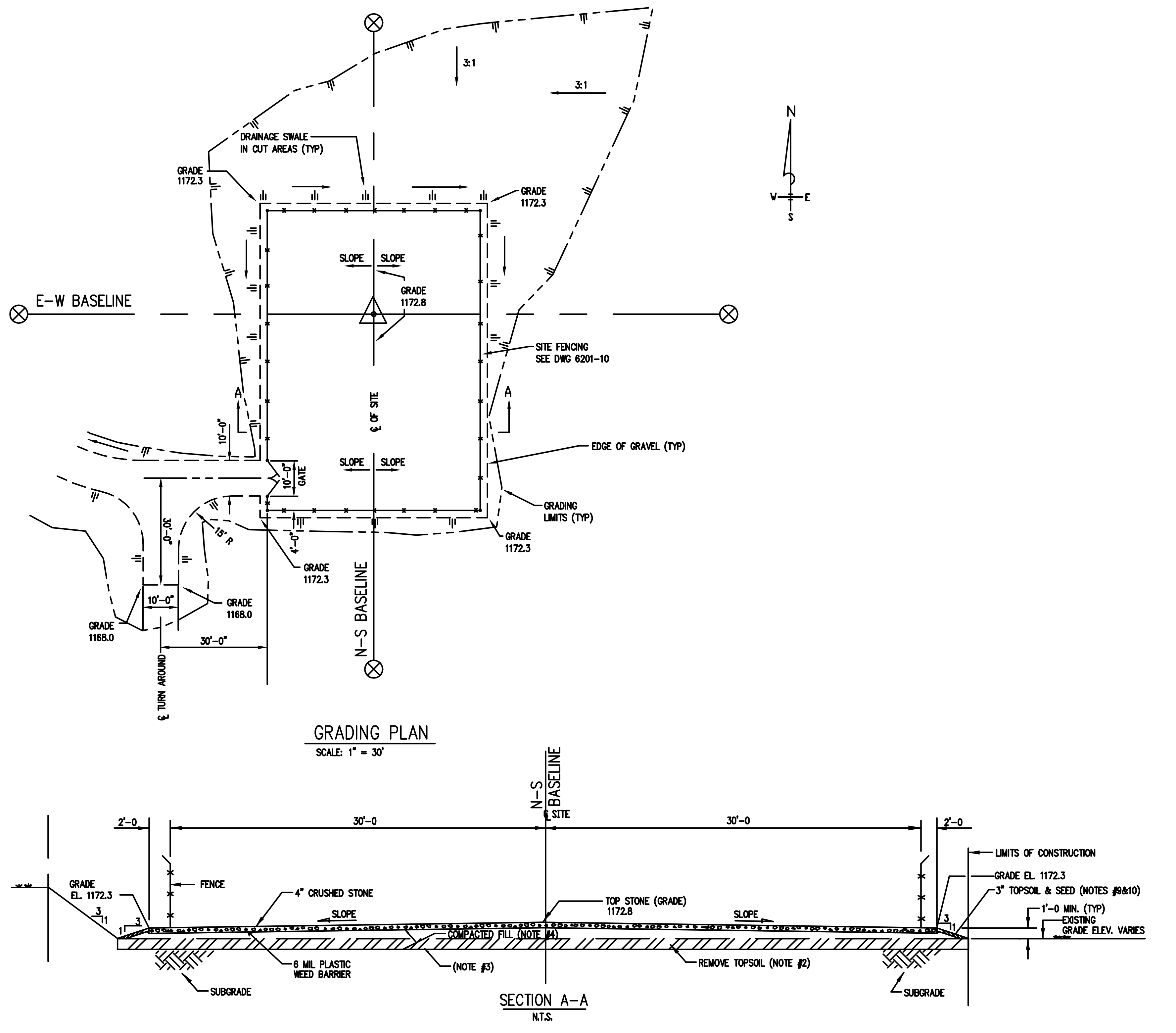
FENCE CORNERS

THE FINAL FENCE CORNERS SHALL BE LOCATED FROM THE CONSTRUCTION BASELINES.

FINAL TOWER FACE DIMENSION MAY CHANGE FROM DIMENSION SHOWN. COORDINATE FINAL TOWER FACE DIMENSION WITH PIROD. ADJUST BUILDING AND ICE BRIDGE LOCATION AS NECESSARY TO ALIGN WITH TOWER LEG.

MOTOROLA

FIGURE G-14 SAMPLE SELF-SUPPORTING TOWER SITE DRAWING PACKAGE — FOUNDATION PLAN



NOTES:

1. CLEAR, GRUB, CUT, FILL & COMPACT SITE COMPOUND AND ACCESS ROAD. FILL, IF REQUIRED, SHALL NOT BE ACQUIRED FROM THE SITE. SPOIL MATERIALS SHALL BE REMOVED FROM THE SITE AND DISPOSED OF PROPERLY.
2. REMOVE ALL TOP SOIL (APPROX. 6") FROM LIMITS OF CONSTRUCTION AS SHOWN ON SITE PLAN.
3. BACKFILL AND UNDERCUT AREAS FOR ALL STRUCTURAL APPLICATIONS ARE TO BE COMPACTED TO 95% OF ITS MODIFIED PROCTOR MAXIMUM DRY DENSITY AS PER ASTM D1557.
4. BACKFILL AND UNDERCUT AREAS FOR NON-STRUCTURAL APPLICATIONS (SUCH AS AROUND PREFABRICATED SHELTER FOUNDATIONS AND ABOVE GROUND LP TANK FOUNDATIONS) ARE TO BE COMPACTED TO 90% OF THE MAXIMUM DRY DENSITY VALUE DETERMINED BY THE STANDARD PROCTOR COMPACTION TEST AS PER ASTM D698.
5. EARTHWORK SHALL BE PERFORMED IN A MANNER CONSISTENT WITH APPLICABLE FLOOD CONTROL AND SEDIMENT CONTROL REGULATIONS.
6. ALL CLEARED DEBRIS AND RUBBISH SHALL IMMEDIATELY BE REMOVED FROM THE SITE. BURNING OF DEBRIS ON THE SITE IS NOT ALLOWED. DEPOSIT OF DEBRIS AND RUBBISH IN THE STATE'S RECEPTACLES IS PROHIBITED.
7. PROVIDE TEMPORARY EROSION CONTROLS, DRAINAGE AND DRAINAGE STRUCTURES TO INCLUDE CULVERTS SUCH THAT WATER SHALL NOT ACCUMULATE IN SUCH A MANNER AS TO PROHIBIT OR RESTRICT ACCESS TO THE SITE OR TO CAUSE DANGER TO INSTALLED EQUIPMENT.
8. ALL DISTURBED AREAS SHALL BE GRADED AS TO HAVE FINISHED SLOPES OF LESS THAN A 2 HORIZONTAL TO 1 VERTICAL RATIO UNLESS SITE CONDITIONS NECESSITATE A STEEPER SLOPE.
9. TOPSOIL IS TO BE STOCKPILED AND REDISTRIBUTED TO DISTURBED AREAS NOT RECEIVING AGGREGATE SURFACING.
10. ALL SLOPES AND DISTURBED AREAS NOT RECEIVING AGGREGATE SURFACING ARE TO BE PREPARED AND BROADCAST SEEDED AND FERTILIZED FOR EROSION PROTECTION. SEEDING FOR AREAS DISTURBED SHALL BE ESTABLISHED SEASONALLY AS INDICATED. THE FOLLOWING SEED MIXTURE RATIOS APPLY FOR EACH 1000 S.F. OF AREA. MULCH SHALL BE APPLIED AT 1 TON/ACRE.

SUMMER (MARCH-AUGUST)	WINTER (SEPTEMBER-FEBRUARY)
6 LBS. BROWN MILLET	8 LBS. ANNUAL RYEGRASS
8 LBS. 16-16-16 FERTILIZER	8 LBS. 16-16-16 FERTILIZER

FENCE CORNERS

THE FINAL FENCE CORNERS SHALL BE LOCATED FROM THE CONSTRUCTION BASELINES. THE LOCATION OF IRONS PRESENTLY SET AT FENCE CORNERS MAY BE OBSOLETE FOR LOCATION DUE TO SITE FINALIZATION.

MOTOROLA

FIGURE G-15 SAMPLE SELF-SUPPORTING TOWER SITE DRAWING PACKAGE — GRADING AND BACKFILLING PLAN

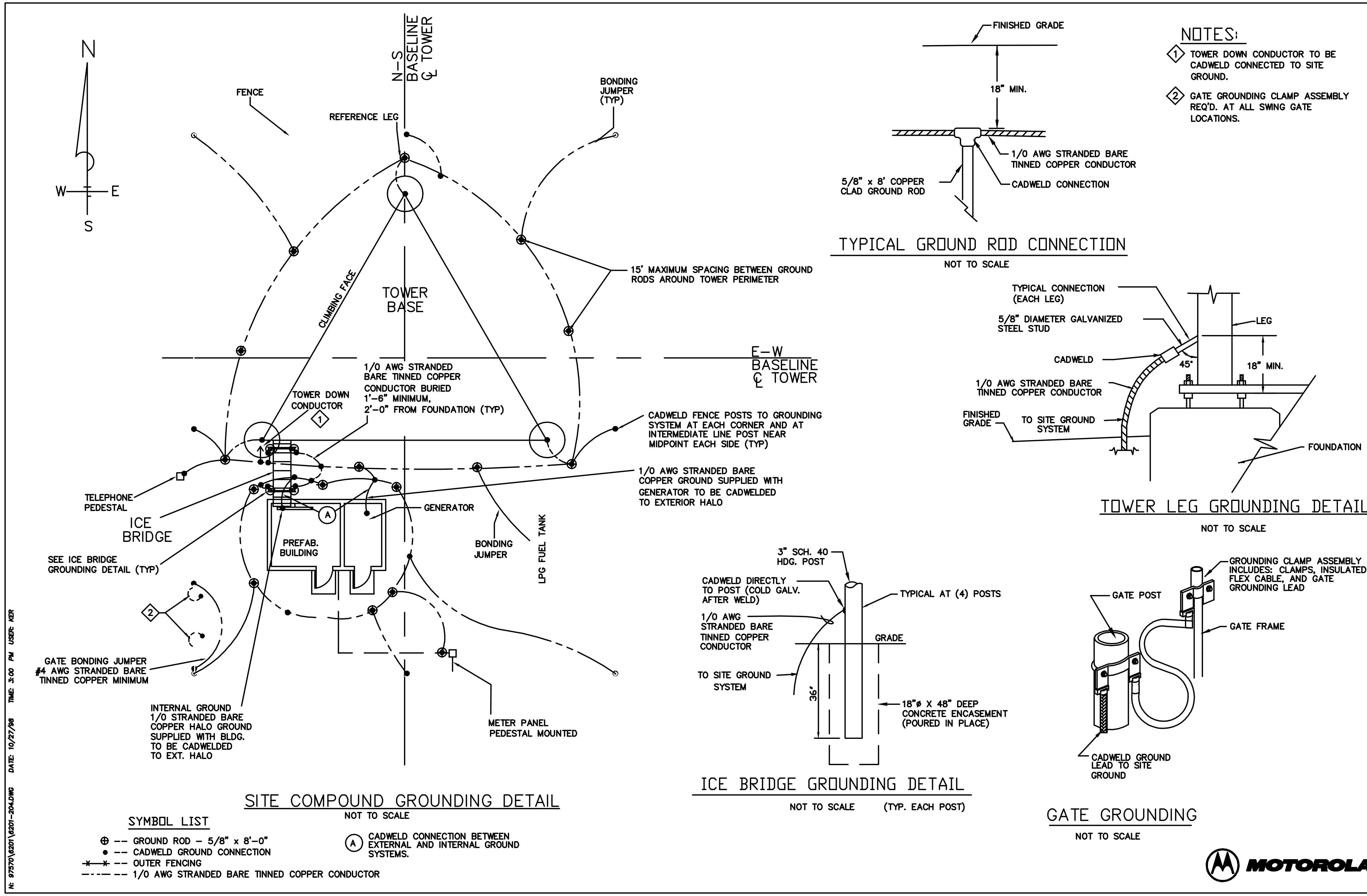


FIGURE G-16 SAMPLE SELF-SUPPORTING TOWER SITE DRAWING PACKAGE — EXTERNAL GROUND SYSTEM

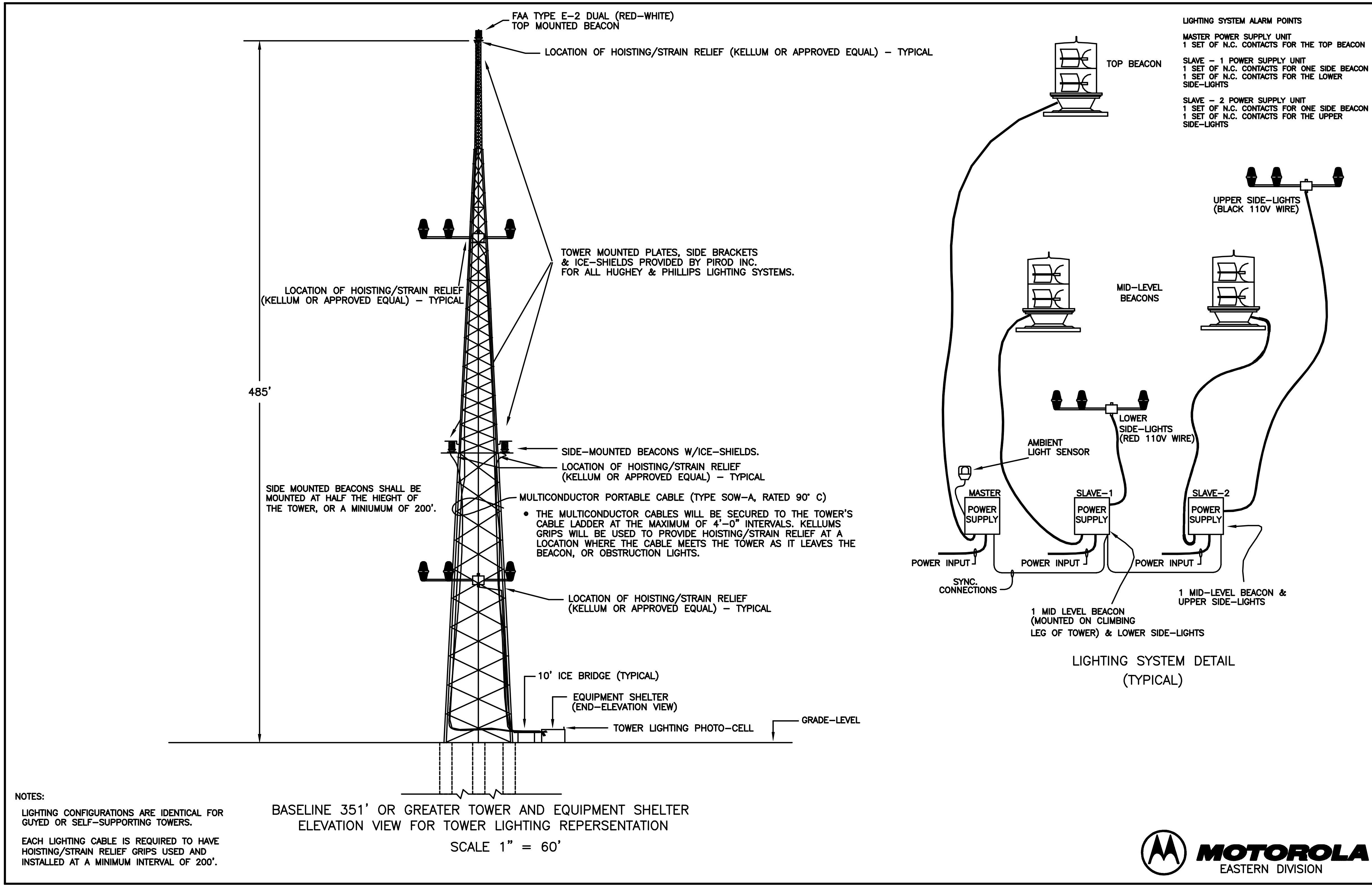


FIGURE G-17 TYPICAL TOWER LIGHTING DIAGRAM FOR TOWERS TALLER THAN 106.7 M (350 FT.)

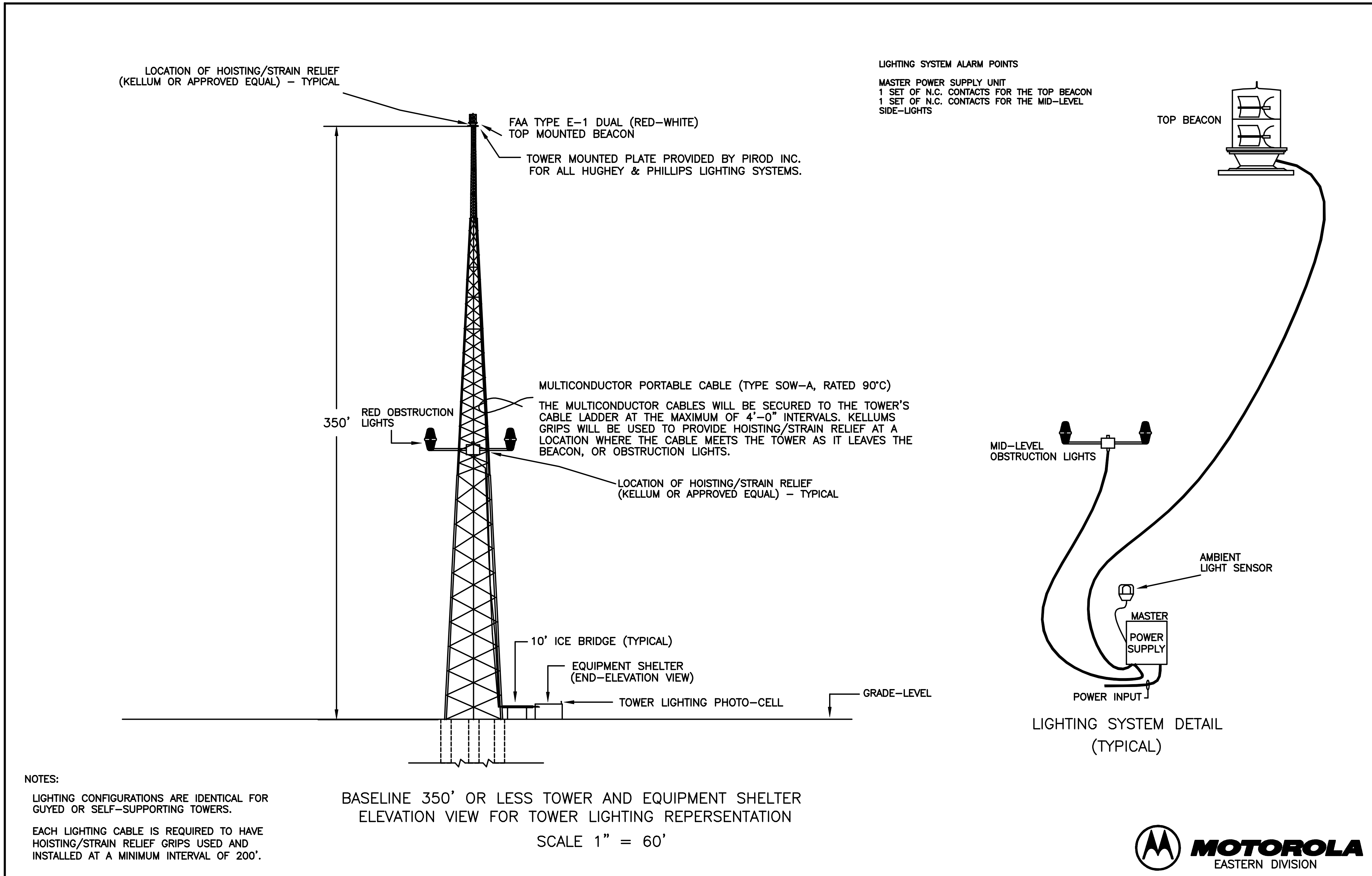


FIGURE G-18 TYPICAL TOWER LIGHTING DIAGRAM
FOR TOWERS SHORTER THAN 106.7 M (350 FT.)

INDEX

A

B

C

D

E

F

G

S