LIGHTNING PROTECTION INSTITUTE

Standard Of Practice For The
DESIGN – INSTALLATION – INSPECTION
Of Lightning Protection Systems

LPI -177 / 2017 Edition
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DEFINITIONS

Air Terminal – A strike termination device that is a lightning receptor for attachment of flashes to the lightning protection system and is listed for the purpose. An air terminal assembly typically consists of a solid or tubular rod, and a mounting base with a conductor connection.

Approved – Acceptable to the authority having jurisdiction.

Authority Having Jurisdiction – The organization, office, or individual responsible for approval and enforcement of equipment, materials, an installation, or a procedure.

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.

Bonding Conductor – A conductor used for potential equalization between grounded metal bodies or electrically conductive objects and a lightning protection system. The bonding conductors are normally smaller in size than current carrying conductors.

Cable – A factory assembly combining multiple wire strands together to form a single conductor.

Catenary Lightning Protection System – A lightning protection system consisting of one or more overhead ground wires (also known as “overhead shielding”).

Chimney - A structure containing one or more vertical or nearly vertical passageways for conveying flue gases to the outside atmosphere. A chimney does not meet the criteria defined for a heavy duty stack (below).

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

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

Combination Waveform Generator – A surge generator with a 2 ohm internal impedance producing a 1.2/50 μs open circuit voltage and an 8/20 μs short-circuit current wave shape.

Conductors – Devices defined by this Standard as suitable to carry lightning current or make bonding interconnections.

Copper-Clad Steel – Steel rod or wire with a coating of copper bonded to it.

Fastener – A component or set of components used to securely attach materials to the structure.

Grounded – Connected to earth or to some conducting body that is connected to earth ground.

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

Integral Lightning Protection System – A lightning protection system directly attached to the structure.

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

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 the equipment or materials, and by whose labeling the manufacturer indicates compliance with appropriate standards or performance in a specified manner.
Lightning Protection System – A complete system of strike termination devices, main conductors (including conductive structural members), grounding electrodes, bonding or interconnecting conductors, surge protection devices, and other connectors or fittings required to complete the system.

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, materials, or service meets appropriate designated standards or has been tested and found suitable for a specified purpose.

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

Main Conductor – A conductor intended to be used to carry lightning currents between strike termination devices and grounding electrodes. This may include strike termination devices, cables, lightning protection fittings, grounding electrodes, or metallic structural members.

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).

Maximum Discharge Current ($I_{\text{max}}$) – The maximum instantaneous value of the current through the SPD having an 8/20 µs waveform.

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 wave shape and amplitude.

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

Metal-Framed Structure – A structure with electrically continuous structural members of sufficient size (according to this Standard) to provide an electrical path equivalent to that of lightning conductors.

Nominal Discharge Current ($I_{\text{n}}$) – Peak value of 8/20 µs current waveform selected by the manufacturer for which an SPD remains functional after 15 surges.

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

Normal Operating Voltage – The normal ac power frequency voltage rating, as specified by the manufacturer, to which the surge protective device (SPD) may be connected.

Shall – Indicates a mandatory requirement.

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

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.

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

Standard – A document, the main text of which contains 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.

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, and qualified permanent metal parts of structures as described in this Standard, and overhead ground wires installed in catenary lightning protection systems.
Surge – A transient wave of current, potential or power in an electric circuit. Surges do not include longer duration temporary over voltages (TOV) consisting of an increase in the power frequency voltage for several cycles.

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.

Transient – A subcycle disturbance in the ac waveform that is evidenced by a sharp, brief discontinuity of the waveform. It may be of either polarity and may be additive to, or subtractive from, the nominal waveform.

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.

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

INSTRUCTIONS:

LPI-177 Follows LPI-175 per paragraph. This inspection guide is to be used with LPI-175 and to aide in the inspection process. Reference the left column for paragraph and page numbers of LPI-175. LPI-177 reviews each section of the standard with more explanation, installation examples and details.

GENERAL REQUIREMENTS

System Overview

Refer to: Paragraphs 1 through 8 on page 16 of LPI-175.

THE PARAGRAPHS CONTAINED IN THIS SECTION ON PAGE 16 OF LPI-175, ARE DEEMED TO BE SELF EXPLANATORY.

- Research indicates lightning protection can reduce personal injury in addition to preventing property damage.
- This document covers the protection of ordinary structures. Watercraft and buildings containing explosives and flammables are not included.
- Observance of this standard is one of the conditions of LPI Certification.
- Components of the lightning protection system must be compatible with the building material on which they are mounted.
- Lightning protection systems shall be installed in a Neat and Workmanlike Manner.
Material Sizes

Par. 26) General requirements apply to all structural protection systems defined by paragraph 26 on page 23 of LPI-175. Special purpose structures such as water craft and buildings used to manufacture or store explosives or flammables are not covered by LPI-175 or this inspection guide.

Page 23

Par. 27) Class 1 Buildings are roof levels that are 75 ft. or less above finished grade/earth. See Figure 1

Page 23

Figure 1

A CLASS I BUILDING IS A BUILDING 75' HIGH OR LESS.

Roof levels 75 ft. and below must utilize a minimum of Class 1 conductors and components. Air terminals must comply with Table 1 on page 26 of LPI-175 and main sized conductors must comply with Table 2 on page 40 of LPI-175. Class I crimp or squeeze type connectors and fittings are acceptable on Class I structures only. See Figure 2

Figure 2

Class I Crimp Type Connectors and Fittings

NOTE: It is acceptable to use Class II components on Class I Structures.

Par. 28) Class II Buildings are roof levels that exceed 75 ft. in height above finished grade/earth. See Figure 3

Page 23
A CLASS II BUILDING IS A STRUCTURE HIGHER THAN 75’

**Par. 28)**

Roof levels over 75 ft. must utilize Class II conductor and components. Air terminals must comply with Table 1 Class II requirements on page 26 of LPI-175. Main sized conductors must comply with Table 2 Class II requirements on page 40 of LPI-175. **CLASS II** bolt type connectors and fittings are required. See Figure 4

**Figure 4**

Class II Bolt Type Connectors and Fittings

**NOTE:** **CLASS I CRIMP TYPE CONNECTORS ARE NOT ACCEPTABLE ON CLASS II INSTALLATIONS.**

**Par. 29)**

Buildings may have some roof levels that are Class II (taller than 75 ft. above grade) and some roof levels that are Class I (75 ft. or less above grade).

- Roof levels 75 ft. and lower may utilize all Class 1 Components.
- Roof levels that are taller than 75 ft. must utilize Class II Conductors, Components and Fittings from the roof all the way down to and including the grounds.

See Figure 5
A BUILDING MAY BE A COMBINATION OF CLASS I AND CLASS II. BOTH CLASS I AND CLASS II MATERIALS MAY BE USED. HOWEVER, ALL MATERIALS SERVING THE CLASS II PORTION OF THE BUILDING MUST BE CLASS II FROM THE ROOF CIRCUIT DOWN TO AND INCLUDING THE GROUND ELECTRODES.

All protected roof levels of a building’s lightning protection system must be interconnected together.

Acceptable methods of interconnecting the system are:
- Main size conductor connections between the roof levels.
- Various roof levels share a common downlead.
- A ground loop at grade interconnecting all downleads.
- Main sized conductor connecting between 2 different grounds.
- Bonds to common structural steel (metallic) members.
- *Only one method is required*

NOTE: Secondary conductor bonds are not satisfactory for the interconnection.

Material Considerations

Galvanized and plated steel are not allowed for use as lightning protection current carrying devices, unless they are 3/16 inch thick structural elements in accordance with paragraph 179 on page 57 of LPI-175.

Galvanized ground rods are NOT acceptable.

Galvanized steel components may only be used for braces and non-current carrying parts of clamps.

NOTE: Bi-metallic splicers, stainless steel shims and washers are acceptable to separate copper and bronze components from aluminum and galvanized surfaces to prevent dissimilar metal corrosion. (See examples of bi-metallic splicers on Page 9 of this guide.)
Copper and aluminum purity and grade requirements - LPI-175 paragraph 32.

Exposed downleads that are subject to damage must be protected by a protective molding or covering, commonly referred to as a cable guard.

Areas where cable guards may be needed include:
- School and playgrounds where children might pull or swing on them.
- Loading dock areas where they might be backed into and cut or damaged.
- Inside and around warehouses where they might be cut or damaged by forklift and pallet storage operations.
- On farms and livestock operations where animals might displace the conductor or become entangled in the downlead.

NOTE: Most residential and light commercial installations do not require cable guards.

Cable Guard Requirements:
- The guard must extend a minimum of 6 ft. above grade.
- May be a tube or pipe that encircles the conductor.
- May be a molding installed over the conductor.
- May be metallic or non-metallic such as plastic or PVC pipe.
- If metallic guards are used, each end of the pipe must be connected to the cable.
  (This connection can be made using secondary bonding wire and clamps.)
- Bonding between the cable guard and conductor is NOT required if non-metallic guards are used.
- See figure 6

Figure 6

NOTE: If aluminum down conductor cable is used, the required bimetallic connector to convert the aluminum to copper may be located directly above the protector.

When guards or shielding is used, all strike termination devices (lightning rods) shall remain exposed.
An owner or architect may want to paint or cover parts of the lightning protection system for aesthetic reasons. Alkaline-based paint may not be used on aluminum conductors or components.

NOTE: The lead covering used on heavy duty smoke stacks, and the lead coating or tinned coating used to prevent corrosion on chimneys and stacks are NOT considered shielding that will affect the function of the components. Refer to paragraph 36.

**Copper**

*Par. 35)* Page 24

Copper lightning protection components shall not be installed on aluminum surfaces, painted or anodized aluminum surfaces, bare “galvalume” type surfaces or where a “galvalume” type coating is present below the paint.

*Par. 36)* Page 24

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

**Aluminum**

*Par. 37)* Page 24

Aluminum components shall not be installed on copper surfaces or where exposed to runoff from copper surfaces.

*Par. 38)* Page 24

Aluminum materials shall not be installed in direct contact with the earth or be embedded in concrete.

*Par. 39)* Page 24

Bimetallic connectors shall be used to join aluminum and copper lightning protection components. See Figure 7

**Figure 7**

Bimetallic Connectors

NOTE: Stainless steel or cadmium plated washers, shims or rods may also be used to provide separation between copper and bronze components and aluminum components. (See Figure 8 below for more approved bimetal applications)

**BIMETAL CONNECTION LOCATIONS FOR DOWNLEADS:**

- For exposed aluminum downleads, the bimetal connector joining the aluminum downlead to the copper grounding tail must occur at least 18 in. above grade.

- For concealed aluminum downleads, the transition from aluminum to copper must occur at least 18 in. above the lowest slab, floor or footing to be pierced. See Figure 8.
Aluminum conductors shall not be attached to a surface coated with alkaline-based paint, embedded in concrete or masonry or installed in a location that is subject to excessive moisture.

Connectors and Fittings

Connectors and fittings shall comply with the following:
- Copper and bronze connectors and fittings shall be used to join copper conductors.
- Aluminum connectors and fittings shall be used to join aluminum conductors.
- Bimetallic connectors shall be used to connect copper and bronze to aluminum.
- Stainless steel shims that provide the required surface contact may be used to separate copper and bronze from aluminum.

STRIKE TERMINATION DEVICES (STDs)

Strike termination devices (STDs) include but are not limited to air terminals (lightning rods), metal masts, hand rails, permanent metal parts of structures and overhead ground wires. STDs are required on all roof levels and projections that are subject to a direct lightning strike.

STDs ARE NOT REQUIRED ON PROJECTIONS THAT ARE UNDER A ZONE OF PROTECTION.

Roof projections that are not within a zone of protection must be protected and bonded to the lightning protection system. See Figure 9.
When bonding plates are not used and conductor is used to connect the STD to the main conductor run:

- Main size conductor and fittings must interconnect the STD to the main roof conductor run.

- “Dead end” conductor restrictions must be observed. Refer to LPI-175 paragraph 104 for dead end conductor restrictions on main roof and lower roofs.

When bonding plates are used:

- A minimum of 2 bonding plates with 2 main sized conductors and fittings must interconnect the main roof conductor run.

  **EXCEPTION**: Metallic masts, flag poles and slender spires that are 3/16 inch thick only require 1 bond.

- Vent bases and bonding plates must have a minimum surface area contact of 3 square inches.

- The bonds shall be made directly to clean bare metal.

- STD’s are not required for metallic objects 3/16” thick or thicker. Only bonding to the lightning protection system is required.

- Metal objects inherently connected to the structural steel metallic frame properly grounded to serve as part of the lightning protection system do not require additional bonding.

Air terminal size requirements—Refer to paragraph 53 and Table 1 on page 26 of LPI-175.

Air terminals must extend at least 10” above the object or area to be protected. See Figure 10.
**Par. 55)**

Page 26

Air Terminals over 24" in length must be braced no less than 1/2 the height of the air terminal. See Figure 11.

**Figure 11**

**Par. 56)**

Page 26

Ornamental and decorative STD restrictions-Refer to paragraph 56 on page 26 of LPI-175.

**Strike Termination Devices for Standard Roofs**

**Par. 57)**

Page 27

When figuring the slope of a roof section to determine if it is to be treated as a PITCHED ROOF requiring only ridge protection, or if it must be treated as a FLAT ROOF requiring perimeter protection, it is very important that EACH ROOF AREA where the roof slope changes be calculated separately using the rise over run method. This especially applies to Hip, Broken Gable and Shed roofs. See Figure 12
The actual span foot print of the roof becomes insignificant when making these calculations. The roof section with the steep slope may be no more than 5’ wide while the gently sloped section may be hundreds of feet wide.

The calculations must be made by using an imaginary number that is equal to 2 TIMES THE DISTANCE OF THE RUN area in question for Hip, Broken Gable and Shed Roofs.

Protection For Pitched Roofs-STD’s shall be placed at the following locations that are not within a zone of protection from higher roof levels or taller STD’s:

- At or within 2 ft. of all ridge endings.

- Along ridge runs at 20 or 25 ft. maximum spacings.

See Figure 13
25 ft. spacing between STD’s is ONLY allowed when STD’s extend at least 24 in. above the area or object to be protected. See Figure 14.

NOTE: Roof ridges already within a zone of protection do NOT require STD’s.

EXCEPTION: For eaves 50 ft or less above grade, and where only a gutter is present and the gutter does not extend more than 2 ft. past the eave line, no eave protection is required.
– Pitched roofs with eave heights greater than 50 ft. above grade must have protection at the eaves if required by the 150 ft. geometric method as shown in Figure 10 on page 30 of LPI-175. See Figure 16

**NOTE:** Projections on pitched roofs such as chimneys, dormers, cupolas, vent stacks, etc. that are not within a zone of protection shall be protected as required by Paragraphs 64 through 73. Refer to paragraphs 64 through 73.

**PROTECTION FOR FLAT AND GENTLY SLOPING ROOFS** – STD’s shall be placed at the following locations that are not within a zone of protection from higher protected roof levels or taller STD’s:

– STD’s shall be located within 2 ft. of all outside corners of the building.

– STD’s shall be located within 2 ft. of all outside edges of the building perimeter. See Figure 17
In some cases, it will not be possible to mount a side mount base near the corner, run the continuous perimeter conductor through the base and still comply with the 8 in. minimum radius bend required in paragraph 107 of LPI-175. To eliminate this problem, the base may be mounted directly in the corner with the perimeter conductor bend properly installed and a jumper used to connect the strike termination device to the perimeter conductor run. See Figure 18

NOTE: Conductor “dead-end” restrictions must be observed. Ref. LPI-175 paragraph 104.

- Spacing around the building perimeter shall not exceed 20 ft. between air terminals that extend less than 2 ft. above the object being protected.

NOTE: 25 ft. spacing between perimeter air terminals is ONLY allowed when they extend at least 24 in. above the area or object to be protected. Otherwise, 20 ft. spacing between air terminals is required. See Figure 19

UNACCEPTABLE FOR 25 FT. SPACING

The air terminal does not extend 24” above the outside edge of the cap.
 ACCEPTABLE FOR 25 FT. SPACING
The air terminal extends the full 24” above the roof and flashing.

A gently sloping ridged roof shall have an air terminal located within 2 ft. of each ridge end. See Figure 20

Figure 20

 Par. 61-62) Flat or gently sloping roofs that exceed 50 ft. in width and length shall also have mid-roof STD’s located at intervals not to exceed 50 ft. See Figure 21

Figure 21

A: Mid-Roof spacing at 50 ft. max.
B: Perimeter spacing at 20 ft or 25 ft. max.
NOTE: In lieu of standard 50 ft. spacings, taller air terminals that create zones of protection per the rolling sphere method may also be used to determine mid-roof STD locations. (Air terminals taller than 2 ft. must be braced no less than 1/2 the length of the air terminal.)

When using this method:

- STD’s must be located so that the arc does not touch the roof itself or any roof mounted equipment that might be present.

- The sag of the arc as it rests on 3 STD’s must be taken into consideration.

The chart and illustration contained in paragraphs 62-63 on pages 30-31 of LPI-175 will assist in determining STD locations using this method. (Allowance has been made for a 2 in. protective clearance.)

NOTE: This can also be used to place low profile roof equipment such as smoke relief vents, roof membrane vents, etc. under a zone of protection.

Roof top equipment such as A/C unit, vents, etc. may be used to elevate air terminals to achieve desired heights for mid-roof zone of protection afforded by the 150 ft. radius arc. Refer to paragraph 63 on page 30 of LPI-175.

Protecting Projections on Structures

All projections on a roof that are subject to a lightning strike must be protected unless they are located within a zone of protections by taller STD’s or higher protected roof levels. These common projections are, but not limited to, chimneys, dormers, mechanical penthouses, mechanical equipment, cooling towers, etc.

Methods for protecting projections that are exposed to a direct strike include:

- STD’s are required on all non metallic projections that are not within a zone of protection. The STD’s must be connected with main size cable and fittings to a main conductor run providing 2 paths to ground. See Figure 22

Figure 22

Non-metallic Cupola  Masonry Chimneys

NOTE: Conductor dead-end restrictions apply. Refer to paragraph 104.
Metal bodies that are 3/16 in. thick and thicker do not require air terminals. They only require bonding to the system per paragraph 65. Refer to paragraph 65. See Figure 23

3/16 in. Thick Steel Stack

STD’s are required on all metal projections that are less than 3/16 in. thick and are not within a zone of protection. The STD may be connected with main size conductor and fittings to a main conductor run providing 2 paths to ground. See Figure 24

Vent Less Than 3/16 in. Thick With Full Conductor

NOTE: Conductor dead-end restrictions apply. Refer to paragraph 104.
- Air terminals may also be installed on vents, roof top units and other metal bodies by use of vent bases and bonding plates per paragraph 69. Refer to paragraph 69.

See Figure 25

Figure 25

![Figure 25](image)

RTU’s Less Than 3/16” Thick

- Units which are in a straight line or row and of similar size may be protected as if they were one larger unit. See Figure 26

Figure 26

![Figure 26](image)

**NOTE:** Air terminal installations on projections must comply with the same requirements as if they were being used to protect a roof level. They must be within 2 ft of the outside corners and edges and spaced no farther than 20 ft. (or 25 ft.) apart on flat surfaces. On projections that have a “pitched” top or cap, the top may be protected the same as a roof ridge.
Exception: The placement of air terminals per the rolling ball method may be used to place the corners and edges or entire projections within a zone of protection. In this case, no further protection is required.

Par. 71) Page 33
Copper lightning protection within the top 24 inches of chimneys and vents that emit corrosive fumes must be hot-dip lead or tin coated.

- If aluminum or stainless steel components are used, they do NOT have to be coated.

Par. 72) Page 33
Guy wires shall be bonded to the system near their base using main size conductors and fittings. Metal guy wires connected to a metal stack may serve as the bond at the top, or they shall be bonded to downleads. Metal guy wire anchors extending into the grounded steel metallic frame of the building may serve as the bottom bond. However, turnbuckles, eyebolts, etc. shall be jumped across using bonding material.

Par. 73) Page 33
Dormers not under a zone of protection must be protected. Dormers that are within a zone of protection from higher protected roofs and STD’s do not require additional protection. Zone of protection for dormers may be determined by using methods described in paragraphs 89 through 99 of LPI-175. See Figure 27

Figure 27

NOTE: On protected dormers, the following rules regarding conductor routing may be applied:

- Horizontal and downward conductor routing in paragraph 101 on page 41 of LPI-175.

- The Exception- for drops from a higher roof to a lower roof paragraph 103 on page 41 of LPI-175.

- The Exception-“dead ended” main size restrictions in paragraph 104 on page 42 of LPI-175
Figure 28 shows examples of acceptable cable routing on dormers. See Figure 28

![Figure 28](image_url)

A: PERMISSIBLE DEAD END - TOTAL CONDUCTOR LENGTHS NOT TO EXCEED 16'-0"

ACCEPTABLE CABLE ROUTING ON DORMERS

Figure 29 shows conductor routing on a dormer that is not acceptable. See Figure 29

![Figure 29](image_url)

UNACCEPTABLE

The only path from the air terminal on the dormer back to the main ridge is routed upward at a steeper slope than ¼ pitch (or the 1 to 4 rise-to-run slope ratio) allows.
Antenna masts serving a protected building shall be grounded to the building lightning protection system to serve as a STD if 3/16” thick or greater. Or, they may be placed under a zone of protection by a STD mounted directly to the antenna mast when it is capable of structural support or remotely mounted STDs.

**Strike Termination Devices for Specialty Roof Types**

Roofs with multiple or intermediate ridges – Providing that all ridges are the same height above grade, the intermediate ridges constitute a “common plane” which is to be protected as a flat roof.

- The outer most ridges shall have STD’s located like a single ridge, within 2 ft. of ridge endings and space along the ridge at 20 ft. (or 25 ft.) maximum spacing.

- The inner ridges shall have STD’s within 2 ft. of ridge endings provided the adjoining ridges are 20 ft. (or 25 ft.) or more apart.

- The “Mid-Roof” STD’s on the inner ridges shall be spaced at 50 ft. maximum intervals along the ridge runs and at 50 ft. maximum intervals across the inner ridges.

NOTE: Caution must be observed to insure horizontal and downward conductor routing that is free of U-Pockets from strike termination devices to ground terminals.

See Figure 30

![Figure 30](image-url)

A: 50’-0” MAXIMUM SPACING ON INTERMEDIATE RIDGES
B: TYPICAL 20’-O” MAXIMUM SPACING
Irregular shaped flat roofs — Each outermost corner end of an irregular flat roof perimeter or parapet must be treated as the corner of a building and have a strike termination device located within 2 ft. of the outside corner. Intermediate projections of the same height or length may be considered to form an imaginary roof edge or a “common plane” and may be protected as a flat roof perimeter with STD’s spaced at maximum intervals of 20 ft. (or 25 ft.). See Figure 31

Examples of Acceptable Irregular Perimeter Protection

“Dead end” restrictions per paragraph 104 on page 42 of LPI-175 shall apply.
Open areas in the middle of roofs often serve as courtyards and mechanical wells. The perimeter of open areas must be protected when:

- BOTH rectangle dimensions exceed 50 ft. AND
- The total open area perimeter EXCEEDS 300 ft.

When both above conditions exist, the open area perimeter shall be protected as if it were a building outer perimeter.

See Figure 32

**Figure 32**

![Diagram of full perimeter protection required](image)

**FULL PERIMETER PROTECTION REQUIRED**

- BOTH rectangle dimensions exceed 50 ft. AND
- The TOTAL PERIMETER IS 310 ft. (Exceeds 300 ft.)

![Diagram of full perimeter protection is not required](image)

**FULL PERIMETER PROTECTION IS NOT REQUIRED**

- BOTH rectangle dimensions exceed 50 ft. HOWEVER
- The TOTAL PERIMETER IS ONLY 220 ft. (Does NOT exceed 300 ft.)
Par. 78)  
Page 35  
Domed roofs – STD’s are to be located so that the entire roof area falls within a zone of protection based on the 150 ft. sphere method. The arc of the sphere shall not touch the roof at any location.

Par. 79)  
Page 35  
Parking ramps – Parking ramps and parking garage floors present an obvious problem due to traffic flow. Air terminals can be placed on light poles, barrier walls and column stubs that have been left for future expansion in order to meet spacing requirements. This may eliminate the need for STD’s in the open areas. If STD’s are still needed in open areas, flush mounted copper ground bars or ground plates may be imbedded at the required locations.  
See Figure 33

Figure 33

Flush Mount Ground Plate

MASTS AND OVERHEAD GROUND WIRES

Refer to: Paragraphs 80 through 81 on page 35 of LPI-175  
Paragraphs 82 through 88 on pages 36-37 of LPI-175

THE PARAGRAPHS CONTAINED IN THIS SECTION ON PAGES 35 THROUGH 37 OF LPI-175 ARE DEEMED TO BE SELF EXPLANATORY.

Masts and overhead systems are other options that may be used to provide lightning protection for a structure.

- The components used are the same as for Ordinary Structures.
- The same material classifications, Class I or Class II, apply according to the height of the mast or overhead system to be used.
- Air terminal clearances, downlead routing and grounding requirements are the same.
- Zone of protection methods are the same.
- A mast or overhead system simply elevates the STD to a level that provides a zone of protection for the structure.
- Wood poles require STD’s, downleads and grounds.
- Steel poles at least 3/16 inch thick only require grounding at the base.
- STD’s are not required on 3/16 inch steel poles. If installed, they only add to the height of the zone of protection arc.
When using masts or overhead ground wires, the same zone of protection arc of the 150 ft. radius sphere, for ordinary structures, is used.

NOTE: When using this method to protect structures that house explosives or flamables the zone of protection is based on the arc of a **100 ft.** radius sphere.
See Figure 34

**Figure 34**

<table>
<thead>
<tr>
<th>UNACCEPTABLE</th>
<th>ACCEPTABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>The pole is either too short or too far away to provide a zone of protection for the structure.</td>
<td>The mast places the structure under a zone of protection.</td>
</tr>
</tbody>
</table>

Wood pole requires STD, downlead and ground.  
3/16" Thick metal pole only requires grounding at the base.

**ZONE OF PROTECTION**

*Par. 89*

The zone of protection created from higher mounted strike termination devices may be used to eliminate the need for protection at lower roof areas and roof projections such as roof mounted mechanical equipment. These calculations are commonly determined by use of scales during the design stage of the system.
See Figure 35
Note: Zone of protection is not limited to roofs and walls of the building. Zone of protection may be used on any properly grounded item that serves as a strike termination device or is properly protected by strike termination devices. This may include, but is not limited to penthouses, screen walls, spires, flag poles, stacks, roof top units, etc.

Note: The proper use of zone of protection from elevated STD's may be used to entirely eliminate the need for air terminals at lower locations, i.e. mid-roof air terminals or those on RTU’S, antennas etc. Each circumstance has to be examined INDIVIDUALLY.

Refer to Figure 36

ACCEPTABLE

STD’s are not required at the mid-roof area or mechanical unit due to the perimeter STD’s being elevated enough to place them under a zone of protection.
The 150' radius sphere has been adopted for use in determining the zone of protection for ordinary structures. Use a 100' radius sphere when determining the zone of protection for structures that house hazardous materials.

**Par. 90**

Page 38

The 150 ft. radius sphere method of determining zone of protection is commonly referred to as the “rolling ball” method. This method “rolls” a 300 ft. diameter ball in every possible direction from grade level, up and over a building, to grade level on the opposite side. The ball must be supported off of all horizontal surfaces that it touches by grounded bodies. Grounded bodies are the earth, all STD’s and components of the lightning protection system. If the ball rests against a vertical wall, the roof area above the wall must be protected. All areas or items beneath the sphere of the ball as it rests on grounded metal bodies are considered under a zone of protection.

**Protection Calculations for Structures**

**Par. 91**

Page 38

Zone of protection examples using various heights from 25 ft. up to 150 ft. are shown in Figure 21 on page 38 of LPI-175.

**Par. 92**

Page 39

The zone of protection provided by the rolling ball method may also be figured mathematically using the following formula:

The distance may be determined mathematically with the following equation:

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

Where:

- \(d\) = horizontal distance, in feet
- \(h_1\) = height of higher roof, in feet
- \(h_2\) = height of lower roof, in feet

**Par. 93**

Page 39

Distance (d), as determined using the above formula, represents the distance on the lower level where protection would need to start. Areas and items less than this distance at the height of (h2) are under a zone of protection from the higher mounted STD (s) at (h1) and do not need further protection. All above grade connected structures and items beyond distance (d) are considered unprotected. These areas must be protected in order to provide a complete system.

**Par. 95**

Page 39

Zone of protection for buildings over 50 ft. and up to 150 ft. tall must be calculated using the rolling sphere method. The zone of protection is the space beneath the arc which is:

- Resting against ground and a strike terminal device on a roof level, or
- Resting on 2 or more STD’s on the different height roof levels, or
- Resting on 3 STD’s on a roof area.

Example – see Figure 35 and Figure 36 on page 28 of this guide.
Zone of protection for buildings over 150 ft. tall must be calculated using the rolling sphere method. The zone of protection is the space beneath the 150 ft. arc which is:

- Resting on lower STD’s or;
- Resting on the ground.

**Optional Zone of Protection at Low Vertical Heights**

Zone of protection can be figured using the 1 to 2 method if the building height is 25 ft. or less:

- Measure the difference in height between the protected high roof and the lower roof and multiply by 2.
- This will be the distance from the wall line of the high roof to the low roof where protection will need to start.
- Draw a straight line from the high roof protected area to the point on the low roof where protection is to start. Any vertical projections that extend above the angle line also require protection.

See Figure 37

![Figure 37](image)

**NOTE:** This is commonly referred to as the 1 to 2 method. It may only be used on structures having a maximum height of 25 ft. or less. Refer to paragraph 98 for additional information.

The use of the 150 ft. radius sphere, or the mathematical formula to determine zone of protection on a building may yield a larger protected area than shown using the 1 to 2 method. However, the 1 to 2 method is easier to calculate in the field and is often used for field work and inspection.
NOTE: Questionable areas that extend past the 1 to 2 zone or 1 to 1 zone in paragraph 99 must be confirmed by use of the 150 ft. radius method by scale drawings or mathematical calculation before they are deemed to be unacceptable.

**Par. 99)**  
*Page 40*

Zone of protection can be figured using the 1 to 1 method if the building height is 50 ft. or less:

- Measure the difference in height between the protected high roof and the lower roof.

- This will be the distance from the wall line of the high roof along the low roof where protection will need to start.

- Draw a straight line from the high roof protected area to the point on the low roof where protection is to start. Any vertical projections that extend above the angle line also require protection.

See Figure 38

![Figure 38](image)

NOTE: This is commonly referred to as the 1 to 1 method. It may only be used on structures having a maximum height of 50 ft. or less. Refer to paragraph 99 for additional information.

**Main Conductors**

**Par. 100)**  
*Page 41*

Current carrying main conductors approved for use with the LPI Inspection Program – Refer to paragraph 100 and **TABLE 2** on page 40 of LPI-175.

**Par. 101)**  
*Page 41*

Main conductors shall be coursed along ridges of gable, cupolas, and hip roofs, around the perimeter of flat roofs, on parapets and across mid roof areas to interconnect all strike termination devices. Conductors shall be coursed through or around obstructions in a horizontal plane.

See Figure 39
Main conductor routed up and down forming a U-pocket

ACCEPTABLE
Main conductor routed horizontally around cupola with tail down from STD

UNACCEPTABLE
Main conductor routed horizontally and down forming a U-pocket

Main conductor runs that intersect STD’s, including those on chimneys and other projections must comply with all of the following:

- Provide 2 paths to ground from each STD.

- Maintain horizontal and downward routing, or rise at a rate no steeper than a 1 to 4 rise-to-run ratio.

- Continue to a location where it connects with the grounding electrode system.

See Figure 40
UNACCEPTABLE
The main conductor run along the parapet rises greater than a 4 to 1
to go up and over the penthouse.

ACCEPTABLE OPTIONS

Option “A” routes the main conductor run along the parapet THROUGH the
penthouse thus maintaining horizontal coursing and eliminating the
steep rise.

Option “B” routes the main conductor run along the parapet AROUND the
penthouse thus maintaining horizontal coursing and eliminating the
stee rise.

Option “C” routes the penthouse down leads to thru-roof assemblies within 40 ft. of
the penthouse per the 40 ft. rule. This could also be accopmlished
routing the penthouse down leads to mid-roof conductor runs that are
routed horizontally to thru-roofs or down leads.
Per the detail, the INCORRECTLY routed conductor on the left leaves the base of the penthouse, goes across the roof and up the parapet to the main conductor run forming a U-Pocket.

Per the detail, the CORRECTLY routed conductor run on the right leaves the base of the penthouse, goes across the roof and slopes up to a roof downlead terminal.

NOTE: SEE EXCEPTION PARAGRAPH 103 ON PAGE 41 AND EXCEPTION PARAGRAPH 104 ON PAGE 42 OF LPI-175.

**Par. 103) Page 41**

**HIGHER TO LOWER ROOF EXCEPTION** – Main conductor drops from a higher roof to a lower roof interconnecting strike termination devices on the lower roof is permitted without an extra downlead, provided the horizontal run of conductor on the lower roof does not exceed 40 ft.

See Figure 41

**Figure 41**

IF LOWER ROOF DISTANCE (A) IS MORE THAN 40'-0", ADDITIONAL DOWNLEAD & GROUND REQUIRED AT LOCATION "X".
DEAD END EXCEPTIONS

NOTE: A “dead end” is a strike termination device or a required main size conductor bond that only has one main conductor path to ground.

A “dead ended” main conductor shall be permitted between a single strike termination device or a full size bond and a main conductor run under the following conditions:

1) The main size conductor run to which the “dead-end” lead is connected must have a two-way path to ground. It may be a mid-roof run, a perimeter circuit or a downlead.

2) At the main protected roof level when the HORIZONTAL portion of the dead-end conductor is not more than 8ft. (4.9m) in total length.

3) On a roof below the main protected level when the dead-end conductor is not more than 16 ft. (4.9m) in TOTAL length.

4) All dead end runs shall maintain a horizontal or downward course from the strike termination device to the connection point with the conductor run.

Cross run conductors are installed across flat and gently sloping roofs to interconnect STD’s in the mid-roof area. Cross run conductors shall be connected to the main perimeter conductor or a roof down lead terminal at intervals not exceeding 150 ft. See Figure 42

Figure 42

A: 50'-0" MAXIMUM SPACING.
B: IF CENTER RIDGE RUNS EXCEED 150'-0" THEY SHALL BE CONNECTED TO THE MAIN PERIMETER OR DOWNLEAD CABLE @ 150'-0".
C: STANDARD 20'-0" SPACING.
Main conductors shall be free from “U” or “V” (down and up) pockets. These often form at the base of chimneys and dormers below the main roof ridge, at parapet walls or along main size bonding runs where multiple bonds are required. “U or V” pockets can be removed by adding a conductor from the air terminal base over to a downlead or ground.

See Figure 43.

Figure 43

UNACCEPTABLE
Conductor from chimney routed back up hill to main conductor run on ridge forming a “U or V” pocket.

ACCEPTABLE
“U” pocket removed by conductor straight over to downlead run.

ACCEPTABLE
No “U” pocket
Conductor bends shall not have an (inside) angle of less than 90 degrees.  The radius of the bend shall not be less than 8".  See Figure 44

Figure 44

Conductor bends shall not have an (inside) angle of less than 90 degrees.  The radius of the bend shall not be less than 8".

Conductors may not be coursed through the air more than 3 ft. without a substantial support.  Examples of support might include a solid rod, angle or channel iron, etc. that is secured in place to support the conductor.

Metal roofing and siding that is less than 3/16 in. thick cannot be substituted for main conductor.  Such structures must have a full conductor system.  They must be protected as though they have a non-metallic covering.  See Figure 45

Figure 45

Metal gutters, down spouts, chutes, door tracks or other metal parts expected to have a shorter life span than main size conductor shall not be substituted for main conductor.  Ladders, handrails, etc. may be used as main conductor provided they comply with all of the following:
- Are electrically continuous.
- Are permanently mounted.
- Are at least 0.064 inches thick or more.

Continuous metal structures, such as screened pool enclosures, green houses, etc., of sufficient thickness and surface area to comply with Table 1 on page 26 or Table 2 on page 40 of LPI-175 may serve as main conductor.

NOTE: METAL-CLAD STRUCTURES' ROOFING AND SIDING MAY NOT BE SUBSTITUTED FOR MAIN CONDUCTOR.
**DOWN CONDUCTORS**

*Par. 111*)
Page 44

Down conductors shall be as widely separated as practical. It is preferrable to locate downleads at opposite sides or corners of the building if construction and site conditions allow it. The location of downleads is contingent on the:

- Size of the structure.
- Most direct routing.
- Security against displacement.
- Location of STD’s.
- Location of grounded metal bodies.
- Grounding Conditions.

*Par. 112*)
Page 44

At least 2 downleads must be provided on all structures, including steeples, chimneys, spires, bell towers, viewing platforms, etc.

*Par. 113*)
Page 44

Structures exceeding 250' in perimeter must have one downlead for every 100' of perimeter or fraction thereof.

- A structure with total perimeter of 250' requires only 2 downleads.
- A structure with a total perimeter of 251' to 300' requires 3 downleads.

Downleads on large structures shall be spaced not to exceed 100 ft. averages. See Figure 46

![Figure 46]

**Total Perimeter of 470 ft. Requires 5 Downleads**

*Par. 114*)
Page 44

Irregular shaped buildings may require additional downleads in order to provide 2 paths to ground for each STD. This happens frequently in multi-level structures.

*Par. 115*)
Page 45

The perimeter of the roof being protected determines the number of downleads required, NOT the number of STD’s on the roof. See Figure 47
- The perimeter of the structure is 400 ft.
- Building only has 2 downleads.

When determining the number of downleads required on a building, only the perimeter requiring protection must be measured. Lower roofs and projections, that are under a zone of protection from the higher roof, do NOT have to be measured.
See Figure 48.

- The perimeter of the structure is 400 ft.
- Four downleads are required.

Determing The Required Number of Grounds:

- The low roof is under a zone of protection.
- Only the high roof must be measured
- High roof perimeter is 300 ft.
- Only 3 downleads are required.
Protecting downlead conductors against physical damage and displacement—See paragraph 33 and 34 on page 23 of LPI-175 and page 8 of this guide.

Downleads installed in corrosive soil must be protected starting at a minimum of 3 ft. above grade and continuing below grade the full length of the downlead.

Downleads that are secured to or cast inside reinforced concrete columns, require bond connections to the reinforcing steel at the top and bottom.

When downleads are routed on structural steel columns, the downlead must be connected to the steel at the top and bottom. See Figure 49

In the case of extremely long vertical downlead runs in reinforced concrete construction, an additional connection shall be made at intervals not exceeding 200 ft.
Installing the downleads in PVC conduit or any other non-metallic chase shall not eliminate the need to satisfy the bonding requirements of paragraph 118 page 46 of LPI-175.

It is preferred that downleads be installed at or near the outside of the building. This is not always possible when concealing retrofit systems on existing buildings. When installing downleads and pipe chases, shafts, or stairwells provide the only possible locations to install the downleads, the following should be observed:

- Downleads shall be as widely separated as possible.
- Downleads should be limited to one per chase, shaft or stairwell.
- Consideration should be given to avoid close proximity to other grounded systems.

Note: Bonding metallic systems becomes even more critical for this type system.

Disconnects may be desired to aid in future resistance testing of the grounding system. When disconnects are installed for this purpose, more accurate readings may be obtained by installing the disconnects as low as possible.

Typical locations for disconnects are, but are not limited to, ground wells, and/or junction boxes where the connections between the downleads and grounding system electrodes occur. Junction boxes are common in concealed systems. For exposed systems, the disconnect is usually made on the wall above grade. For short buildings, the connection between the roof circuit and the downlead may serve as the disconnect.

NOTE: Disconnects are often requested by the owner or AHJ but are not required by LPI-175.

GROUNDING

Properly made ground connections and ample contact with the earth are essential components in lightning protection systems. This does not necessarily mean that the resistance to earth must be low. Rather that the distribution of metal in contact with the earth shall permit the dissipation of the lightning charge.

Low resistance between the grounding system and earth is desirable, but may vary greatly due to soil conditions. Grounding in moist clay soil using only single ground rods at each downlead connection may result in a resistance between the grounding system and earth of 50 ohms or less.

For EXTREME CASES, when buildings are located on solid rock, it is basically impossible to provide good contact with earth using single ground rods. In order to obtain good contact with the earth’s surface for proper dissipation of the charge, it may be necessary to use a network of ground conductor circling the structure and interconnecting the downleads. The resistance may be high. However, the distribution potential should be about the same as if the building were setting on good soil.

The extent of the grounding system needed will depend on the soil conditions. Connections to re-bar, isolated concrete encased pilings, etc. are not acceptable as grounding for the lightning protection system.
The ground network should be buried if soil conditions will permit it. The more contact with earth the better the grounding system will be.

Essentials of good grounding practices are:

- Each downlead shall connect to a grounding electrode that is dedicated to the lightning protection system or to a grounding electrode system.

**NOTE:** Using an electrical, phone or communications ground in lieu of lightning protection ground electrodes is unacceptable. This does not prohibit required bonding to make them common.

- Ground rod clamps shall be 2 bolt type and have a conductor to rod contact length of 1-1/2”, or exothermic welding.

See Figure 50

**NOTE:** SMALL ONE BOLT ELECTRICAL GROUND ROD CLAMPS ARE NOT ACCEPTABLE FOR LIGHTNING PROTECTION GROUNDING.

**Figure 50**

<table>
<thead>
<tr>
<th>UNACCEPTABLE</th>
<th>ACCEPTABLE</th>
<th>ACCEPTABLE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Only 1 Bolt &amp; Less Than 1-1/2” Cond. To Rod Contact</td>
<td>2 Bolts and 1-1/2” conductor To Rod Contact</td>
<td>Exothermic Weld (Forms may vary)</td>
</tr>
</tbody>
</table>

Essentials of good grounding practices:

- Where possible the cable to rod connection shall be a minimum of 1’ below grade and 2’ from the foundation and away from buried footings and pipes.

- Installed below the frost line when possible.

- Locate grounds as widely apart as practical, at corners and outside edges.

- Site conditions and building additions may make it necessary to put grounds inside or under the structure.
Grounding Electrodes

Ground rod requirements:

- Minimum ½” O.D. X 8’ long.
- Free of paint and non-conductive coatings.
- Made of copper clad steel, solid copper or stainless steel. **(GALVANIZED GROUND RODS ARE UNACCEPTABLE.)**
- Extend vertically into the earth 10 ft. below grade.
- The earth must be compacted against the length of the rod.

**NOTE:** GROUND RODS SERVING LIGHTNING PROTECTION MAY NOT BE LAYED HORIZONTALLY IN A TRENCH. They must penetrate the earth vertically. If this is not possible an alternate type of ground electrode that is acceptable under this standard must be used.

Multiple grounds at a single downlead shall be spaced apart at least 2 times the length the rod penetrates the earth. Refer to Figure 35 on page 48 of LPI-175.

Ground ring electrode (Ground loops/Counterpoise) systems shall:

- Encircle the structure or outer perimeter of the structure.
- Be buried a minimum of 18 inches deep in direct contact with the earth.
- May be encased in a concrete footing provided they meet the requirements of paragraph 135 on page 49 of LPI-175.
- Must be main size conductor minimum, sized properly for Class I or II system.
- Ground ring electrode may be common with qualified electrical ground ring.
See Figure 52 for various ground Loop connection configurations

**Par. 133)**
Page 49

Ground radials—refer to paragraph 133 on page 49 of LPI-175.

**Par. 134)**
Page 49

Ground plates shall be made of solid copper and a minimum of .032 in. thick and provide a minimum of 2 sq. ft. surface contact with the earth. The conductor to plate connection may be made by mechanical or exothermic welding. See Figure 53
NOTE: A plate that is 1 FT. X 1 FT. meets this requirement provided both sides of the plate are in contact with the earth.

Concrete encased electrodes-Refer to paragraph 135 on page 49 of LPI-175.

Combinations of grounding electrodes approved by LPI-175 may be used to make up the overall grounding system.

Soil Conditions/Selection Criteria

Moist clay soils provide the best grounding conditions. They provide the least resistance between the ground electrode and earth. Standard practice is to use ground rods in this type soil. However, other types of grounding electrodes or combinations may be used.

Sandy or gravely soil conditions are highly resistant to grounding. The use of multiple rods per paragraph 138 on page 50 of LPI-175, or the use of sectional rods to drive deeper into the earth may be considered.

Grounding in shallow top soil-Refer to paragraph 140 on page 50 of LPI-175

A zero property line situation requires special considerations for ground placement below structures. Refer to paragraph 141 on page 50-51 of LPI-175.

An exterior ground loop or ground ring electrode is acceptable under any soil conditions.

A concrete encased electrode is suitable for any soil conditions, but should be considered more often when there is no soil or in very shallow soil.
INTERCONNECTION (BONDING)

Common grounding

Par. 143) Page 51
All grounded systems and underground metallic piping shall be made common. This can be accomplished by:

- Bonding with main size conductor.
- Bonding to the water pipe.
- Bonding to a common ground bar.
- Inherent connections to metal-framed (steel) members of the building.

NOTE: Refer to inherent common bonding in paragraph 152 on page 52 of LPI-175.

Par. 144) Page 51
Structures taller than 60 ft. above grade must have a ground loop interconnecting each downlead and the other grounded systems. The ground loop shall be main size conductor that meets or exceeds the requirements of Table 2 on page 40 of LPI-175 as required for the height of the building.

- Connection to building reinforcing steel (rebar) only, does not serve as a substitute for the grounding loop, although each downlead is required to connect with rebar near the base of a structure or column.

- The ground loop is used for potential equalization of all grounded building systems and may be installed in a suitable location inside or outside the structure. The most benefit is gained from mounting outside in contact with the earth, since this will add to or enhance the total grounding system.

A completely closed loop on the outside or inside of the building is preferred but may not be possible. This is often the case when additions are added to buildings. When a closed loop is not possible, a main size conductor run that interconnects all downleads and grounded media should be considered as an alternative.

Par. 148) Page 52
Metallic underground water pipes must be bonded. Refer to paragraph 105 on page 30 of LPI-175.

The main size connection between the conductor and the water pipe shall extend for 1-1/2 inches in length along the axis of the pipe.

Par. 148) Page 52
Well casings within 25 ft. of the building shall be bonded to the grounding electrode system with main size conductors and fittings. All underground metallic piping systems entering the building shall be bonded. These include metallic conduits, liquified petroleum piping, gas piping, etc. No connections shall be made to incoming pipes made of plastic or non-metallic material.

NOTE: Refer to inherent common bonding in paragraph 152 on page 52 of LPI-175.

NOTE: CONNECTION TO THE GAS LINE SHALL BE MADE ON THE CUSTOMERS SIDE OF THE METER.
When the grounding for the electric, communications, antenna, data and others are commonly bonded with a metallic water pipe only ONE CONNECTION between the lighting protection and the waterpipe at this bonding point is required.

NOTE: THIS COMMON BONDING REQUIREMENT MAY ALSO BE ACCOMPLISHED BY EACH SYSTEM BEING CONNECTED TO A COMMON GROUND BAR OR BUS OR BY CONNECTION TO A BUILDING STEEL MEMBER.

Interconnection to Building Systems

A side flash between parts of the lightning protection system and other grounded systems can occur during the discharge of a lightning strike. Grounded metal bodies, such as exhaust fans, plumbing vents, roof drains and ladders that can contribute to a lightning hazard shall be bonded to the system.

NOTE: The industry practice for secondary bonding to metal bodies that are located within a zone of protection is to bond within 6 ft. of the system unless inherently bonded.

SEE INHERENTLY INTERCONNECTED IN PARAGRAPHS 152 OF LPI-175 AND BELOW

Metal bodies “inherently grounded” refers to those metal objects on a metallic frame (steel) building that are attached to the frame of the building by the construction process.

METAL BODIES THAT ARE MOUNTED ON STEEL MEMBERS AND PROPERLY GROUNDED REQUIRE NO FURTHER BONDING.

METAL BODIES AUTOMATICALLY COMMON WITH THE METAL WATER PIPE SYSTEM (structurally connected to the water pipe), REQUIRE NO FURTHER BONDING.

All prominent metal bodies not located within a zone of protection shall be bonded to the system using main size conductors UNLESS INHERENTLY BONDED BY THE CONSTRUCTION PROCESS. These metal bodies that are 3/16 inch thick may serve as STDs.

Exception: Where safety is a factor, personnel handrails may serve as STD’s provided they are at least 1/8 inch thick. They shall be bonded at each end and at 100 feet intervals.

Potential Equalization

Various grounded systems within a building have varying ground potential because of differing inductive lengths of materials. This difference in potential may cause arcing between these items and the lightning protection system during a lightning discharge. Bonding these various systems together at various heights will equalize the potential and eliminate this side flash effect.
Structures Exceeding 60ft. in Height

**Par. 157)**
Page 53
All common connections between the lightning protection grounding, other service grounds and metal conduits entering a building shall occur no higher than 12 ft. above grade. They may be made below grade, within a ceiling space, or in a basement or crawl space.

**Par. 157)**
Page 53
Roof-level potential equalization-Refer to paragraph 157 on page 53 of LPI-175.

**Par. 158)**
Page 53
The bonding of roof mounted equipment must be considered on an individual basis. Multiple units may have common inherent connections somewhere just below the roof. In this case, only bonding to one of the units in the group would be required. Multiple vents may also be extensions of long verticle systems that split near the bottom of the structure and require additional bonding.

**Par. 159)**
Page 54
When steel roof framing is connected to the lightning protection downleads and the unit(s) in questions are inherently common with the steel, additional bonding is not required.

**Par. 160)**
Page 54
Intermediate-level potential equalization requires additional potential equalization bonding at levels between the roof and grade for structures of certain heights and types as follows:

- **Steel framed structures**-NO INTERMEDIATE LOOP AND BONDING REQUIRED.

- **Reinforced concrete structures**-a main size conductor loop interconnecting the downleads and grounded systems at intervals not exceeding 200 ft.

**NOTE:** -A building 200 ft. or shorter does not require an intermediate loop.

- For multi-level buildings, ONLY sections of the building with roof levels that exceed 200 ft. require intermediate loops.

- **Other structures**-require intermediate loops not exceeding 60 ft. intervals.

**NOTE:** In an example of a 70 ft. tall wood structure with eave perimeter protection at 55 ft., the eave protection would serve as the intermediate loop.

- **Long vertical bodies**-exceeding 60 ft. in vertical height shall be bonded to the system if they are not already inherently bonded through construction. The bonding should be as close as practical to the extremities.

Structures Up to 60 ft. in Vertical Height

**Par. 162)**
Page 54
Ground-level potential equalization- Refer to paragraphs 143-150 on pages 51-52 of LPI-175. All grounded media shall be interconnected within 12 ft. of grade per paragraph 143 on page 51 of LPI-175.

**NOTE:** A ground loop is NOT required by LPI-175 for structures not taller than 60 ft. above grade.
Bonding Calculations

Par. 164-166) Pages 54-55

Grounded metal bodies—Refer to paragraphs 164, 165 and 166 on pages 54-55 of LPI-175.

NOTE: Secondary bonding of “grounded” metal bodies in order to prevent a side flash occurrence is very important. “Grounded” metal bodies are those that have an alternate path to ground such as motorized power vents, etc.

For the installer or inspector working in the field, the bonding formula and calculations may be complex and inconvenient. The following more practical method to use when determining secondary bonding requirements for potential equalization of “grounded” metal bodies in order to prevent side flash is:

- Use of a simple continuity test light is acceptable.

- Testing is only required on those grounded metal bodies located within 6 ft. of the system.

- For concrete structures, if the test light “lights up” a secondary connection to the system must be made unless:
  1) a bond has already been made below the roof.
  2) it can be confirmed the electrical ground wire in the unit meets the requirements for secondary bonding of TABLE 4 on page 57 of LPI-175.

- For steel structures, if the test light “lights up” NO FURTHER BONDING IS REQUIRED. They are consider to also be inherently bonded through the steel structure.

NOTE: Secondary bonds may be made using secondary conductors per TABLE 4 on page 57 of LPI-175 and secondary fittings. See Figure 54

Figure 54

Examples of Secondary Fittings

Par. 167) Pages 56

Long horizontal grounded metal bodies on roofs exceeding 60 ft. in length shall be bonded to the system at each end and 100’ intermediate intervals according to par. 167 of LPI-175.

Par. 168-170) Pages 56

Ungrounded metallic bodies—The influence of ungrounded metal bodies is not considered to be as great as that of “grounded” metal bodies. They do not necessarily require secondary bonding. However, bonding of these does not constitute a violation of LPI-175.
Potential Equalization Materials

Par. 171) Page 56
Horizontal loop conductors-Refer to paragraph 169 on page 56 and TABLE 2 on page 40 of LPI-175.

Par. 172) Page 56
Interconnecting prominent metal bodies-Refer to paragraph 170 on page 56 and TABLE 2 on page 40 of LPI-175.

Par. 173) Page 56
Secondary bonding connections-Refer to paragraph 171 on page 56 and TABLE 4 on page 57 of LPI-175.

CONCEALED SYSTEMS

Par. 174) Page 57
Advantages for concealment of lightning protection system components-Refer to paragraph 174 on page 57 of LPI-175.

Par. 175) Page 57
All requirements for exposed installations apply to concealed installations-Refer to paragraph 175 on page 57 of LPI-175.

Par. 176) Page 57
Conductors in metallic and non-metallic conduit. Refer to paragraph 176 on page 57 of LPI-175.

NOTE: When metallic conduit is used, the conduit must be bonded to the conductor at both ends as it enters or leaves a conduit run. This may be done by use of bonding wedges or clamps. See figure 6 on page 8 of this guide for details.

Par. 177) Page 57
Conductors embedded in concrete require re-bar connections-Refer to paragraph 177 on page 57 of LPI-175.

Par. 178) Page 57
It is acceptable to route conductors, components and air terminals concealed in chimney construction and masonry.

HOWEVER, the exposed portion of the air terminal must be aluminum, stainless steel or hot-dip lead coated or tin coated to aid against the corrosive effects of chimney gases.

See Figure 55

Figure 55

![Diagram of chimney downlead in mortar to main roof conductor](Image)
As previously stated, it is acceptable to install the grounds below concrete slabs. This includes building, garage and basement slabs and in crawl spaces. The ground electrodes shall be located as close as practical to the outside of the building perimeter. The grounds may also be routed through a wall and installed there.
See Figure 56

Figure 56

Continuity of the concealed conductors and connections shall be verified at the time of the installation. The inspector should be provided with a set of “As-Built” drawings to aid in confirming the design, continuity and completeness of all concealed parts of the system.
See Figure 57

Figure 57

<table>
<thead>
<tr>
<th>SYMBOL LEGEND</th>
</tr>
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<tbody>
<tr>
<td>SYMBOL</td>
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</tbody>
</table>

SAMPLE OF “AS-BUILT” DRAWING
STRUCTURAL STEEL OR METALLIC FRAME SYSTEMS

Par. 180-181) Structural steel or metallic framework utilized as main conductor must be:
- A minimum of 3/16 inches thick.
- Be electrically continuous or made so by main size bonding jumpers.
- Provide horizontal coursing from all STD’s to the grounding system.

Par. 182) STD’s may be connected to structural steel/metal framing by the following:
- Drilling and tapping the steel/metal. (Refer to paragraph 183 on page 57 of LPI-175 for requirements.)

See Figure 58

Par. 182) Individual vertical main size conductors routed from the STD through the roof or wall to the steel. This will require some provision for the roofer to complete a water-tight seal such using as a thru-roof or thru-wall. The conductor itself may not directly penetrate the roof.

See figure 59

Bonding Plate or Clamp Must Provide 8 sq. in. of Contact
An exterior horizontal main conductor connecting to the STDs and back to the steel/metal at 100 ft. average spacing.

See Figure 60

Figure 60

Connections to steel must be made to clean areas of the base steel/metal. Connections may be made by:

- A bonding plate or clamp having 8 sq. in. of surface contact.
- welding or brazing.
- Removal of rust protective coatings-Refer to paragraph 183 on page 58 of LPI-175.

See Figure 61

Figure 61

Bonding Plates & Clamps Must Provide 8 sq. in. of Surface Contact

Weld Connection Forms May Vary
Drilling and tapping steel/metal requirements-Refer to paragraph 184 on page 58 of LPI-175

Steel/metal columns must be grounded at NO more that 60 ft. average intervals-Refer to paragraph 185 on page 58 of LPI-175.

Metal bodies inherently connected to steel/metal structures may not require additional bonding-Refer to paragraph 186 on page 58 of LPI-175.

Material classification requirements for multi-level steel structures.

- All sections of a structure that are taller than 75 ft. above grade shall require Class II components for that section from top to bottom; including STD’s, conductors, fittings and ground electrodes.

- Sections of a structure that are no taller than 75 ft. above grade only require Class I materials for those sections.

Class II materials may be installed on Class I sections of a structure.

SURGE PROTECTION

Refer to: Paragraphs 188 through 194 on page 59 of LPI-175
Paragraphs 195 through 201 on pages 60-61 of LPI-175
Paragraphs 202 through 212 on page 61 of LPI-175

Surge protection equipment is required at the electrical, communications, antenna systems or other electrical system hardware. The responsibility for the surge requirements is under the contractor responsible for the specific equipment, service or system involved.

Electrical service entrances require a surge protection device (SPD) with a nominal discharge current (In) of at least 20kA per phase. For transient voltage surge protection suppressor (TVSS), see TABLE 5 SURGE PROTECTION DEVICES on page 60 of LPI-175. The surge protection device is required to be visible during inspection.

Data communication lines require surge protection if the lines enter the structure. Surge protection devices, if installed at the entrance, shall have a 10kA rating or greater. Surge protection can also be installed on both ends of the external signal lines.

THE PARAGRAPHS CONTAINED IN THIS SECTION ON PAGES 59 THROUGH 61 OF LPI-175 ARE DEEMED TO BE SELF EXPLANATORY.
ELEVATED STORAGE STRUCTURES (SILOS)

The protection required for silos is the same as for any other structure and has been covered in the previous sections and paragraphs of this guide. The placement of STD’s, conductor routing, downlead routing and ground methods apply to silos as well.

Refer to: Paragraphs 213 through 215 on page 62 of LPI-175
          Paragraphs 216 through 224 on page 63 of LPI-175

THE PARAGRAPHS CONTAINED IN THIS SECTION ON PAGES 62 AND 63 OF LPI-175 ARE DEEMED TO BE SELF EXPLANATORY.

HEAVY DUTY SMOKE STACKS

Refer to: Paragraphs 225 through 226 on page 63 of LPI-175
          Paragraphs 227 through 229 on page 64 of LPI-175
          Paragraphs 230 through 239 on page 65 of LPI-175
          Paragraphs 240 through 248 on page 66 of LPI-175

THE PARAGRAPHS CONTAINED IN THIS SECTION ON PAGES 63 THROUGH 66 OF LPI-175 ARE DEEMED TO BE SELF EXPLANATORY.

The basic principals for protecting Heavy Duty Smoke Stacks are the same as for protecting Ordinary Structures. Some of the key specific differences are:

- Heavy duty smoke stacks are stacks more than 75 ft. above grade and having a cross sectional flue area exceeding 500 sq. in. Otherwise, they are classified as an ordinary chimney and protected as such.
- Air terminals must be solid copper, stainless steel, or monel metal* and at least 5/8 inch in diameter.
- Aluminum components are NOT approved.
- All copper and copper alloy material within 25 ft. of the top must have a lead covering or jacket at least 1/16 inch thick, or approved corrosion resistant covering or coating. (Thin hot-dip lead or tin coatings do not comply.)
- The lead covering or jacket must be removed to allow for component connections at the contact area.
- Stainless and monel metals do not require a protective coating.
- Spacing between STD’s can NOT exceed 8 ft.
- Air terminals must extend at least 18 inches above the stack and no more than 30 inches above the stack.
- Vertical conductors must be fastened at 48 inch maximum intervals.
- Horizontal conductors must be fastened at 24 inch maximum intervals.
*NOTE: Monel metal is the brand name for a metal primarily composed of nickel, copper and iron. Similar to stainless steel, it is highly resistant to corrosion and rust.

**Figure 62**

<table>
<thead>
<tr>
<th>Lead Covered Std</th>
<th>Lead Covered Conductor Splice</th>
<th>Lead Covered Fastener</th>
<th>Lead Covered Conductor</th>
</tr>
</thead>
</table>

**EXAMPLES – LEAD COVERED HEAVY DUTY SMOKE Stack COMPONENTS**

**TREE PROTECTION**

Refer to: Paragraphs 249 through 250 on page 67 of LPI-175  
Paragraphs 251 through 257 on page 68 of LPI-175

**THE PARAGRAPHS CONTAINED IN THIS SECTION ON PAGES 67 AND 68 OF LPI-175 ARE DEEMED TO BE SELF EXPLANATORY.**

**PROTECTION FOR OPEN SHELTERS**

Refer to: Paragraphs 258 through 259 on page 68 of LPI-175  
Paragraphs 260 through 263 on page 69 of LPI-175

**THE PARAGRAPHS CONTAINED IN THIS SECTION ON PAGES 68 AND 69 OF LPI-175 ARE DEEMED TO BE SELF EXPLANATORY.**
### VISUAL MAINTENANCE – INSPECTION CHECKLIST

<table>
<thead>
<tr>
<th>A) AIR TERMINALS &amp; BASES.</th>
<th>CORRECTION NEEDED / DATE APPROVED FINAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>1) Straight and unbroken</td>
<td>1) ____________</td>
</tr>
<tr>
<td>2) Not cracked</td>
<td>2) ____________</td>
</tr>
<tr>
<td>3) Securely fastened to building</td>
<td>3) ____________</td>
</tr>
<tr>
<td>4) Clamped tightly to conductor</td>
<td>4) ____________</td>
</tr>
<tr>
<td>5) Located as installed</td>
<td>5) ____________</td>
</tr>
</tbody>
</table>

| B) BONDING CONNECTION TO METAL OBJECTS. | |
|----------------------------------------| |
| 6) Secured tightly to metal equipment  | 6) ____________ |
| 7) Clamped tightly to connecting cable | 7) ____________ |
| 8) In electrical contact with metal object | 8) ____________ |
| 9) Compatibility of fitting to surface (no corrosion) | 9) ____________ |
| 10) Reinstalled properly if they have been removed | 10) ____________ |

| C) BUILDING ADDITIONS OR ALTERATIONS. | |
|--------------------------------------| |
| 11) No new additions are unprotected | 11) ____________ |
| 12) Alterations have not changed or damaged the system | 12) ____________ |
| 13) No new equipment left unconnected | 13) ____________ |

| D) CABLE HOLDERS/FASTENERS. | |
|----------------------------| |
| 14) Are still tight and secure | 14) ____________ |
| 15) Are properly spaced at 3'-0" O.C. | 15) ____________ |
| 16) Have not been removed | 16) ____________ |

| E) CONDUCTORS, IN GENERAL. | |
|---------------------------| |
| 17) Unbroken              | 17) ____________ |
| 18) Connected as installed | 18) ____________ |
| 19) Adequately secured and routed as originally installed | 19) ____________ |
| 20) Proper bends – no radius less than 90 degrees, no kinks | 20) ____________ |

| F) GROUND CONNECTORS. (If accessible) | |
|--------------------------------------| |
| 21) Connections are tight and unbroken | 21) ____________ |
| 22) No evidence of corrosion or damage to ground device | 22) ____________ |
| 23) Not accessible – No check made | 23) ____________ |

| G) SPLICERS & CONNECTOR FITTINGS. | |
|-----------------------------------| |
| 24) Are still tight on conductors | 24) ____________ |
| 25) Have not cracked or broken    | 25) ____________ |
| 26) Cable secure as installed (no loose ends) | 26) ____________ |

| H) THRU-ROOF CONNECTORS. | |
|--------------------------| |
| 27) Connectors are tight and unbroken | 27) ____________ |
| 28) They are watertight | 28) ____________ |
| 29) Leads to roof cable are intact | 29) ____________ |
| 30) Number appropriate for the perimeter | 30) ____________ |

| I) SURGE PROTECTION DEVICES. Verify that: | |
|--------------------------------------------| |
| 31) Surge protection provided at all service entrances | 31) ____________ |
| 32) Devices are wired properly to lines and ground | 32) ____________ |
| 33) Surge devices are operational/undamaged | 33) ____________ |
Lightning Protection Institute

The Lightning Protection Institute was founded in 1966, chartered as a not-for-profit corporation.

The aims and objectives of the Lightning Protection Institute are:

1. Develop means of protecting life and property from loss by lightning.
2. Assure greater public safety by extending the use of proper lightning protection systems and promoting the practice of personal safety measures.
3. Inform the public in regard to proper and positive lightning protection.
4. Compile and disseminate data and information on lightning, and on losses caused by lightning.
5. Initiate and conduct lightning protection research and development.
6. Formulate and promote standards for lightning protection materials and systems.
7. Conduct educational programs on the science and methods of lightning protection.
8. Conduct training and educational programs for installers, designers, and inspectors of lightning protection systems.
9. Work with engineers and building owners to provide comprehensive, timely inspection and certification of lightning protection systems.
10. Test and certify competence in lightning protection system design, installation, and inspection.
11. Promote and enforce high standards of quality and safety in the design and installation of lightning protection systems.
12. Operate according to the fundamental principles of the Code of Ethics in relations with clients and peers to enhance the reputation of LPI and its programs.

The lightning Protection Institute has adopted the latest edition of the NFPA 780 Standard as its reference for this document. This document and any updates, or revisions to this document are intended as an installation guide for LPI System Certification.

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