

A lightning-protection system
can add value to steel framing and resilience to an entire building.

When Lightning STRIKES

BY JENNIFER A. MORGAN AND MICHAEL CHUSID



Lightning protection by Associated Lightning Rod Co., Inc., photo by Benjamin Benschneider



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LIGHTNING HAPPENS.

And designers and builders can take advantage of steel's electrical conductivity to get extra value from the structural framing system. That's because it typically costs less to install lightning protection systems in buildings with structural steel frames compared to concrete, wood and other less electrically conductive materials.

Lightning-protection systems (LPSs) require a network of electrically conductive paths to safely transmit a lightning strike's 300 million volts from rooftop air terminals—formerly called lightning rods—to ground electrodes. In most buildings, lightning's energy is conveyed through large, multi-strand cables made from highly conductive grades of copper or aluminum. However, the cost of cables, connectors and fittings, plus installation labor, can be reduced by using the structural steel framing as conductors.

National Fire Protection Association (NFPA) 780, 2017 ed.—*Standard for the Installation of Lightning Protection Systems*, Paragraph 4.19.1 states:



Lightning protection by Burchell Lightning Protection Ltd., Photo by Udo Dengler

◀ Air terminals are required on the wood-framed roof of this residence by Olson Kundig Architects in the Berkshires. But the steel chimney cap and cantilevered beam do not require air terminals; they are connected to the grounding system and act as strike termination devices. The beam supports a trolley-mounted glass wall that can be rolled into place to seal the house against weather.

▲ The steel framing of Toronto’s L Tower was used as lightning conductors reaching more than 670 ft from crown to grade. This eliminated the expense of running Class II down conductor cables and intermediate equalization loops around the structure’s girth. The building’s curved shoulder required special calculations to determine acceptable spacing of the air terminals. The building is designed by Studio Libeskind and structural engineer Jablonsky, Ast and Partners.

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

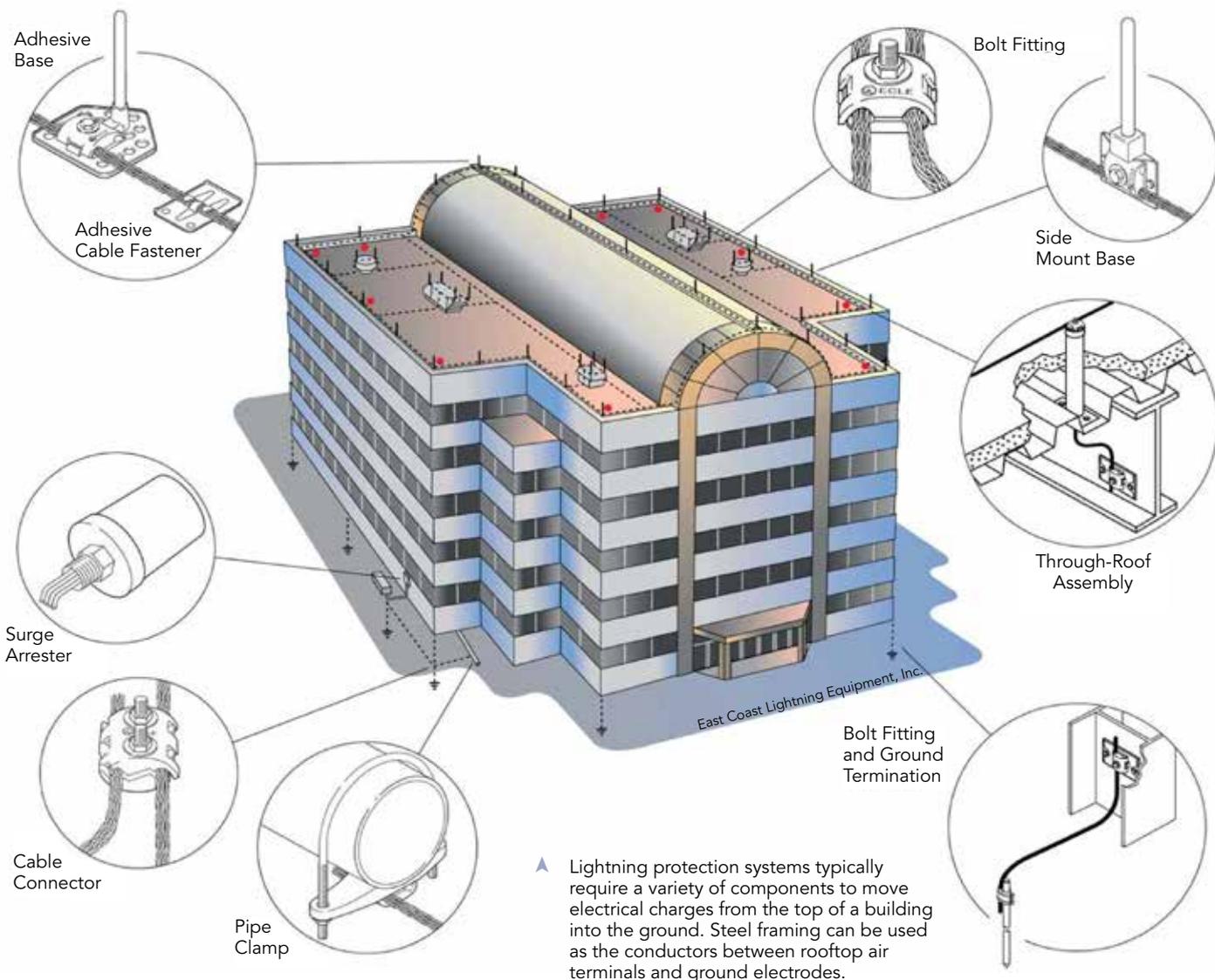
Under special situations, even thinner metal can be used. NFPA 780 Paragraph 4.9.3.2 allows exposed roof-top steel handrails and ladders to be used as main conductors if they are at least 0.064 inch (1.63 mm) thick. (Note that components of a lightning protection system should comply with UL 96–*Standard for Lightning Protection Components* and be listed by UL. Components listed for ordinary electrical service are not safe for lightning protection.)

While steel framing can be used to interconnect air terminals and other roof level equipment, doing so could require many penetrations through the roofing. Instead, cables are used to interconnect items on the roof and then lead to special through-roof penetration devices. Under the roof deck, cables connect to down conductors that extend to the bottom of the building.

It is when steel framing is used as down conductors that it shows its mettle. NFPA requires at least two widely separated down conductors on a structure—or if the building perimeter exceeds 250 ft, a down conductor for each 100 ft of perimeter. Steel framing can therefore eliminate the expense of installing many down conductor cables in a large building.

Cost savings are even greater on structures over 75 ft in height. Considered Class II buildings by NFPA, they require down conductor cables with larger cross-sectional areas. Steel-framed buildings are also exempt from Class II requirements for intermediate cables around a building’s girth for electrical potential equalization loops.

At grade level, framing needs to be connected to ground electrodes at spacings that “shall not average more than 60 ft apart,” as stated in UL 96A–*Installation Requirements for Lightning Protection Systems*. Coupled with the requirement to widely separate grounding points, this commonly means grounding every other column around the building perimeter. It also means that the steel frame may require more LPS connections at grade than at the roof. For example, a building with a 250-



▲ Lightning protection systems typically require a variety of components to move electrical charges from the top of a building into the ground. Steel framing can be used as the conductors between rooftop air terminals and ground electrodes.

ft perimeter may require four or five ground terminations but only three connections at the roof level.

If, for some reason, cables are used for down conductors, it may still be necessary to bond steel structural elements and metal bodies to the LPS. Seeking the path of least resistance from sky to ground, lightning will arc or side-flash from conductors into electrical, plumbing, HVAC and other metallic systems—including structural framing—if electrical potential is not equalized between all grounded systems.

Detailing

If steel is used as conductors, NFPA 780 requires the following:

- ▶ 4.19.3 Connections to framework. Conductors shall be connected to areas of the structural steel framework that have been cleaned to base metal, by use of bonding plates having a surface contact area of not less than 8 sq. in. or by welding or brazing.
- ▶ 4.19.3.1 Drilling and tapping the steel column to accept a threaded connector also shall be permitted.
- ▶ 4.19.3.2 The threaded device shall be installed with five threads fully engaged and secured with a jam nut.

- ▶ 4.19.3.3 The threaded portion of the connector shall be not less than ½ in. in diameter.
- ▶ 4.19.3.4 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.
- ▶ 4.19.3.5 Where rust-protective paint or coating is removed, the base steel shall be protected with a conductive, corrosion-inhibiting coating.

Using steel as conductors can eliminate the need for some through-structure penetrations and trade coordination issues where cables pass through floors or walls. Exposed cables can be damaged or stolen for scrap, and concealing cables incurs the cost of applying finishes.

The LPS grounding system is much more robust than the building's electrical grounding system and therefore must be grounded separately from the electrical grounding system. Steel pilings may be able to serve as the lightning protection ground.

Using structural members for conductors can also be useful when retrofitting an LPS on an existing building. For example, at the Virginia Museum of Fine Arts in Richmond, Va., exist-



▲ From air terminals above the roof, lightning travels via a roof-penetration device to a cable and bolted connection into the steel framing.



▲ At column bottom, an exothermic weld connects a cable leading to ground electrodes.

ing steel columns provided electrical continuity between new rooftop air terminals and ground electrodes—without damaging interior finishes.

Strike Termination Devices

Air terminals rise above a building to intercept lightning before it reaches the structure. Lightning is modeled as a 300-ft diameter sphere being rolled over a building's envelope; anywhere the sphere touches the building is susceptible to becoming lightning's attachment point. Based on this, NFPA 780 requires air terminals at roof corners and 20 ft on center along roof ridges and edges, on top of roof top equipment that is not within the zone of protection of an air terminal mounted higher on the structure and 50 ft on center through the field of the roof.

Air terminals are not highly visible from the ground. They can be as slim as $\frac{3}{8}$ in. in diameter, just 10 in. tall and set up to 24 in. in from roof edges. Light colored air terminals—either aluminum or plated copper—reflect and blend into the sky. Yet there are locations where a traditional air terminal might be visually or functionally objectionable.

NFPA 780 Paragraph 4.6.1.4 allows air terminals to be replaced by other strike termination devices made from metal at least $\frac{3}{16}$ in. thick. Examples of strike termination devices include:

- Structural elements such as pylons or exposed trusses and beams that rise above the roof.
- Railings around balconies and terraces where air terminal might interfere with views or be subject to damage due to proximity to pedestrians.
- Rooftop structures such as sculptures, decorative elements or equipment screens are fabricated metal.
- At the supertall 432 Park Avenue residential tower in New York City (nearly 1,400 ft tall), parapet caps made from metal plate are being used instead of vertical air terminals to comply with strict enforcement of building height limitations.
- Helipads and other structures with exposed metal framing.

These fabrications must be electrically continuous and connected to the building ground.

Resilience

As lightning strikes increase in frequency thanks to changing weather patterns (in large part due to climate change) LPSs are on the rise. The growing use of electronic devices and the internet of things also make buildings more vulnerable to lightning surges. According to insurance industry estimates, lightning results in \$1 billion of residential insurance claims and \$108 million in direct property damage to nonresidential buildings. These estimates are conservative since damage caused by lightning surges can be misattributed. Lightning can accompany tornadoes, hurricanes and floods, and lightning protection programs must be considered as part of building and community resilience.

Lightning protection is not mandated under national building codes but is required in some local codes, by government agencies and by an increasing number of sophisticated building owners. It is the design professional's responsibility to evaluate the need for LPS and advise his or her client accordingly. For example, American Institute of Architects document AIA D200—*Project Checklist* requires designers to “obtain seasonal climate and microclimate data from the weather service” as part of site analysis.

Structural engineers should ask their clients and design team members about lightning protection during design development so it can be taken into account when selecting a building's structural system and subsequent detailing.

NFPA 780 Appendix L contains a simplified lightning risk assessment with criteria for assessing a building's vulnerability to lightning and tolerance for damage. Calculations can be performed online in just a few minutes at www.ecle.biz/riskcalculator.

Project specifications usually delegate LPS design to installers employing a Master Designer-Installer certified by the Lightning Protection Institute (LPI). In addition to NFPA standards, specifications should require compliance with UL and LPI standards. The general contractor should meet with the steel erector and lightning protection installer to coordinate locations of and scheduling for installation of penetrations and other connections. Finally, third-party inspection services are available through UL and LPI-Inspection Program and should be part of the building commissioning process. A nonproprietary, CSI-formatted guide specifica-



Bonded Lightning Protection Systems, Inc.



Credit: Priestley Lightning Protection, LLC



Loehr Lightning Protection Co.

- ▲ Steel railings act as a strike termination device around this mechanical equipment penthouse at a Florida hospital. The UL-listed cable at the bottom of railing connects it to the rest of the lightning penetration system.
- ◀ Existing steel columns were used as down conductors when lightning protection was installed on the existing Virginia Museum of Fine Art. Openings in the brick fire protection were made so that cables, leading to ground electrodes, could be fixed to the steel with bolted copper fittings. The fitting was sealed and painted to provide additional corrosion protection.

- ▲ Steel components must be $\frac{3}{16}$ in. thick to be used as conductors. Framing this wood-framed corner was simplified and visually cleaner by not having to run a full-height cable. Conductors can contact wood and other combustible materials because they are sized to create a low-resistance path that does not get hot during a momentary lightning surge.

A Lightning-Protection Installer Speaks

Justin Harger, is certified as a Master Installer-Designer by the Lightning Protection Institute. He is executive vice president for HLP Systems, Inc., and has installed lightning protection systems on many major buildings in the Chicago area and the Midwest. He shared these thoughts:

In our market, LPSs on mid- to high-rise steel-framed buildings are 20% to 30% less expensive than on a reinforced concrete structure. The cost advantage is lower on low-rise buildings, but it still can be found when dealing with complex structures.

For connections between lightning-protection components and structural steel, we use UL-listed clamps or exothermic welds depending on the requirements of the specifications and the project. On most projects we make connections to bare steel and prior to fireproofing. The standards do not have specific testing or resistance requirements for the electrical continuity of the framing, but the necessary continuity is there due to steel-to-steel contact. Occasionally, we have to provide jumper cables if continuity is broken by epoxy coatings or other conditions, but that is rare.

Structural steel gives the most flexibility to an LPS, in my opinion. It is easier to conceal, install and maintain an LPS on steel buildings. Grounded structural steel is very versatile in allowing for changes to the LPS that might be required down the road. It is also far easier to incorporate architectural elements into the design of the lightning protection as such elements are often already connected to the structural steel and require very little work by the lightning-protection installer. That means less expense to the building owner and less visual impact to the architectural design.



Boston Lightning Rod Co.



Lightning protection by Boston Lightning Rod Co., Bruce Buck, courtesy Le Méridien Hotels

▲ The steel turret atop Le Méridien-MIT Hotel in Cambridge, Mass., acts as a strike-termination device and is connected via the LPS to ground. A conventional air terminal is visible on the parapet in the lower-left corner of the left photo.

tion can be downloaded at www.constructionspecifier.com/lightning-specs.

And of course, there's the ever-present issue of money, so it's important to point out that lightning protection provides affordable security; a construction cost study of non-residential buildings five stories or less found that LPSs cost between \$0.30 and \$0.60 per sq. ft of floor area. Additionally, a system can last the life of a building with little maintenance expense, and its metallurgical value can be recovered at the end of a building's life cycle. (Download cost study at www.ecl.biz/coststudy.)

Even so, designers and builders can seize economies when they present themselves. Steel framing plays a vital role in protecting structures, their contents and their occupants against wind storms, earthquakes, flood surges and other ravages of nature. It is comforting to know that steel can also play an important role in protection against lightning without adding to the cost of the framing. ■

For a more complete architectural overview of lightning protection, see "Lightning Protection and the Building Envelope" in the August 2015 issue of Construction Specifier, available at www.ecl.biz/constructionspecifier.