

NFPA® 780

Standard for the Installation of Lightning Protection Systems

2011 Edition



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NFPA® 780

Standard for the Installation of Lightning Protection Systems

2011 Edition

This edition of NFPA 780, *Standard for the Installation of Lightning Protection Systems*, was prepared by the Technical Committee on Lightning Protection. It was issued by the Standards Council on June 1, 2010, with an effective date of June 21, 2010, and supersedes all previous editions.

This edition of NFPA 780 was approved as an American National Standard on June 21, 2010.

Origin and Development of NFPA 780

NFPA first adopted *Specifications for Protection of Buildings Against Lightning* in 1904. Revised standards were adopted in 1905, 1906, 1925, 1932, and 1937. In 1945, the NFPA Committee and the parallel American Standards Association (ASA) Committee on Protection Against Lightning were reorganized and combined under the sponsorship of NFPA, the National Bureau of Standards, and the American Institute of Electrical Engineers (now the IEEE). In 1946, NFPA acted to adopt Part III and in 1947 published a revised edition incorporating this part. Further revisions recommended by the Committee were adopted by NFPA in 1949, 1950, 1951, 1952, 1957, 1959, 1963, 1965, 1968, 1975, 1977, 1980, 1983, 1986, 1989, and 1992.

Commencing with the 1992 edition of the *Lightning Protection Code*, the NFPA numerical designation of the document was changed from NFPA 78 to NFPA 780.

With the issuance of the 1995 edition, the name of the document was changed from *Lightning Protection Code* to *Standard for the Installation of Lightning Protection Systems*. This change was directed by the Standards Council in order to make the title more accurately reflect the document's content. In addition, the Council directed certain changes to the scope of the document to clarify that the document did not cover lightning protection installation requirements for early streamer emission systems or lightning dissipater array systems.

The 1997 edition of NFPA 780 incorporated editorial changes to make the document more user friendly.

In issuing this document, the Standards Council noted that lightning is a stochastic, if not capricious, natural process. Its behavior is not yet completely understood. This standard is intended to provide requirements, within the limits of the current state of knowledge, for the installation of those lightning protection systems covered by the standard.

The 2000 edition of NFPA 780 was amended to provide requirements for open structures such as those found on golf courses. A 1998 lightning flash density chart replaced the 1972 lightning frequency isoceraunic chart.

The 2004 edition of NFPA 780 reflected an extensive editorial revision of the standard to comply with the concurrent edition of the *NFPA Manual of Style for Technical Committee Documents*. These revisions included the addition of three administrative chapters at the beginning of the standard: "Administration," "Referenced Publications," and "Definitions." Five technical chapters followed the administrative chapters in the same sequence as in the 2000 edition. Other editorial revisions included the breakout of paragraphs with multiple requirements into an individually numbered paragraph for each requirement, the minimization of the use of exceptions, the use of consistent headings for sections and section subdivisions, and reorganization to limit paragraph numbering to six digits. The International System of Units, commonly known as SI or metric, was used throughout the document. The appendixes were renamed annexes and reordered in a more logical sequence.

The 2004 edition also contained a number of technical revisions throughout the standard. These revisions included the following: a main conductor, solid strip, was added for Class II material requirements for ordinary structures exceeding 75 ft in height; handrails could be used as a substitute for down conductors; additional separation between ground rods was

required where multiple ground rods are used; additional guidance was provided for those instances where it is necessary to install the grounding conductor directly on bedrock; the section entitled Surge Suppression was entirely rewritten; titanium strike termination devices were permitted to be used; and in Annex K the term *Faraday cage* was replaced with *metallic cage*.

The 2008 edition provided requirements for surge protective devices to be installed at all power service entrances, at the entrance of conductive communications systems and antenna systems, and where an electrical or electronic system conductor leaves the structure.

The new definition for *lightning protection system* included the term *conductive structural members*. Clarification was provided relative to the use of ancillary metal parts that cannot be substituted for the main conductor. Strike termination devices included air terminals, metal masts, certain permanent metal parts of structures, and elevated conductors. Revisions clarified that metal masts and overhead ground wires were included in the requirements of Chapter 4.

Significant changes were made to the requirements for the use of bimetallic clamps and aluminum in proximity to earth. The standard has long required that grounding electrodes be located near the outside perimeter of the structure, and in the 2008 edition additional guidance was provided to assist the system designer. Changes were also made to better address the requirements for grounding electrodes in shallow topsoil applications.

The requirements for the use of multiple ground rods were revised. Revisions were also made in numerous areas of the standard for clarity and to enhance its usability. Revisions to the graphs and formulas for the rolling sphere method were made to facilitate their use in metric units.

Requirements were added to address proper installation of lightning protection equipment on large rooftop mechanical units. The installation of air terminals and main-size conductors in these applications were quantified and detailed.

Revisions were made to enhance and clarify the requirements for the bonding together of all grounded media and underground metallic piping. The intent was to provide for potential equalization and not to use the metallic piping as a lightning protection system grounding electrode. All grounding media and buried metallic conductors that might assist in providing a path for lightning currents in or on a structure must be interconnected to provide a common ground potential. Guidance was provided on the use of isolating spark gaps.

Significant changes were made to the requirements pertaining to the conductors and other lightning protection system hardware used near the top of a heavy-duty stack.

Other significant changes included a complete rewrite of Chapter 8, Protection for Watercraft, providing a number of technical revisions; more user information added in Annex B, Principles of Lightning Protection; and a revision of Annex F, Protection for Trees.

In addition to significant technical changes, the 2011 edition includes new and revised text.

With the addition of two new chapters, the 2011 edition of the standard presents a major change in the scope of the document. The first new chapter addresses the protection of structures housing ammunition and explosive materials. The second new chapter includes requirements for providing lightning protection for wind turbines, specifically wind turbine structures that comprise externally rotating blades, a nacelle, and a supporting tower. The 2011 edition has been substantially reorganized to accommodate these new chapters in a logical order.

The sections pertaining to strike termination devices, zones of protection, and the rolling sphere method have been totally reorganized for better usability. The text clearly provides that strike termination devices include air terminals, metal masts, permanent metal parts of structures, and overhead ground wires. The text qualifies where a metal mast would be permitted to serve as the down conductor. The requirements for overhead ground wires and masts and overhead ground wires have been relocated.

The 2011 edition clarifies the requirements for strike termination devices at the eaves for a pitched roof. Further, a figure has been added to graphically illustrate this condition.

A new section on roof top helipads provides requirements to ensure that an adequate level of protection is provided to these areas within the height and safety criteria set forth by the Federal Aviation Administration (FAA) or other AHJs.

Chapter 7 provides requirements for the protection of structures containing flammable vapors, flammable gases, or liquids that can give off flammable vapors. The section on floating-roof tanks has been revised in its entirety as a result of recent testing and research conducted for aboveground storage tanks.

The lightning risk assessment methodology provided in Annex L has been completely rewritten. The lightning risk assessment is provided to assist the building owner, safety professional, or architect/engineer in determining the risk of damage or injury due to lightning. This annex now provides both a simplified, quick-look assessment and a more detailed assessment for those requiring a more detailed analysis. Once the level of risk has been determined, the development of appropriate lightning protection measures can begin.

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NFPA 780

Standard for the

Installation of Lightning Protection Systems

2011 Edition

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Information on referenced publications can be found in Chapter 2 and Annex O.

Chapter 1 Administration

1.1 Scope.

1.1.1 This document shall cover traditional lightning protection system installation requirements for the following:

- (1) Ordinary structures
- (2) Miscellaneous structures and special occupancies
- (3) Heavy-duty stacks
- (4) Watercraft
- (5) Structures containing flammable vapors, flammable gases, or liquids that give off flammable vapors

1.1.2* This document shall not cover lightning protection system installation requirements for electric generating, transmission, and distribution systems.

1.1.3 This document shall not cover lightning protection system installation requirements for early streamer emission systems or charge dissipation systems.

1.2 Purpose. The purpose of this standard shall be to provide for the safeguarding of persons and property from hazards arising from exposure to lightning.

1.3 Listed, Labeled, or Approved Components. Where fittings, devices, or other components required by this standard are available as listed or labeled, such components shall be used.

1.4 Mechanical Execution of Work.

1.4.1 Lightning protection systems shall be installed in a neat and workmanlike manner.

1.4.2 The individual(s) responsible for the installation shall be certified for fitness on the requirements of this standard by the authority having jurisdiction.

1.5* Maintenance. Recommended guidelines for the maintenance of the lightning protection system shall be provided to the owner at the completion of installation.

1.6 Metric Units of Measurement. Metric units of measurement in this standard shall be in accordance with the modernized metric system known as the International System of Units (SI).

1.6.1 If a value for measurement as given in this standard is followed by an equivalent value in other units, the first stated value shall be the requirement.

1.6.2 A given equivalent value shall be approximate.

Chapter 2 Referenced Publications

2.1 General. The documents or portions thereof listed in this chapter are referenced within this standard and shall be considered part of the requirements of this document.

2.2 NFPA Publications. National Fire Protection Association, 1 Batterymarch Park, Quincy, MA 02169-7471.

NFPA 70®, *National Electrical Code*®, 2011 edition.

2.3 Other Publications.

2.3.1 UL Publications. Underwriters Laboratories Inc., 333 Pfingsten Road, Northbrook, IL 60062-2096.

ANSI/UL 1449, *UL Standard for Safety for Surge Protective Devices*, Third Edition, September 29, 2006.

2.3.2 Other Publications.

Merriam-Webster's Collegiate Dictionary, 11th edition, Merriam-Webster, Inc., Springfield, MA, 2003.

2.4 References for Extracts in Mandatory Sections.

NFPA 70®, *National Electrical Code*®, 2011 edition.

NFPA 115, *Standard for Laser Fire Protection*, 2008 edition.

Chapter 3 Definitions

3.1 General. The definitions contained in this chapter shall apply to the terms used in this standard. Where terms are not defined in this chapter or within another chapter, they shall be defined using their ordinarily accepted meanings within the context in which they are used. *Merriam-Webster's Collegiate Dictionary*, 11th edition, shall be the source for the ordinarily accepted meaning.

3.2 NFPA Official Definitions.

3.2.1* Approved. Acceptable to the authority having jurisdiction.

3.2.2* Authority Having Jurisdiction (AHJ). An organization, office, or individual responsible for enforcing the requirements of a code or standard, or for approving equipment, materials, an installation, or a procedure.



3.2.3 Labeled. Equipment or materials to which has been attached a label, symbol, or other identifying mark of an organization that is acceptable to the authority having jurisdiction and concerned with product evaluation, that maintains periodic inspection of production of labeled equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.

3.2.4* Listed. Equipment, materials, or services included in a list published by an organization that is acceptable to the authority having jurisdiction and concerned with evaluation of products or services, that maintains periodic inspection of production of listed equipment or materials or periodic evaluation of services, and whose listing states that either the equipment, material, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

3.2.5 Shall. Indicates a mandatory requirement.

3.2.6 Should. Indicates a recommendation or that which is advised but not required.

3.2.7 Standard. A document, the main text of which contains only mandatory provisions using the word “shall” to indicate requirements and which is in a form generally suitable for mandatory reference by another standard or code or for adoption into law. Nonmandatory provisions shall be located in an appendix or annex, footnote, or fine-print note and are not to be considered a part of the requirements of a standard.

3.3 General Definitions.

3.3.1* Air Terminal. A strike termination device that is a receptor for attachment of flashes to the lightning protection system and is listed for the purpose.

3.3.2 Bonding. An electrical connection between an electrically conductive object and a component of a lightning protection system that is intended to significantly reduce potential differences created by lightning currents.

3.3.3* Cable. A conductor formed of a number of wires stranded together.

3.3.4 Catenary Lightning Protection System. A lightning protection system consisting of one or more overhead ground wires.

3.3.5 Chimney. A construction containing one or more flues that does not meet the criteria defined for heavy-duty stack.

3.3.6* Combination Waveform Generator. A surge generator with a 2-ohm internal impedance producing a 1.2/50 μ s open circuit voltage and an 8/20 μ s short-circuit current waveshape.

3.3.7 Conductor.

3.3.7.1 Bonding Conductor. A conductor used for potential equalization between grounded metal bodies or electrically conductive objects and a lightning protection system.

3.3.7.2 Loop Conductor. A conductor encircling a structure that is used to interconnect grounding electrodes, main conductors, or other electrically conductive bodies.

3.3.7.3* Main Conductor. A conductor intended to be used to carry lightning currents between strike termination devices and grounding electrodes.

3.3.8 Copper-Clad Steel. Steel with a coating of copper bonded to it.

3.3.9 Discharge Current.

3.3.9.1 Maximum Discharge Current (I_{max}). The maximum instantaneous value of the current through the surge protective device (SPD) having an 8/20 μ s waveform.

3.3.9.2 Nominal Discharge Current (I_n). Peak value of 8/20 μ s current waveform selected by the manufacturer for which an SPD remains functional after 15 surges.

3.3.10 Fastener. An attachment device used to secure the conductor to the structure.

3.3.11 Flame Protection. Self-closing gauge hatches, vapor seals, pressure-vacuum breather valves, flame arresters, or other effective means to minimize the possibility of flame entering the vapor space of a tank.

3.3.12* Flammable Air-Vapor Mixtures. Flammable vapors mixed with air in proportions that will cause the mixture to burn rapidly when ignited.

3.3.13 Flammable Vapors. A concentration of constituents in air that exceeds 10 percent of its lower flammable limit (LFL). [115, 2008]

3.3.14 Flash Point. The minimum temperature at which a liquid or a solid emits vapor sufficient to form an ignitable mixture with air near the surface of the liquid or the solid.

3.3.15 Gastight. Describes a structure so constructed that gas or air cannot enter or leave the structure except through vents or piping provided for the purpose.

3.3.16 Grounded (Grounding). Connected (connecting) to ground or to a conductive body that extends the ground connection. [70: Article 100]

3.3.17 Grounding Electrode. The portion of a lightning protection system, such as a ground rod, ground plate electrode, or ground conductor, that is installed for the purpose of providing electrical contact with the earth.

3.3.18 Hazard Division 1.4. Ammunition and explosives that produce a moderate fire with no significant blast or fragment hazards.

3.3.19 Headwall. A retaining wall at the outlet of an earth-covered magazine.

3.3.20 Heavy-Duty Stack. A smoke or vent stack with a flue that has a cross-sectional area of the flue greater than 0.3 m² (500 in.²) and a height greater than 23 m (75 ft).

3.3.21 Lightning Electromagnetic Impulse (LEMP). Electromagnetic effects of lightning current, which includes conducted surges as well as radiated impulse electromagnetic field effects.

3.3.22* Lightning Protection System. A complete system of strike termination devices, conductors (which could include conductive structural members), grounding electrodes, interconnecting conductors, surge protective devices, and other connectors and fittings required to complete the system.

3.3.23 Liquid.

3.3.23.1 Class I Flammable Liquid. Any liquid that has a closed-cup flash point below 37.8°C (100°F) and a Reid vapor pressure not exceeding an absolute pressure of 276 kPa (40 psi) at 37.8°C (100°F).

3.3.23.2 Combustible Liquid. Any liquid that has a closed-cup flash point at or above 37.8°C (100°F).

3.3.24 Magazine. A structure specifically designed to store ammunition and explosives.

3.3.24.1 Earth-Covered Magazine (ECM) An aboveground, earth-covered structure with a minimum of 0.6 m (2 ft) soil cover depth and a slope of 2 horizontal and 1 vertical.

3.3.24.2 Portable Magazine. A magazine that can be moved from one location to another.

3.3.25 Magnetically Shielded. Enclosing all or part of an object in a metallic grid or continuous screen to reduce failures of electrical and electronic system components.

3.3.26 Materials.

3.3.26.1* Class I Materials. Lightning conductors, air terminals, grounding electrodes, and associated fittings required for the protection of structures not exceeding 23 m (75 ft) in height.

3.3.26.2* Class II Materials. Lightning conductors, air terminals, grounding electrodes, and associated fittings required for the protection of structures exceeding 23 m (75 ft) in height.

3.3.26.3 Explosive Materials. Materials, including explosives, blasting agents, and detonators, that are authorized for transportation by the Department of Transportation or the Department of Defense as explosive materials.

3.3.27 Sideflash. An electrical spark, caused by differences of potential, that occurs between conductive metal bodies or between conductive metal bodies and a component of a lightning protection system or ground.

3.3.28 Spark Gap. Any short air space between two conductors that are electrically insulated from or remotely electrically connected to each other.

3.3.29 Strike Termination Device. A component of a lightning protection system that intercepts lightning flashes and connects them to a path to ground. Strike termination devices include air terminals, metal masts, permanent metal parts of structures as described in Section 4.9, and overhead ground wires installed in catenary lightning protection systems.

3.3.30 Striking Distance. The distance over which the final breakdown of the initial lightning stroke to ground or to a grounded object occurs.

3.3.31 Structure.

3.3.31.1 Metal-Clad Structure. A structure with sides or roof, or both, covered with metal.

3.3.31.2 Metal-Framed Structure. A structure with electrically continuous structural members of sufficient size to provide an electrical path equivalent to that of lightning conductors.

3.3.32 Surge. A transient wave of current, potential, or power in an electric circuit. Surges do not include longer duration temporary overvoltages (TOV) consisting of an increase in the power frequency voltage for several cycles.

3.3.33 Surge Protective Device (SPD). A device intended for limiting surge voltages on equipment by diverting or limiting surge current that comprises at least one nonlinear component.

3.3.34 Transient. A subcycle disturbance in the ac waveform that is evidenced by a sharp, brief discontinuity of the wave-

form. It can be of either polarity and can be additive to, or subtractive from, the nominal waveform.

3.3.35 Vapor Opening. An opening through a tank shell or roof that is above the surface of the stored liquid and that is provided for tank breathing, tank gauging, fire-fighting, or other operating purposes.

3.3.36 Voltage.

3.3.36.1 Maximum Continuous Operating Voltage (MCOV).

The maximum designated rms value of the power frequency voltage that can be continuously applied to the mode of protection of a surge protective device (SPD).

3.3.36.2 Measured Limiting Voltage (MLV). Maximum magnitude of voltage that is measured across the terminals of the surge protective device (SPD) during the application of impulses of specified waveshape and amplitude.

3.3.36.3 Nominal System Voltage. The nominal voltage (rms) of the power frequency supply.

3.3.36.4 Normal Operating Voltage. The normal ac power frequency voltage rating, as specified by the manufacturer, to which the SPD may be connected.

3.3.37* Voltage Protection Rating (VPR). A rating (or ratings) selected by the manufacturer based on the measured limiting voltage determined when the SPD is subjected to a combination waveform with an open circuit voltage of 6 kV and a short-circuit current of 3 kA. The value is rounded up to the next highest 100 V level.

3.3.38 Watercraft. All forms of boats and vessels up to 272 metric tons (300 gross tons) used for pleasure or commercial purposes, but excluding seaplanes, hovercraft, vessels with a cargo of flammable liquids, and submersible vessels.

3.3.39 Zone of Protection. The space adjacent to a lightning protection system that is substantially immune to direct lightning flashes.

Chapter 4 Protection for Ordinary Structures

4.1 General.

4.1.1 Ordinary Structures. An ordinary structure shall be any structure that is used for ordinary purposes, whether commercial, industrial, farm, institutional, or residential.

4.1.1.1 Ordinary structures shall be protected according to 4.1.1.1.1 or 4.1.1.1.2.

4.1.1.1.1 Ordinary structures not exceeding 23 m (75 ft) in height shall be protected with Class I materials as shown in Table 4.1.1.1.1.

4.1.1.1.2 Ordinary structures exceeding 23 m (75 ft) in height shall be protected with Class II materials as shown in Table 4.1.1.1.2.

4.1.1.2 If part of a structure exceeds 23 m (75 ft) in height (e.g., a steeple) and the remaining portion does not exceed 23 m (75 ft) in height, the requirements for Class II air terminals and conductors shall apply only to that portion exceeding 23 m (75 ft) in height.

4.1.1.3 Class II conductors from the higher portion shall be extended to ground and shall be interconnected with the balance of the system.



Table 4.1.1.1.1 Minimum Class I Material Requirements

Type of Conductor	Parameter	Copper		Aluminum	
		SI	U.S.	SI	U.S.
Air terminal, solid	Diameter	9.5 mm	$\frac{3}{8}$ in.	12.7 mm	$\frac{1}{2}$ in.
Air terminal, tubular	Diameter	15.9 mm	$\frac{5}{8}$ in.	15.9 mm	$\frac{5}{8}$ in.
	Wall thickness	0.8 mm	0.033 in.	1.63 mm	0.064 in.
Main conductor, cable	Size each strand		17 AWG		14 AWG
	Weight per length	278 g/m	187 lb/1000 ft	141 g/m	95 lb/1000 ft
	Cross-section area	29 mm ²	57,400 cir. mils	50 mm ²	98,600 cir. mils
Bonding conductor, cable (solid or stranded)	Size each strand		17 AWG		14 AWG
	Cross-section area		26,240 cir. mils		41,100 cir. mils
Bonding conductor, solid strip	Thickness	1.30 mm	0.051 in.	1.63 mm	0.064 in.
	Width	12.7 mm	$\frac{1}{2}$ in.	12.7 mm	$\frac{1}{2}$ in.
Main conductor, solid strip	Thickness	1.30 mm	0.051 in.	1.63 mm	0.064 in.
	Cross-section area	29 mm ²	57,400 cir. mils	50 mm ²	98,600 cir. mils

Table 4.1.1.1.2 Minimum Class II Material Requirements

Type of Conductor	Parameter	Copper		Aluminum	
		SI	U.S.	SI	U.S.
Air terminal, solid	Diameter	12.7 mm	$\frac{1}{2}$ in.	15.9 mm	$\frac{5}{8}$ in.
Main conductor, cable	Size each strand		15 AWG		13 AWG
	Weight per length	558 g/m	375 lb/1000 ft	283 g/m	190 lb/1000 ft
	Cross-section area	58 mm ²	115,000 cir. mils	97 mm ²	192,000 cir. mils
Bonding conductor, cable (solid or stranded)	Size each strand		17 AWG		14 AWG
	Cross-section area		26,240 cir. mils		41,100 cir. mils
Bonding conductor, solid strip	Thickness	1.30 mm	0.051 in.	1.63 mm	0.064 in.
	Width	12.7 mm	$\frac{1}{2}$ in.	12.7 mm	$\frac{1}{2}$ in.
Main conductor, solid strip	Thickness	1.63 mm	0.064 in.	2.61 mm	0.1026 in.
	Cross-section area	58 mm ²	115,000 cir. mils	97 mm ²	192,000 cir. mils

4.1.2 Roof Types and Slope.

4.1.2.1 Pitched roofs shall be defined as roofs having a span of 12 m (40 ft) or less and a slope $\frac{1}{8}$ or greater, and roofs having a span of more than 12 m (40 ft) and a slope $\frac{1}{4}$ or greater.

4.1.2.2 A flat or gently sloping roof is defined as a roof with a slope less than a pitched roof.

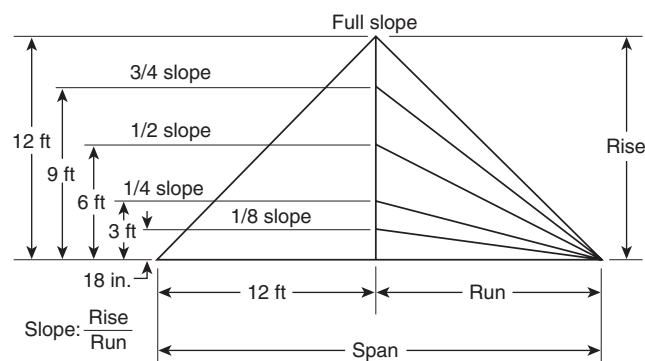
4.1.2.3 For purposes of this standard, roof pitches shall be as shown in Figure 4.1.2.3.

4.1.2.4 Protection for a shed roof shall be as illustrated for the gable method in Figure 4.1.2.4.

4.2 Materials. Protection systems shall be made of materials that are resistant to corrosion or protected against corrosion.

4.2.1 Combinations of materials that form electrolytic couples of such a nature that, in the presence of moisture, corrosion is accelerated shall not be used.

4.2.2 One or more of the materials in 4.2.2.1 through 4.2.2.3 shall be used.



Example: Rise = 3 ft
Run = 12 ft
Slope: $\frac{3 \text{ ft}}{12 \text{ ft}}$ ($\frac{1}{4}$ slope)

For SI units, 1 in. = 25.4 mm; 1 ft = 0.305 m.

FIGURE 4.1.2.3 Roof Slope.

4.2.2.1 Copper. Copper shall be of the grade required for commercial electrical work and shall be of 95 percent conductivity when annealed.

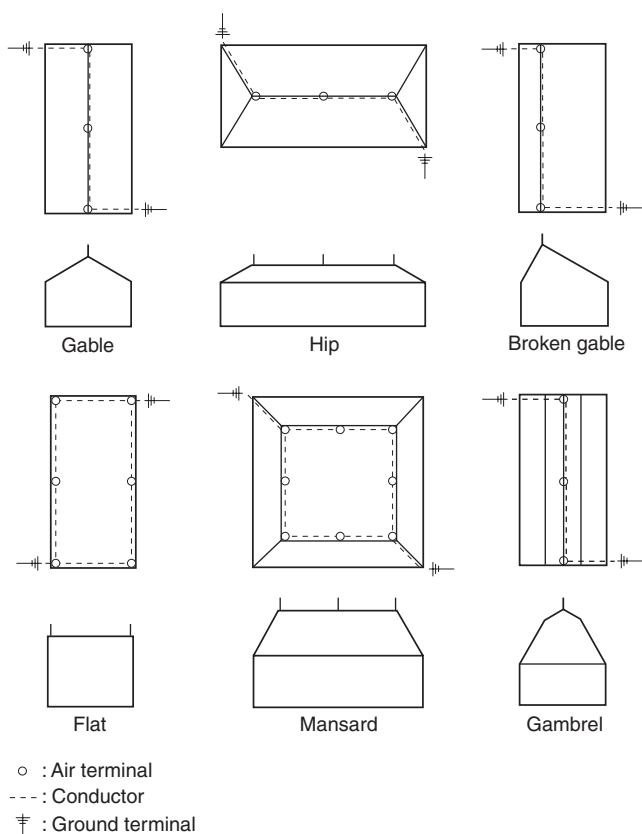


FIGURE 4.1.2.4 Protection Methods for Various Roof Types.
 (Drawings are top and end views of each roof type.)

4.2.2.2 Copper Alloys. Copper alloy shall be as resistant to corrosion as is copper.

4.2.2.3 Aluminum.

4.2.2.3.1 Aluminum shall not be used where contact with the earth is possible or where rapid deterioration is possible.

4.2.2.3.2 Conductors shall be of electrical-grade aluminum.

4.2.3 Copper lightning protection materials shall not be installed on or in contact with aluminum roofing, aluminum siding, or other aluminum surfaces.

4.2.4 Aluminum lightning protection materials shall not be installed on or in contact with copper surfaces.

4.3 Corrosion Protection.

4.3.1 Protection shall be provided against deterioration of lightning protection components due to local conditions.

4.3.2 Copper components installed within 600 mm (24 in.) of the top of a chimney or vent emitting corrosive gases shall be protected by a hot-dipped lead or tin coating.

4.3.3 Connectors and Fittings.

4.3.3.1 Connectors and fittings shall be compatible for use with the conductor and the surfaces on which they are installed.

4.3.3.2 Bimetallic connectors and fittings shall be used for splicing or bonding dissimilar metals.

4.4 Mechanical Damage or Displacement.

4.4.1 Any part of a lightning protection system that is subject to mechanical damage or displacement shall be protected with a protective molding or covering.

4.4.2 Where metal pipe or tubing is used around the conductor, the conductor shall be bonded to the pipe or tubing at both ends.

4.5 Use of Aluminum. Aluminum systems shall be installed in accordance with other applicable sections and 4.5.1 through 4.5.3.

4.5.1 Aluminum lightning protection equipment shall not be installed on or in direct contact with copper roofing materials or other copper surfaces, or where exposed to runoff from copper surfaces.

4.5.2 Aluminum materials shall not be used within 460 mm (18 in.) of the point where the lightning protection system conductor comes into contact with the earth.

4.5.2.1 Fittings used for the connection of aluminum down conductors to copper or copper-clad grounding equipment shall be of the bimetallic type.

4.5.2.2 Bimetallic connectors shall be installed not less than 460 mm (18 in.) above earth level.

4.5.3 An aluminum conductor shall not be attached to a surface coated with alkaline-base paint, embedded in concrete or masonry, or installed in a location subject to excessive moisture.

4.6 Strike Termination Devices.

4.6.1 General.

4.6.1.1 Strike termination devices shall include air terminals, metal masts, permanent metal parts of structures as described in 4.6.1.4, and overhead ground wires.

4.6.1.2 Combinations of these strike termination devices shall be permitted.

4.6.1.3 Strike termination devices shall be provided where required by other sections of this standard.

4.6.1.4 Metal parts of a structure that are exposed to direct lightning flashes and that have a metal thickness of 4.8 mm ($\frac{3}{16}$ in.) or greater shall require only connection to the lightning protection system in accordance with Section 4.9.

4.6.1.5 Strike termination devices shall not be required for those parts of a structure located within a zone of protection.

4.6.2 Air Terminals.

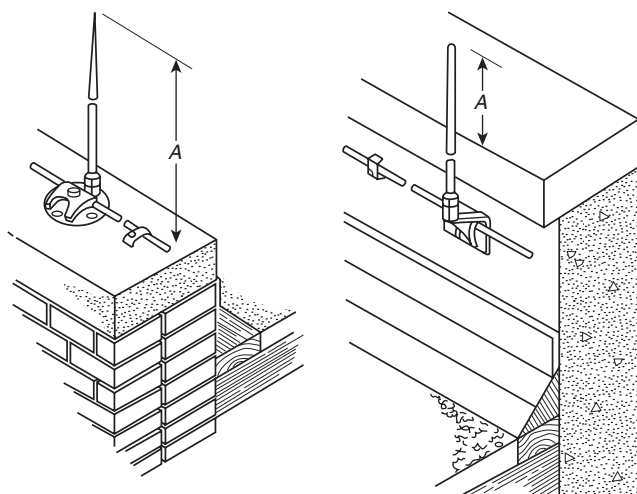
4.6.2.1* The tip of an air terminal shall be not less than 254 mm (10 in.) above the object or area it is to protect, as shown in Figure 4.6.2.1.

4.6.2.2 Air Terminal Support.

4.6.2.2.1 Air terminals shall be secured against overturning or displacement by one of the following methods:

- (1) Attachment to the object to be protected
- (2) Braces that are permanently and rigidly attached to the structure

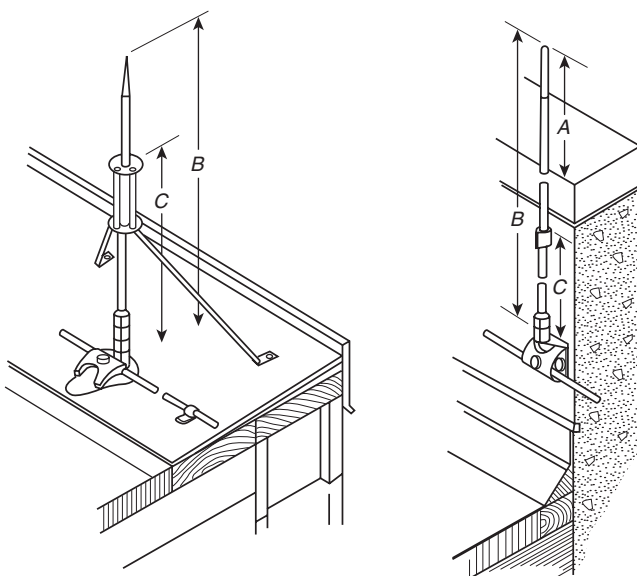
4.6.2.2.2 Air terminals exceeding 600 mm (24 in.) in height shall be supported at a point not less than one-half their height, as shown in Figure 4.6.2.2.2.



A: 254 mm (10 in.)

Note: Air terminal tip configurations can be sharp or blunt.

FIGURE 4.6.2.1 Air Terminal Height.



A: 600 mm (24 in.)

B: Air terminals over 600 mm (24 in.) high are supported

C: Air terminal supports are located at a point not less than one-half the height of the air terminal

Note: Air terminal tip configurations can be sharp or blunt.

FIGURE 4.6.2.2.2 Air Terminal Support.

4.6.2.3 Ornaments.

4.6.2.3.1 An ornament or decoration on a freestanding, unbraced air terminal shall not present, in any plane, a wind-resistance area in excess of 0.01 m² (20 in.²).

4.6.2.3.2 The requirement of 4.6.2.3.1 shall permit the use of an ornamental ball 127 mm (5 in.) or less in diameter.

4.6.3 Lightning Protection Masts.

4.6.3.1 Lightning protection masts shall be permitted to provide a zone of protection.

4.6.3.2 Metal masts shall comply with 4.6.1.4 or be protected with a strike termination device.

4.6.3.3 Nonmetallic masts shall be provided with at least one strike termination device.

4.6.3.4 The top of the metallic mast shall have a metal thickness of 4.8 mm (³/₁₆ in.) or greater or be provided with at least one strike termination device.

4.6.3.5 The mast shall be permitted to serve as the down conductor, provided it is electrically continuous and has a wall thickness of 1.63 mm (0.064 in.) minimum.

4.6.4 Overhead Ground Wires.

4.6.4.1 Overhead ground wires shall be permitted to provide a zone of protection.

4.6.4.2 Overhead ground wire material shall be constructed of aluminum, copper, stainless steel, galvanized steel, or protected steel such as copper-clad, aluminum-clad, or aluminum conductor steel reinforced (ACSR).

4.6.4.3 The overhead ground wire material shall be chosen to minimize corrosion from conditions at the site.

4.6.4.4 The overhead ground wire shall be sized to have the same cross-sectional area as a main lightning conductor and shall be self-supporting with minimum sag under all conditions.

4.6.5* Isolated Masts and Overhead Ground Wires. To prevent sideflashes, the minimum distance between a mast or overhead ground wire and the structure to be protected shall be calculated.

4.6.5.1 Sideflash distance from a mast shall be calculated from the following formula:

$$D = \frac{h}{6}$$

where:

D = sideflash distance from a mast

h = height of structure (or object being calculated)

4.6.5.2 The sideflash distance from an overhead ground wire shall be calculated as follows:

$$D = \frac{l}{6n}$$

where:

D = sideflash distance from a mast or overhead ground wire

l = length of lightning protection conductor between its grounded point and the point being calculated

n = 1 where there is a single overhead ground wire that exceeds 60 m (200 ft) in horizontal length

n = 1.5 where there is a single overhead wire or more than one wire interconnected above the structure to be protected, such that only two down conductors are located greater than 6 m (20 ft) and less than 30 m (100 ft) apart

n = 2.25 where there are more than two down conductors spaced more than 7.6 m (25 ft) apart within a 30 m (100 ft) wide area that are interconnected above the structure being protected

4.7 Zones of Protection. The geometry of the structure shall determine the zone of protection.

4.7.1 One or more of the methods described in 4.7.2 through 4.7.4 and Section 4.8 shall be used to determine the overall zone of protection.

4.7.2 Roof Types. The zone of protection for the following roof types shall include the roof and appurtenances where protected in accordance with Section 4.8:

- (1) Pitched roofs
- (2) Flat or gently sloping roofs
- (3) Dormers
- (4) Domed roofs
- (5) Roofs with ridges, wells, chimneys, or vents

4.7.3 Multiple-Level Roofs.

4.7.3.1 For structures with multiple-level roofs no more than 15 m (50 ft) in height, the zone of protection shall include areas as identified in 4.7.3.3 and 4.7.3.4.

4.7.3.2 The zone of protection shall be permitted to be delineated by a cone with the apex located at the highest point of the strike termination device, with its surface formed by a 45-degree or 63-degree angle from the vertical, based on the height of the strike termination device above the ground as defined in 4.7.3.3 and 4.7.3.4.

4.7.3.3 Structures that do not exceed 7.6 m (25 ft) above earth shall be considered to protect lower portions of a structure located within a one-to-two zone of protection as shown in Figure 4.7.3.3(a) and Figure 4.7.3.3(b).

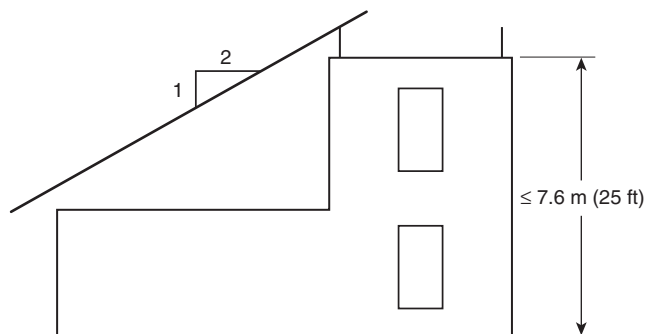


FIGURE 4.7.3.3(a) Lower Roof Protection for Flat-Roof Buildings 7.6 m (25 ft) or Less in Height.

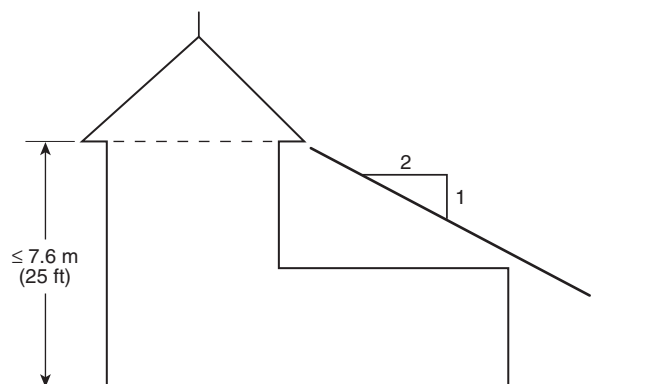


FIGURE 4.7.3.3(b) Lower Roof Protection Provided by Pitched-Roof Buildings 7.6 m (25 ft) or Less in Height.

4.7.3.4* Structures that do not exceed 15 m (50 ft) above earth shall be considered to protect lower portions of a structure located within a one-to-one zone of protection as shown in Figure 4.7.3.4(a) and Figure 4.7.3.4(b).

4.7.4 Rolling Sphere Method.

4.7.4.1* The zone of protection shall include the space not intruded by a rolling sphere having a radius of the striking distance determined for the type of structure being protected, as shown in Figure 4.7.4.1.

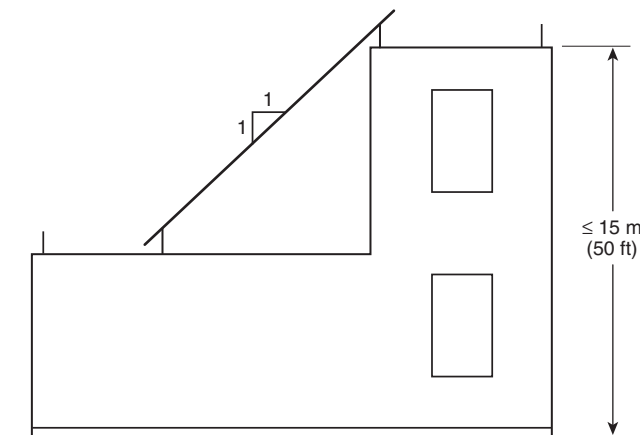


FIGURE 4.7.3.4(a) Lower Roof Protection for Buildings 15 m (50 ft) or Less in Height.

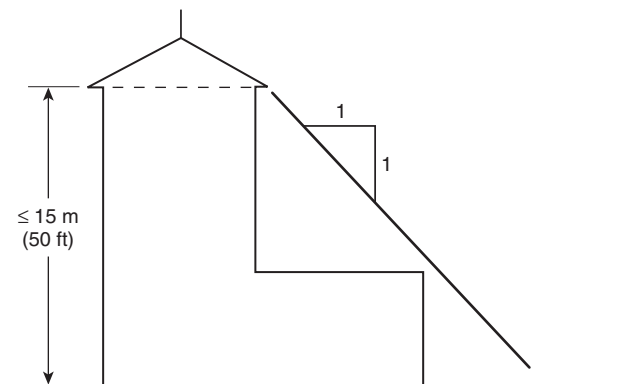


FIGURE 4.7.3.4(b) Lower Roof Protection Provided by Pitched-Roof Buildings 15 m (50 ft) or Less in Height.

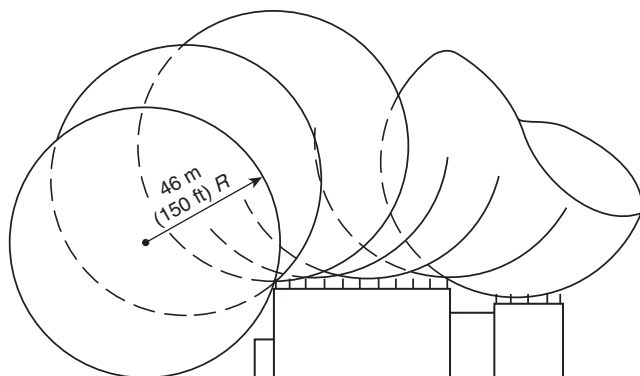


FIGURE 4.7.4.1 Zone of Protection Depicting Rolling Sphere Method.

4.7.4.1.1 Where the sphere is tangent to earth and resting against a strike termination device, all space in the vertical plane between the two points of contact and under the sphere shall be considered to be in the zone of protection.

4.7.4.1.2 A zone of protection shall also be formed where such a sphere is resting on two or more strike termination devices and shall include the space in the vertical plane under the sphere and between those devices, as shown in Figure 4.7.4.1.

4.7.4.1.3 All possible placements of the sphere shall be considered when determining the overall zone of protection using the rolling sphere method.

4.7.4.1.4 The striking distance of an ordinary structure shall not exceed 46 m (150 ft).

4.7.4.2* For structure heights exceeding the striking distance above earth or above a lower strike termination device, the zone of protection shall be the space in the vertical plane between the points of contact, and also under the sphere where the sphere is resting against a vertical surface of the structure and the lower strike termination device(s) or earth.

4.7.4.3 Under the rolling sphere method, the horizontal protected distance found geometrically by Figure A.4.7.4.1 also shall be permitted to be calculated using the following formula (units shall be consistent, m or ft):

$$d = \sqrt{h_1(2R - h_1)} - \sqrt{h_2(2R - h_2)}$$

where:

d = horizontal protected distance (m or ft)

h_1 = height of the higher roof (m or ft)

R = rolling sphere striking distance radius (m or ft)

h_2 = height of the lower roof (top of the object) (m or ft)

4.7.4.3.1 For the formula to be valid, the sphere shall be either tangent to the lower roof or in contact with the earth, and in contact with the vertical side of the higher portion of the structure.

4.7.4.3.2 In addition, the difference in heights between the upper and lower roofs or earth shall be the striking distance or less.

4.8 Strike Termination Devices on Roofs.

4.8.1* Location of Devices. As shown in Figure 4.8.1, the distance between strike termination devices and ridge ends on pitched roofs, or edges and outside corners of flat or gently sloping roofs, shall not exceed 0.6 m (2 ft).

4.8.1.1 Strike termination devices shall be placed on ridges of pitched roofs, and around the perimeter of flat or gently sloping roofs, at intervals not exceeding 6 m (20 ft).

4.8.1.2 Strike termination devices 0.6 m (2 ft) or more above the object or area to be protected shall be permitted to be placed at intervals not exceeding 7.6 m (25 ft).

4.8.2 Pitched Roof Area. For a pitched roof with eave heights over 15 m (50 ft) but less than 46 m (150 ft) above grade, it shall be permitted to omit strike termination devices at the eaves if the slope of that roof is equal to or steeper than the tangent of the arc at the eave elevation of a rolling sphere having a 46 m (150 ft) radius. (See Figure 4.8.2.)

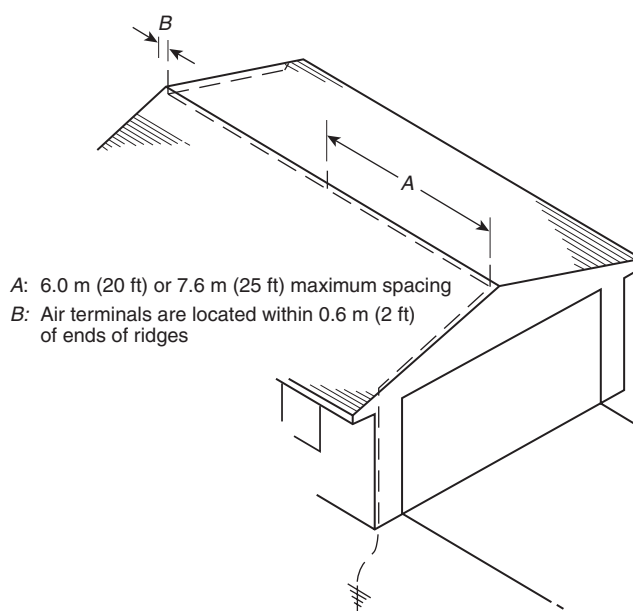


FIGURE 4.8.1 Air Terminals on a Pitched Roof.

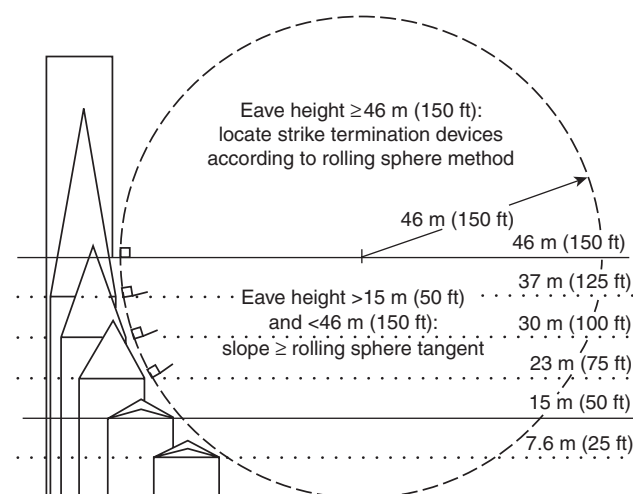


FIGURE 4.8.2 Illustration of Tangent of Rolling Sphere Method.

4.8.2.1 Except for the gutter, any portion of the building that extends beyond that tangent shall be protected.

4.8.2.2 Eaves over 46 m (150 ft) above grade shall be protected in accordance with 4.8.1.

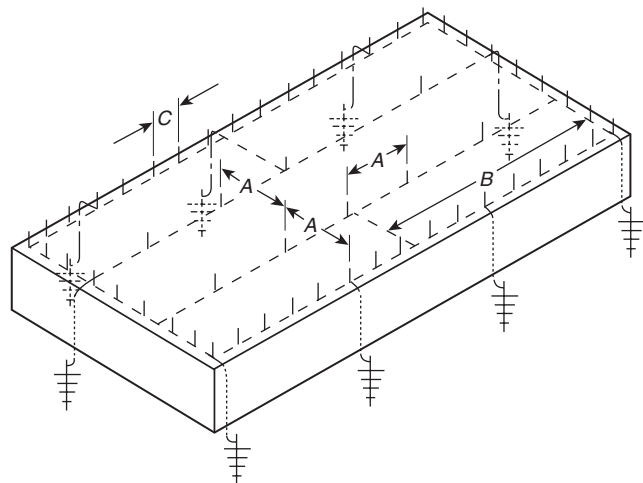
4.8.2.3 The tangent of the rolling sphere arc shall be considered a vertical line over 46 m (150 ft) above grade, except as permitted by 4.7.3.4.

4.8.3 Flat or Gently Sloping Roof Area. Flat or gently sloping roofs that exceed 15 m (50 ft) in width or length shall have additional strike termination devices located at intervals

not to exceed 15 m (50 ft) on the flat or gently sloping areas, as shown in Figure 4.8.3(a) and Figure 4.8.3(b), or such area can also be protected using taller strike termination devices that create zones of protection using the rolling sphere method so the sphere does not contact the flat or gently sloping roof area.

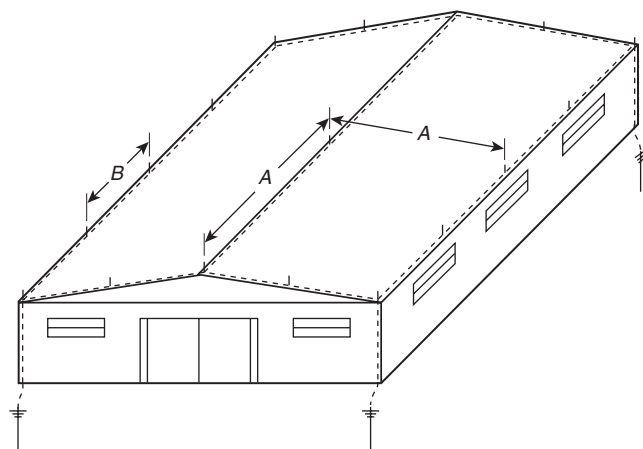
4.8.4* Dormers.

4.8.4.1 Dormers as high as or higher than the main roof ridge shall be protected with strike termination devices, conductors, and grounds.



- A: 15 m (50 ft) maximum spacing between air terminals
 B: 45 m (150 ft) maximum length of cross-run conductor permitted without a connection from the cross-run conductor to the main perimeter or down conductor
 C: 6 m (20 ft) or 7.6 m (25 ft) maximum spacings between air terminals along edge

FIGURE 4.8.3(a) Air Terminals on a Flat Roof.



- A: 15 m (50 ft) maximum spacing
 B: 6 m (20 ft) or 7.6 m (25 ft) maximum spacing

FIGURE 4.8.3(b) Air Terminals on a Gently Sloping Roof.

4.8.4.2 Dormers and projections below the main ridge shall require protection only on those areas extending outside a zone of protection.

4.8.5 Roofs with Intermediate Ridges. Strike termination devices shall be located along the outermost ridges of buildings that have a series of intermediate ridges at the same intervals as required by 4.8.1.

4.8.5.1 Strike termination devices shall be located on the intermediate ridges in accordance with the requirements for the spacing of strike termination devices on flat or gently sloping roofs.

4.8.5.2 If any intermediate ridge is higher than the outermost ridges, it shall be treated as a main ridge and protected according to 4.8.1.

4.8.6 Flat or Gently Sloping Roofs with Irregular Perimeters. Structures that have exterior wall designs that result in irregular roof perimeters shall be treated on an individual basis.

4.8.6.1 The imaginary roof edge formed by the outermost projections shall be used to locate the strike termination devices in accordance with 4.8.1.

4.8.6.2 In all cases, however, strike termination devices shall be located in accordance with Section 4.8, as shown in Figure 4.8.6.2.

4.8.6.3 Strike termination devices installed on vertical roof members shall be permitted to use a single main-size cable to connect to a main roof conductor.

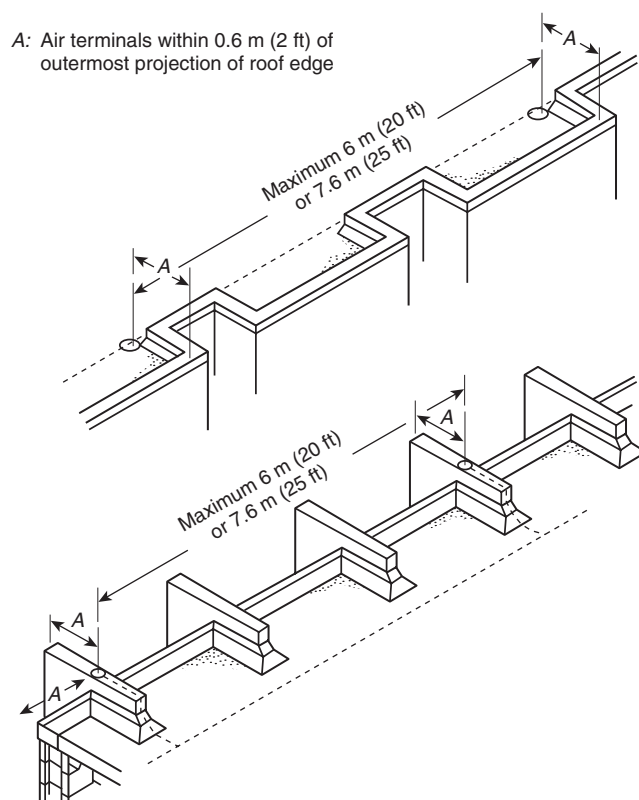
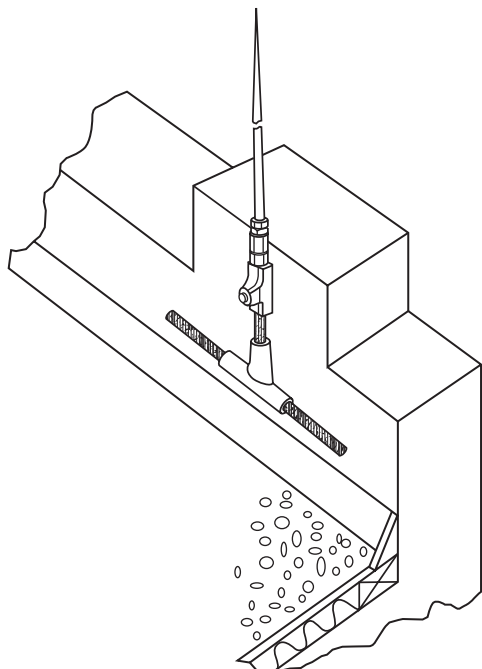


FIGURE 4.8.6.2 Flat or Gently Sloping Roof with an Irregular Perimeter.



4.8.6.4 The main roof conductor shall be run adjacent to the vertical roof members so that the single cable from the strike termination device is as short as possible and in no case longer than 4.9 m (16 ft).

4.8.6.5 The connection of the single cable to the down conductor shall be made with a tee splice or other fitting listed for the purpose, as shown in Figure 4.8.6.5.



Note: Air terminal tip configurations can be sharp or blunt.

FIGURE 4.8.6.5 Irregular Roof Perimeter.

4.8.7 Open Areas in Flat Roofs. The perimeter of open areas, such as light or mechanical wells, shall be protected if the open area perimeter exceeds 92 m (300 ft), provided both rectangular dimensions exceed 15 m (50 ft).

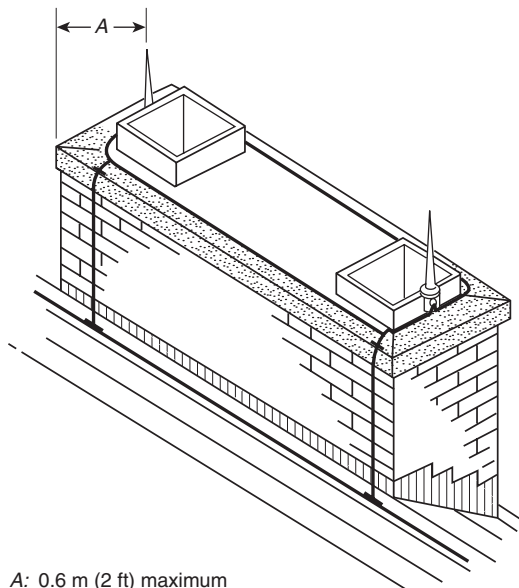
4.8.8 Domed or Rounded Roofs. Strike termination devices shall be located so that no portion of the structure is located outside a zone of protection, as set forth in Section 4.7.

4.8.9 Chimneys and Vents. Strike termination devices shall be required on all chimneys and vents that are not located within a zone of protection, including metal chimneys having a metal thickness of less than 4.8 mm ($\frac{3}{16}$ in.).

4.8.9.1 Chimneys or vents with a metal thickness of 4.8 mm ($\frac{3}{16}$ in.) or more shall require only a connection to the lightning protection system.

4.8.9.2 The connection for 4.8.9.1 shall be made using a main-size lightning conductor and a connector that has a surface contact area of not less than 1940 mm² (3 in.²) and shall provide two or more paths to ground, as is required for strike termination devices.

4.8.9.3* Required strike termination devices shall be installed on chimneys and vents, as shown in Figure 4.8.9.3, so that the distance from a strike termination device to an outside corner or the distance perpendicular to an outside edge is not greater than 0.6 m (2 ft).



A: 0.6 m (2 ft) maximum

Note: Air terminal tip configurations can be sharp or blunt.

FIGURE 4.8.9.3 Air Terminals on a Chimney.

4.8.9.4 Where only one strike termination device is required on a chimney or vent, at least one main-size conductor shall connect the strike termination device to a main conductor at the location where the chimney or vent meets the roof surface and provides two or more paths to ground from that location in accordance with Section 4.9 and 4.9.2.

4.8.10 Metal Roof Top Units. Strike termination devices shall be required in accordance with 4.8.10.1 through 4.8.10.3.2 on all roof top mechanical units with continuous metal housings less than 4.8 mm ($\frac{3}{16}$ in.) thick such as air-conditioning/heating units, metal air intake/exhaust housings, and cooling towers, that are not located in a zone of protection.

4.8.10.1 Air terminals shall be installed in accordance with 4.8.1 through 4.8.3.

4.8.10.2 The air terminals shall be mounted on bases having a minimum contact area of 1940 mm² (3 in.²), each secured to bare metal of the housing or mounted by drilling and tapping to the unit's frame in accordance with 4.16.3.2 and 4.16.3.3.

4.8.10.3 At least two main-size conductors shall be installed to connect the unit to the lightning protection system.

4.8.10.3.1 The connection shall be made to bare metal at the base or lower edges of the unit using main-size lightning conductors and bonding devices that have a surface contact area of not less than 1940 mm² (3 in.²) and shall provide two or more paths to ground, as is required for strike termination devices.

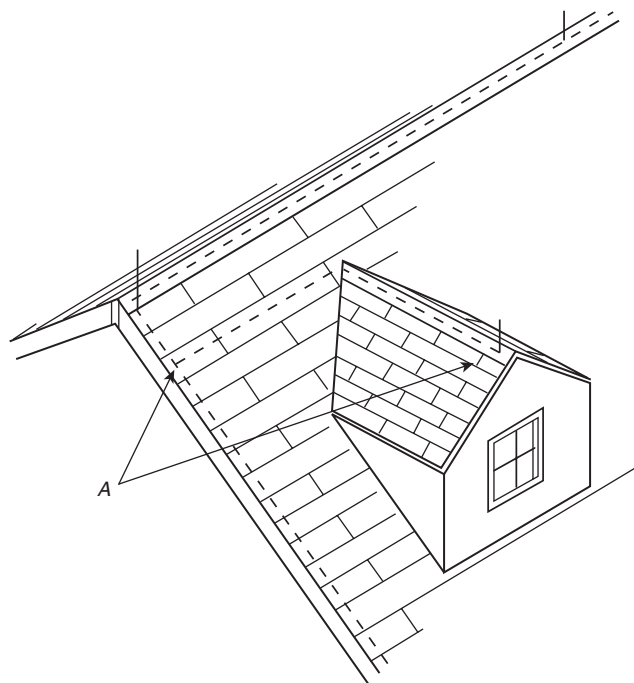
4.8.10.3.2 The two main bonding plates shall be located as far apart as practicable at the base or lower edges of the unit's electrically continuous metal housing and connected to the lightning protection system.

4.9 Conductors. Main conductors shall interconnect all strike termination devices and shall form two or more paths from each strike termination device downward, horizontally, or rising at no more than 1/4 slope to connections with grounding electrodes, except as permitted by 4.9.1 and 4.9.2.

4.9.1 One-Way Path. Strike termination devices on a lower roof level that are interconnected by a conductor run from a higher roof level shall require only one horizontal or downward path to ground, provided the lower level roof conductor run does not exceed 12 m (40 ft).

4.9.2 Dead Ends. A "dead ended" main conductor shall be permitted between a single strike termination device or connector fitting and a main conductor run under the following conditions:

- (1) Where the main-size conductor run to which the dead end is connected has a two-way path to ground
- (2) At a main protected roof level, where the horizontal portion of the dead-end conductor is not more than 2.4 m (8 ft) in total length
- (3) On a roof below the main protected roof level, where the dead-end conductor is not more than 4.9 m (16 ft) in total length, as shown in Figure 4.9.2
- (4) Where all dead-end conductor runs maintain a horizontal or downward course from the strike termination device to the connection point with the main conductor run



A: Permissible dead-end total conductor length not over 4.9 m (16 ft)

FIGURE 4.9.2 Dead End.

4.9.3 Substitution of Main Conductor.

4.9.3.1 Ancillary metal parts of a structure, such as eave troughs, downspouts, ladders, chutes, or other metal parts except as permitted in 4.16.1, shall not be substituted for the main conductor.

4.9.3.2 Permanent exterior metal handrails and ladders that are subject to direct lightning strikes (e.g., on roofs or between roofs) and are electrically continuous shall be permitted to be used as main conductors where the minimum thickness is 1.63 mm (0.064 in.).

4.9.3.3 Likewise, metal roofing or siding having a thickness of less than 4.8 mm (3/16 in.) shall not be substituted for main conductors.

4.9.4 "U" or "V" Pockets.

4.9.4.1 Conductors shall maintain a horizontal or downward coursing free from "U" or "V" (down and up) pockets.

4.9.4.2 Such pockets, often formed at low-positioned chimneys, dormers, or other projections on sloped roofs or at parapet walls, shall be provided with a down conductor from the base of the pocket to ground or to an adjacent downlead conductor, as shown in Figure 4.9.4.2.

4.9.5 Conductor Bends. No bend of a conductor shall form an included angle of less than 90 degrees, nor shall it have a radius of bend less than 203 mm (8 in.), as shown in Figure 4.9.5.

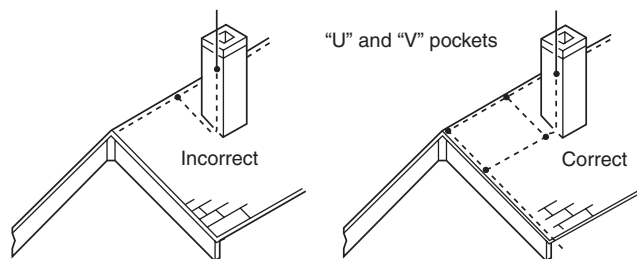
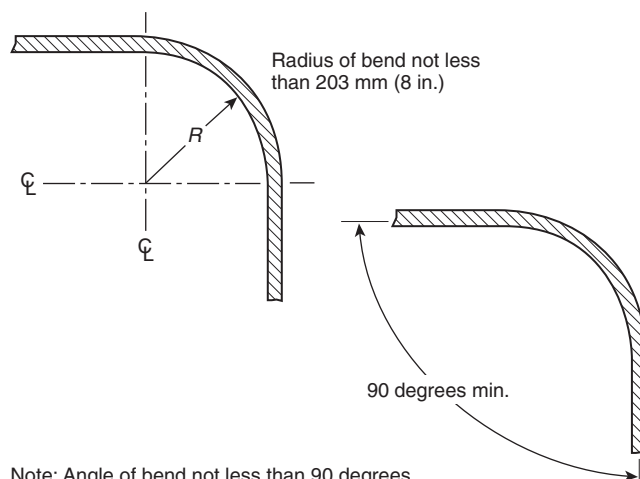


FIGURE 4.9.4.2 Pockets.



Note: Angle of bend not less than 90 degrees.

FIGURE 4.9.5 Conductor Bends.

4.9.6 Conductor Supports.

4.9.6.1 Conductors shall be permitted to be coursed through air without support for a distance of 0.9 m (3 ft) or less.

4.9.6.2 Conductors that must be coursed through air for distances longer than that permitted in 4.9.6.1 shall be provided with a positive means of support that will prevent damage or displacement of the conductor.

4.9.7 Roof Conductors.

4.9.7.1 Roof conductors shall be coursed along ridges of gable, gambrel, and hip roofs; around the perimeter of flat roofs; behind or on top of parapets; and across flat or gently sloping roof areas as required to interconnect all strike termination devices.

4.9.7.2 Conductors shall be coursed through or around obstructions (e.g., cupolas and ventilators) in a horizontal plane with the main conductor.

4.9.8 Cross-Run Conductors. Cross-run conductors (main conductors) shall be required to interconnect the strike termination devices on flat or gently sloping roofs that exceed 15 m (50 ft) in width.

4.9.8.1 For example, roofs from 15 m to 30 m (50 ft to 100 ft) in width shall require one cross-run conductor, roofs 30 m to 46 m (100 ft to 150 ft) in width shall require two cross-run conductors, and so on.

4.9.8.2 Cross-run conductors shall be connected to the main perimeter cable at intervals not exceeding 46 m (150 ft), as shown in Figure 4.8.3(a).

4.9.9 Down Conductors.

4.9.9.1 Down conductors shall be as widely separated as practicable.

4.9.9.2 The location of down conductors shall depend on considerations such as the following:

- (1) Placement of strike termination devices
- (2) Most direct coursing of conductors
- (3) Earth conditions
- (4) Security against displacement
- (5) Location of large metallic bodies
- (6) Location of underground metallic piping systems

4.9.10 Number of Down Conductors. At least two down conductors shall be provided on any kind of structure, including steeples.

4.9.10.1 Structures exceeding 76 m (250 ft) in perimeter shall have a down conductor for every 30 m (100 ft) of perimeter or fraction thereof.

4.9.10.2 The total number of down conductors on structures having flat or gently sloping roofs shall be such that the average distance between all down conductors does not exceed 30 m (100 ft).

4.9.10.3 Irregularly shaped structures shall have additional down conductors as necessary to provide a two-way path from each strike termination device.

4.9.10.4 For a flat or gently sloping roof structure, only the perimeter of the roof areas requiring protection shall be measured.

4.9.10.5 When determining the perimeter of a pitched roof structure, the horizontal projection (footprint) of the protected roof shall be measured as shown in Figure 4.9.10.5.

4.9.10.6 Lower roofs or projections that are located within a zone of protection shall not be required to be included in the perimeter measurement.

4.9.11 Protecting Down Conductors. Down conductors located in runways, driveways, school playgrounds, cattle yards, public walks, or other locations subject to physical damage or displacement shall be guarded.

4.9.11.1 Metallic guards shall be bonded at each end.

4.9.11.2 The down conductor shall be protected for a minimum distance of 1.8 m (6 ft) above grade level.

4.9.12 Down Conductors Entering Corrosive Soil. Down conductors entering corrosive soil shall be protected against corrosion by a protective covering beginning at a point 0.9 m (3 ft) above grade level and extending for their entire length below grade.

4.9.13 Down Conductors and Structural Columns. Down conductors coursed on or in reinforced concrete columns or on structural steel columns shall be connected to the reinforcing steel or the structural steel member at their upper and lower extremities.

4.9.13.1 In the case of long vertical members, an additional connection shall be made at intervals not exceeding 60 m (200 ft).

4.9.13.2 The connections for 4.9.13.1 shall be made using listed clamps or listed bonding plates or by welding or brazing.

4.9.13.3 Where the bonding requirements of 4.9.13.1 and 4.9.13.2 are not satisfied, provisions shall be made to ensure the required interconnection of these parallel vertical paths.

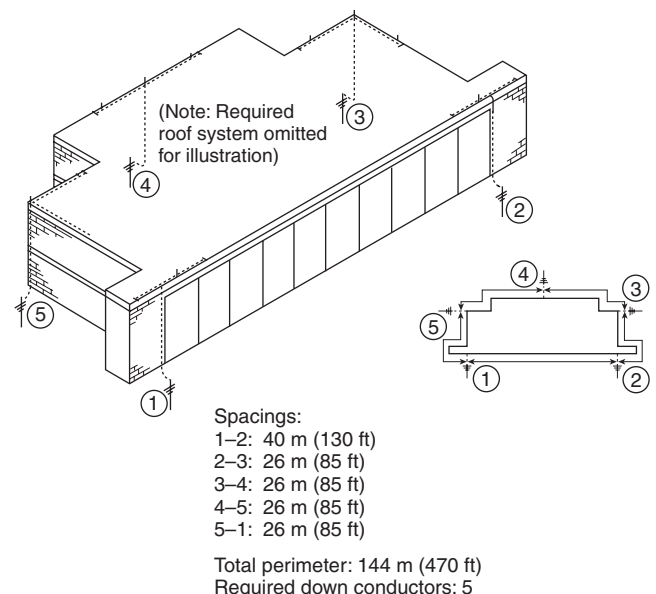


FIGURE 4.9.10.5 Quantity of Down Conductors.

4.9.14 Down Conductors in Nonmetallic Enclosures. The use of PVC conduit or other nonmetallic chase shall not eliminate the need to satisfy the bonding requirements of Sections 4.19, 4.20, and 4.21.

4.10 Conductor Fasteners. Conductors shall be fastened to the structure upon which they are placed at intervals not exceeding 0.9 m (3 ft).

4.10.1 Attached by 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.

4.10.2 No combination of materials shall be used that will form an electrolytic couple of such a nature that, in the presence of moisture, corrosion will be accelerated.

4.11 Masonry Anchors. Masonry anchors used to attach lightning protection materials shall have a minimum outside diameter of 6.4 mm ($\frac{1}{4}$ in.).

4.11.1 Holes made to receive the body of the anchor shall be of the correct size and made in the brick, stone, or other masonry unit rather than in mortar joints.

4.11.2 Where the anchors are installed, the fit shall be tight against moisture, thus reducing the possibility of damage due to freezing.

4.12 Connector Fittings. Connector fittings shall be used at all "end-to-end," "tee," or "Y" splices of lightning conductors.

4.12.1 Fittings shall be attached so as to withstand a pull test of 890 N (200 lb).

4.12.2 Fittings used for required connections to metal bodies in or on a structure shall be secured to the metal body by bolting, brazing, welding, or using high-compression connectors listed for the purpose.

4.12.3 Conductor connections shall be of the bolted, welded, high compression, or crimp type.

4.12.4 Crimp-type connections shall not be used with Class II conductors.

4.13 Grounding Electrodes.

4.13.1 General.

4.13.1.1 Each down conductor shall terminate at a grounding electrode dedicated to the lightning protection system.

4.13.1.2 The design, size, depth, and number of grounding electrodes used shall comply with 4.13.2 through 4.13.8.

4.13.1.3 Underground metallic piping or ground rod-type electrodes for electrical, communications, or other systems shall not be used in lieu of lightning grounding electrodes.

4.13.1.4 The down conductor(s) shall be attached permanently to the grounding electrode system by bolting, brazing, welding, or high-compression connectors listed for the purpose, and clamps shall be suitable for direct burial.

4.13.1.5 Grounding electrodes shall be installed below the frost line where possible (excluding shallow topsoil conditions).

4.13.1.6* In corrosive environments, the use of stainless steel alloy grounding electrodes shall be permitted.

4.13.2* Ground Rods.

4.13.2.1 Ground rods shall be not less than 12.7 mm ($\frac{1}{2}$ in.) in diameter and 2.4 m (8 ft) long.

4.13.2.2 Rods shall be free of paint or other nonconductive coatings.

4.13.2.3 Ground Rod Depth.

4.13.2.3.1 The ground rods shall extend vertically not less than 3 m (10 ft) into the earth.

4.13.2.3.2 The earth shall be compacted and made tight against the length of the conductor and ground rod, as illustrated in Figure 4.13.2.3.2.

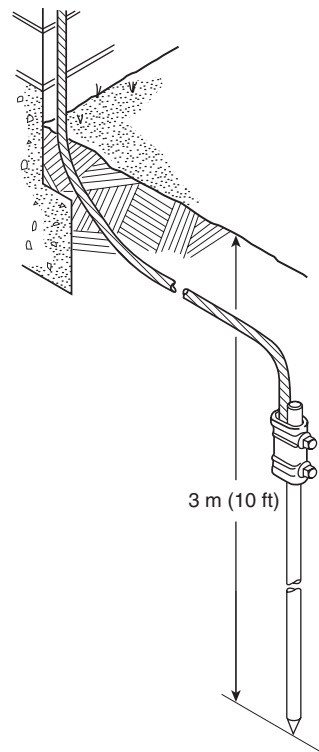


FIGURE 4.13.2.3.2 Typical Single Ground Rod Installation.

4.13.2.4* Multiple Ground Rods. Where multiple connected ground rods are used, the separation between any two ground rods shall be at least the sum of their driven depths, where practicable.

4.13.2.5 Ground rods shall be copper-clad steel, solid copper, or stainless steel.

4.13.3 Concrete-Encased Electrodes. Concrete-encased electrodes shall be used only in new construction.

4.13.3.1 The electrode shall be located near the bottom of a concrete foundation or footing that is in direct contact with the earth and shall be encased by not less than 50 mm (2 in.) of concrete.

4.13.3.2 The encased electrode shall consist of one of the following:

- (1) Not less than 6 m (20 ft) of bare copper main-size conductor
- (2) At least 6 m (20 ft) of one or more steel reinforcing bars or rods not less than 12.7 mm ($\frac{1}{2}$ in.) in diameter that have been effectively bonded together by either welding or overlapping 20 diameters and wire tying

4.13.4 Ground Ring Electrode. A ground ring electrode encircling a structure shall be as shown in Figure 4.13.4.

4.13.4.1 The ground ring electrode shall be in direct contact with earth at a depth of not less than 460 mm (18 in.) or encased in a concrete footing in accordance with 4.13.3.

4.13.4.2 The ground ring electrode shall be a main-size lightning conductor.

4.13.5* Radials.

4.13.5.1 A radial electrode system shall consist of one or more main-size conductors, each in a separate trench extending outward from the location of each down conductor.

4.13.5.2 Each radial electrode shall be not less than 3.6 m (12 ft) in length.

4.13.5.3 The radial electrode shall be buried not less than 460 mm (18 in.) below grade.

4.13.6* Plate Electrode or Ground Plate Electrode.

4.13.6.1 A ground plate or plate electrode shall have a minimum thickness of 0.8 mm (0.032 in.) and a minimum surface area of 0.18 m² (2 ft²).

4.13.6.2 The ground plate electrode shall be buried not less than 460 mm (18 in.) below grade.

4.13.7 Combinations. Combinations of the grounding electrodes in Section 4.13 shall be permitted.

4.13.8 Grounding Electrode Selection Criteria. The site limitations and soil conditions shall determine the selection of the type or combinations of types of grounding electrodes used.

4.13.8.1* Shallow Topsoil. The methods in 4.13.3 through 4.13.7 shall be used in shallow topsoil conditions where practicable.

4.13.8.1.1 Where the methods described in 4.13.3 through 4.13.6 are found to be impractical due to topsoil depth less than 460 mm (18 in.), it shall be permitted to provide a ground terminal buried at the maximum depth of topsoil available.

4.13.8.1.2 The ground terminal for shallow topsoil shall be either a ground ring electrode, in accordance with 4.13.4, a

minimum distance of 0.6 m (2 ft) from the foundation or exterior footing; radial(s) in accordance with 4.13.5; or a plate electrode, in accordance with 4.13.6, a minimum distance of 0.6 m (2 ft) from the foundation or exterior footing. The ground ring electrode, radial(s), or plate electrode shall be buried at maximum depth of topsoil available.

4.13.8.1.3 Where a method of 4.13.8.1.2 is impossible, radial(s) shall be permitted to be laid directly on bedrock a minimum distance of 3.6 m (12 ft) from the foundation or exterior footing. A ground ring electrode encircling the structure shall be permitted to be laid directly on bedrock a minimum distance of 0.6 m (2 ft) from the foundation or exterior footing.

4.13.8.1.4 In those cases where the grounding conductor is laid directly on bedrock, the conductor shall be secured to the bedrock every 0.9 m (3 ft) by nailing, conductive cement, or a conductive adhesive to ensure electrical contact and protect against movement.

4.13.8.2 Sandy Soil Conditions. Because sandy or gravelly soil conditions are characterized by high soil resistivity, multiple grounding electrodes shall be used to augment the lightning grounding electrode system.

4.14 Common Grounding.

4.14.1 General. All grounding media and buried metallic conductors that can assist in providing a path for lightning currents in or on a structure shall be interconnected to provide a common ground potential.

4.14.1.1 This interconnection shall include lightning protection, electric service, communications, and antenna system grounds, as well as underground metallic piping systems.

4.14.1.2 Underground metallic piping systems shall include water service, well casings located within 7.6 m (25 ft) of the structure, gas piping, underground conduits, underground liquefied petroleum gas piping systems, and so on.

4.14.1.3 Connection to gas piping shall comply with the following requirements:

- (1)*Interconnection to a gas line shall be made on the customer's side of the meter.
- (2) Bonding shall not be permitted to the utility side of the meter.

4.14.1.4 Main-size lightning conductors shall be used for interconnecting these grounding systems to the lightning protection system.

4.14.1.5* Where galvanic corrosion is a concern or where a direct bond is prohibited by local code, an isolating spark gap shall be permitted.

4.14.2 Common Ground Bondings.

4.14.2.1 Where electric, community antenna television (CATV), data, communications, or other systems are bonded to a metallic water pipe, only one connection from the lightning protection system to the water pipe system shall be required, provided the water pipe is electrically continuous between all systems.

4.14.2.2 If the water pipe is not electrically continuous due to the use of plastic pipe sections or other reasons, the nonconductive sections shall be bridged with main-size conductors, or the connection shall be made at a point where electrical continuity is ensured.

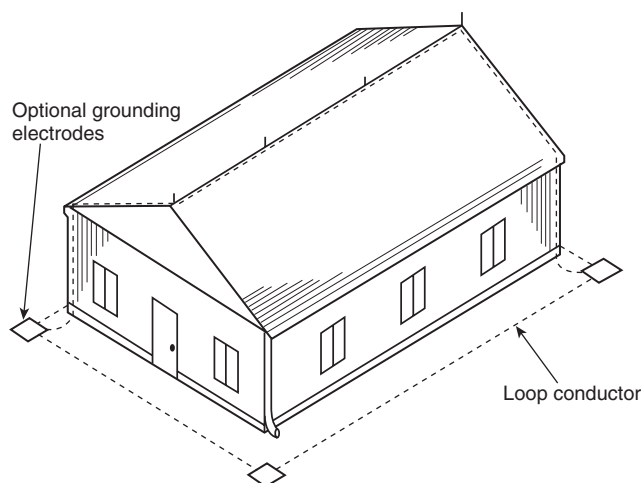


FIGURE 4.13.4 Typical Ground Ring Electrode Installation.

4.15 Concealed Systems.

4.15.1 General.

4.15.1.1 Requirements covering exposed systems also shall apply to concealed systems, except conductors shall be permitted to be coursed under roofing materials, under roof framing, behind exterior wall facing, between wall studding, in conduit chases, or embedded directly in concrete or masonry construction.

4.15.1.2 Where a conductor is run in metal conduit, it shall be bonded to the conduit at the point where it enters the conduit, at the point where it emerges from the conduit, and at all locations where the conduit is not electrically continuous.

4.15.2 Masonry Chimneys. Chimney strike termination devices and conductors shall be permitted to be concealed within masonry chimneys or to be attached to the exterior of masonry chimneys and routed through the structure to concealed main conductors.

4.15.3 Concealment in Steel-Reinforced Concrete. Conductors or other components of the lightning protection system concealed in steel-reinforced concrete units shall be connected to the reinforcing steel.

4.15.3.1 Concealed down conductors shall be connected to the vertical reinforcing steel in accordance with 4.9.13.

4.15.3.2 Roof conductors or other concealed horizontal conductor runs shall be connected to the reinforcing steel at intervals not exceeding 30 m (100 ft).

4.15.4 Grounding Electrodes. Grounding electrodes for concealed systems shall comply with Section 4.13.

4.15.4.1* Grounding electrodes located under basement slabs or in crawl spaces shall be installed as near as practicable to the outside perimeter of the structure.

4.15.4.2 Where rod or cable conductors are used for grounding electrodes, they shall be in contact with the earth for a minimum of 3 m (10 ft) and shall extend to a depth of not less than 3 m (10 ft) below finished grade, except as permitted by 4.13.4 and 4.13.5.

4.16 Structural Metallic Systems.

4.16.1 General. The metal framework of a structure shall be permitted to be utilized as the main conductor of a lightning protection system if it is equal to or greater than 4.8 mm ($\frac{3}{16}$ in.) in thickness and is electrically continuous, or it is made electrically continuous by methods specified in 4.16.3.

4.16.2 Strike Termination Devices.

4.16.2.1 Strike termination devices shall be connected to the structural metal framing by direct connection, by use of individual conductors routed through the roof or parapet walls to the steel framework, or by use of an exterior conductor that interconnects all strike termination devices and that is connected to the metal framework.

4.16.2.2 Where such an exterior conductor is used, it shall be connected to the metal framework of the structure at intervals not exceeding an average distance of 30 m (100 ft), as widely spaced as practicable.

4.16.3 Connections to Framework. Conductors shall be connected to areas of the structural metal framework that have been cleaned to base metal, by use of bonding plates having a surface contact area of not less than 5200 mm² (8 in.²) or by welding or brazing.

4.16.3.1 Drilling and tapping the metal column to accept a threaded connector also shall be permitted.

4.16.3.2 The threaded device shall be installed with at least five threads fully engaged and secured with a jam nut or equivalent.

4.16.3.3 The threaded portion of the connector shall be not less than 12.7 mm ($\frac{1}{2}$ in.) in diameter.

4.16.3.4 Bonding plates shall have bolt-pressure cable connectors and shall be bolted, welded, or brazed to the structural steel framework so as to maintain electrical continuity.

4.16.3.5* Where corrosion-protective paint or coatings are removed, the completed electrical connection shall have corrosion protection equivalent to the original coating.

4.16.4 Grounding Electrodes.

4.16.4.1 Grounding electrodes shall be connected to steel columns around the perimeter of the structure at intervals averaging not more than 18 m (60 ft).

4.16.4.2 Connections shall be made near the base of the column in accordance with the requirements in 4.16.3.

4.16.5 Bonding Connections. Where metal bodies located within a steel-framed structure are inherently bonded to the structure through the construction, separate bonding connections shall not be required.

4.17 Metal Antenna Masts and Supports. Metal antenna masts or supports located on a protected structure shall be connected to the lightning protection system using main-size conductors and listed fittings unless they are within a zone of protection.

4.18 Surge Protection.

4.18.1* General. The requirements for surge protection systems installed for the electrical, communications (including, but not limited to, CATV, alarm, and data), or antenna systems or for other electrical system hardware shall apply only to permanently installed SPDs.

4.18.2* Surge Protection Requirements.

4.18.2.1 SPDs shall be installed at all power service entrances.

4.18.2.2* SPDs shall be installed at entrances of conductive communications systems (including, but not limited to, CATV, alarm, and data) and antenna systems.

4.18.2.3 SPDs shall be installed at all points where an electrical or electronic system conductor leaves a structure to supply another structure if the conductors or cables are run over 30 m (100 ft).

4.18.2.4* Surge protection shall be permitted for installation at subpanels or branch panels and at the point of utilization (outlet or signal termination; also termed *supplementary protection*).

4.18.2.5* SPDs shall not be required where, under engineering supervision, it is determined that surge threat is negligible or the lines are equivalently protected or where installation compromises safety.

4.18.3 Surge Threat Levels.

4.18.3.1* Electrical Power Circuits.

4.18.3.1.1 The SPD shall protect against surges produced by a 1.2/50 μ s and 8/20 μ s combination waveform generator.



4.18.3.1.2 SPDs at the service entrance shall have a nominal discharge current (I_n) rating of at least 20 kA 8/20 μ s per phase.

4.18.3.2 Signal, Data, and Communication Protection. SPDs shall be listed for the protection of signal, data, and communications systems and shall have an I_{max} rating of at least 10 kA 8/20 μ s or greater when installed at the entrance.

4.18.4* Measured Limiting Voltage of an SPD. The published voltage protection rating (VPR) for each mode of protection shall be selected to be no greater than those given in Table 4.18.4 for the different power distribution systems to which they can be connected.

4.18.5* Facility ac Surge Protection.

4.18.5.1 The short-circuit current rating of the SPD shall be coordinated with the available fault current rating of the supply (panel) to which it is connected, in accordance with *NFPA 70, National Electrical Code*.

4.18.5.2 The maximum continuous operating voltage (MCOV) of the SPD shall be selected to ensure that it is greater than the upper tolerance of the utility power system to which it is connected.

4.18.5.3 The protection of service entrances shall use Type 1 or Type 2 SPD, in compliance with applicable standards such as UL 1449, *UL Standard for Safety for Surge Protective Devices*, Edition 3.

4.18.5.4 SPDs at grounded service entrances shall be wired in a line-to-ground (L-G) or line-to-neutral (L-N) configuration.

4.18.5.4.1 Additional modes, line-to-line (L-L), or neutral-to-ground (N-G) shall be permitted at the service entrance.

4.18.5.4.2 For services without a neutral, SPD elements shall be connected line-to-ground (L-G). Additional line-to-line (L-L) connections shall also be permitted.

4.18.6 Communications Surge Protection.

4.18.6.1* SPDs shall be provided for all communications systems (including but not limited to CATV, alarm, and data) and antenna systems at facility entrances.

4.18.6.2 The selection of SPDs shall take into consideration aspects such as the frequency, bandwidth, and voltage.

4.18.6.3 Losses (such as returns loss, insertion loss, impedance mismatch, or other attenuation) introduced by the SPD(s) shall be within acceptable operational limits.

4.18.6.4 SPDs protecting communications systems shall be grounded.

4.18.6.4.1* SPDs protecting communications systems shall be grounded in accordance with *NFPA 70, National Electrical Code*, Chapter 8.

4.18.6.4.2 If the point of grounding in 4.18.6.4.1 is greater than 6 m (20 ft) away, a supplementary earth electrode or electrode system shall be installed at the SPD location.

4.18.6.4.3 SPDs shall not be grounded through a down conductor of the lightning protection system.

4.18.6.4.4* SPDs for data and signal line protection shall provide common mode protection.

4.18.7 Installation.

4.18.7.1 Installation of surge suppression hardware shall conform to the requirements of *NFPA 70, National Electrical Code*.

4.18.7.2* SPDs shall be located and installed so as to minimize lead length. Interconnecting leads shall be routed so as to avoid sharp bends or kinks.

4.18.7.3 The SPD grounding conductor shall be installed in accordance with the manufacturer's instructions.

4.18.7.4* All SPD components shall be accessible for inspection and maintenance.

4.18.8* Earth Grounding Electrode. Resistance of the earth electrode system used in the grounding of SPDs shall comply with *NFPA 70, National Electrical Code*.

Table 4.18.4 Maximum Allowed Voltage Protection Rating per Mode of Protection Provided for Different Power Distribution Systems to Which the SPD May Be Connected

Power Distribution System	Line-to-Neutral	Line-to-Ground	Neutral-to-Ground	Line-to-Line
120 2W + ground	600	600	600	—
240 2W + ground	1000	1000	1000	—
120/240 3W + ground	600	600	600	1200
120/208 WYE 4W + ground	600	600	600	1200
277/480 WYE 4W + ground	1200	1200	1200	1200
277/480 WYE 4W + HRG (high resistance ground)	1200	1200	1200	1200
347/600 WYE 4W + ground	1800	1800	1800	4000
240 DELTA 3W + ground (corner grounded)	1000	1000	1000	1000
240 DELTA 3W (ungrounded)	1000	1000	1000	1000
480 DELTA 3W + ground (corner grounded)	1800	1800	1800	1800
480 DELTA 3W (ungrounded)	1800	1800	1800	1800