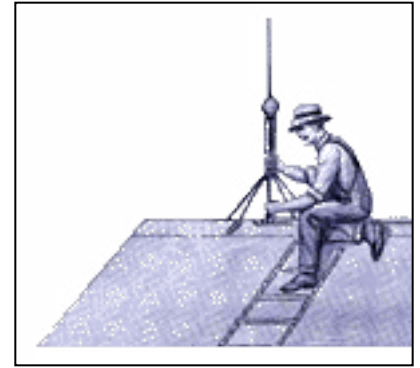


50 PRESERVATION BRIEFS

Lightning Protection for Historic Structures

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Technical Preservation Services

Introduction

The loss of historic buildings as a result of lightning strikes makes local front page news every year. Lightning strikes make no distinction between historic properties and other types of structures. Historic barns, churches, museums, homes, stores, factories, lighthouses, schools, and other buildings, as well as structures such as tall monuments, may be at unnecessary risk of damage or loss as a result of a strike by lightning.

The insurance industry reports that 5% of all claims are lightning-related in the U.S., with annual building damage estimated as high as \$1 billion according to Underwriters Laboratories, Inc. Certain types of structures are especially susceptible to damage, particularly churches where lightning accounts for nearly one-third of all church-building fires each year (Fig.1).

Lightning protection systems in the United States date back to colonial days and the time of Benjamin Franklin.



Figure 1. Saved from a wrecking ball and renovated in 1970 by a 70-person congregation, the Sanctuary of the Holy Spirit church was the oldest operating place of worship in Winder, Georgia. Just five years later, the 1904 church was destroyed by fire, having been struck by lightning during a violent thunderstorm. Photo: Paul Brennen/shutterstock.com

Old systems that have survived in whole or in part on historic structures may be historic features in their own right and deserve preservation. Such historic lightning protection systems may still be operating properly or can be repaired and upgraded. Some old systems simply are too deteriorated, incomplete, or archaic to repair and make fully functional, raising the question whether they should be saved in place or removed in whole or in part for safety. For historic structures that have none and are located in areas that are prone to lightning strikes, or are of special significance and deemed irreplaceable, a modern lightning protection system may merit installation.

This Preservation Brief is designed for owners, property managers, architects, contractors, and others involved in the preservation of historic structures. It includes information on the care, maintenance, and repair of historic and older lightning protection systems; discusses factors to consider in assessing the need for a lightning protection system where none exists; and includes historic preservation guidance on the design and installation of new systems.

What Causes a Lightning Strike?

During violent storms, ice particles form in the atmosphere and collide with each other, resulting in a transfer of negative ions among ice particles. Smaller ice particles or crystals tend to lose negative ions, becoming positively charged, and are then carried through updrafts to the upper levels of the clouds. Heavier ice particles gain negative charges and settle below within the clouds. Lightning is produced when these opposite-charged cloud values create high electric fields—nature's way of reducing the imbalance.

The more typical negative electrical charges travel in leaders or about 150-foot segments. During thunderstorms, bursts of negative charges extend closer to the ground. Under such conditions, higher exposed objects on the ground in turn may send positively charged leaders upward. When two oppositely charged

leaders connect, a massive stroke of current travels to the ground along one or more paths of low resistance (Fig. 2). Usually several strokes occur in rapid succession, appearing to the human eye as a single lightning bolt to the ground.

The mechanical force of this enormous energy flow can have a blast effect on a structure, exploding, for example, a large chimney, parapet or corner of a building. Heat up to 50,000°F generated along its path through wood and other building material can result in fire and considerable damage. Besides the risk of injury and loss of human life, irreparable damage to cultural resources can occur as a consequence of a lightning strike.

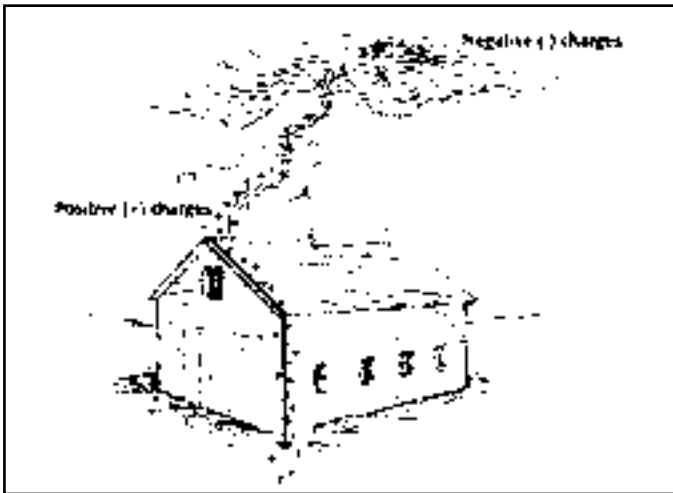


Figure 2. Positive and negative electrical charges occur naturally under certain weather conditions, causing imbalances. When a downward stream of strong negative charges in the air meets with a shorter leader of positive charges that have accumulated on, and are arising from a building, tree, or object, the resulting flash is lightning. The drawing shows a building with a lightning protection system providing a safe path for the lightning to travel to the ground rod beneath the soil. Courtesy: Cornell Agricultural Safety and Health Program, Jim Houghton, illustrator.

Components of Conventional (Traditional) Systems

The function of a conventional lightning protection system is not to prevent lightning from striking a structure, but rather to provide a specific path of low resistance for lightning current to travel to the ground that will result in no damage or injury. Since the 18th century, it has proven effective.

There are three principal components of a conventional system: the *lightning rod (air terminals)*, *conductor*, and *ground* (Fig. 3). Besides these three traditional components, a system includes the *bonding* of other metal features of a building considered to be a lightning hazard and, particularly today, the use of *surge suppressors*.

The *lightning rod (air terminal)* typically is the most prominent visual component of the system, and in

its older, more traditional form could appear as an ornamental feature on a structure. In most cases, rods are used at prescribed locations and distances, joined together by connecting wires to conductors. In today's contemporary applications, the lightning rods are very simple in design, most often consisting of utilitarian air terminals measuring 10 to 12 inches in height, although certain conditions may require taller terminals. By contrast, lightning rods of the late 19th and early 20th century were usually taller, typically four to six feet in height, and often had a more decorative appearance with embellishments, such as a weather or directional vane or glass balls (Fig. 4).

Each *lightning rod* must be attached to the grounding system through horizontal roof cables and vertical *conductors*. Cables are used to join individual lightning rods, most often in loops or series, and then in turn attached to two or more main conductors running to metal grounds. One major exception occurs in structures with structural steel where, under certain conditions, lightning rods may be tied directly to the steel frame. The steel needs to be continuously connected, since it must serve as the conductor and be tied to the ground for the lightning protection system to be complete.

Cables vary by weight and number of strands of wire, with heavier cables required for use on structures taller than 75 feet. The number of required main conductors depends in part on the perimeter length of the structure. Even on smaller historic buildings, two or more down conductors are needed to help diffuse the electrical charge from a lightning strike along its path to the ground.

The *grounding system* usually consists of long solid-metal grounding rods driven into the soil, usually to a depth of at least 10 feet, to which the down cables

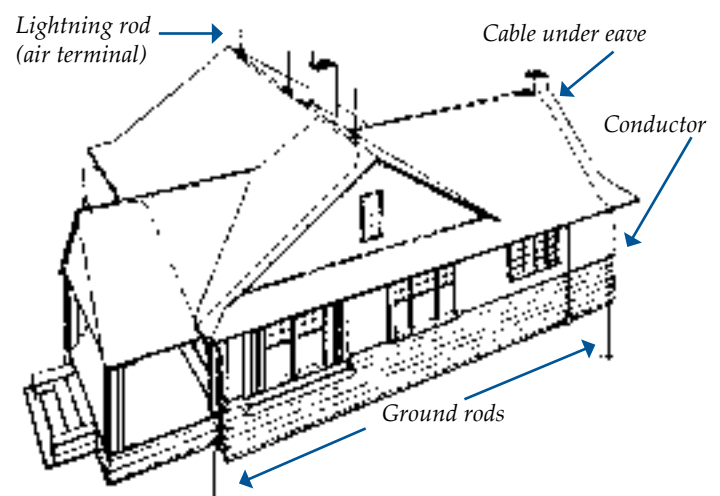


Figure 3. Conventional lightning protection systems consist of three principal components: the lightning rods, which are connected by cables to the system; two or more down conductors, which connect the lightning rods to the grounding system; and the ground rods. Adapted from a 1950 U. S. Department of Agriculture illustration.

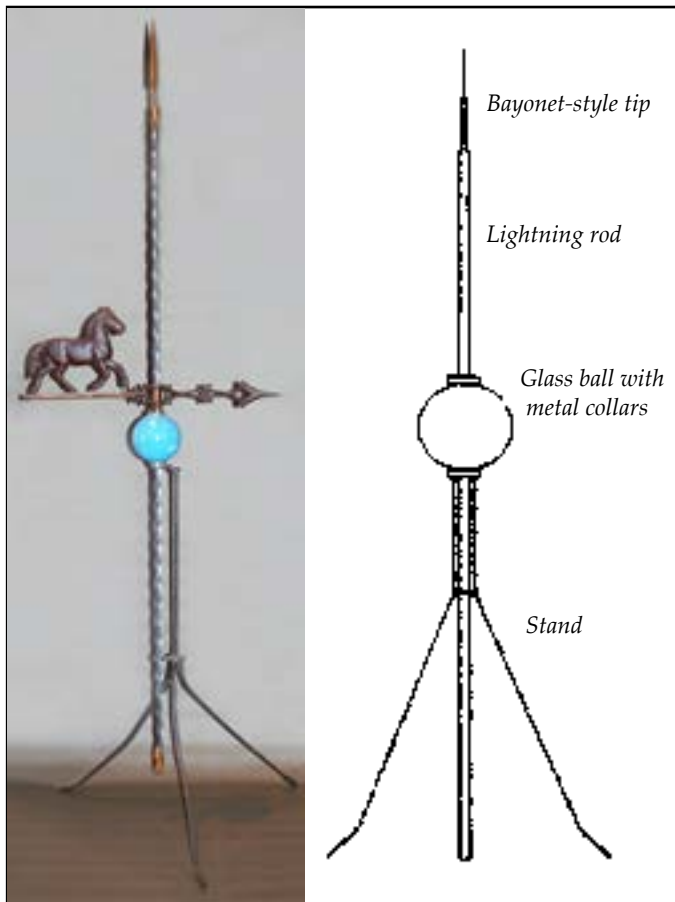


Figure 4. The most common historic lightning rods of the late 19th to early 20th century consisted of a lightning rod or air terminal, glass ball, and a stand attached to the roof. These rods tended to run four to six feet in height and were quite prominent on the roof. Courtesy: Charles Fisher Collection. Drawing: New Old Products, Inc.

are attached at one end using special connectors. On buildings today, the most commonly used grounding rod is an 8 to 10-foot copper, copper-clad steel, or stainless steel rod. Depending on the soil condition, depth of soil, and presence of bedrock near the surface, additional grounding rods may be needed or may need to be placed in a different manner. In some cases, an alternate grounding system is needed altogether. Other grounding systems, such as those used for electrical, telephone service, or a satellite dish, need to be connected to the lightning protection ground.

Whenever a structure has metal gutters and downspouts, metal roof vents, large metal awnings or other conductive objects that contribute to lightning hazards, these objects need to be bonded to the lightning protection system. On the inside of a building, copper and galvanized-iron water lines as well as steam or hot water heating systems with metal pipes must be connected to the ground conductors. Bonding of these objects to the lightning protection system through use of metal conductors deters an electrical charge caused by a lightning strike from seeking alternative paths to the earth. Bonding also deters side flashing whereby current otherwise could jump from components of the lightning protection system to nearby conductive objects. As it

is impractical to bond all metal objects, such as each steel or aluminum window on a building, only objects considered more hazardous are usually bonded to the lightning protection system (Fig. 5).

Lightning damage to a structure can occur from lightning striking distant or nearby power lines. Resulting power surges can affect not only sensitive electronic equipment, such as computers and security systems, but also common household items such as land-line telephones, electric appliances, and home entertainment centers. There is always the human safety risk as well from such power surges, thus the adage stay off the phone (land-line) during an electrical storm. For safety and to protect against excess voltage, different types of surge protective devices (SPD) are used.

History

Lightning strikes have mystified man since the beginning of time. While it has been observed long ago that lightning tends to strike tall objects, not until the mid-1700s did there emerge a general understanding of lightning and how to prevent damage to structures.

In the late 1740s and early 1750s, interest in static electricity led Benjamin Franklin to investigate the nature of electricity, including lightning. In a series of letters to Peter Collinson, a Fellow of the Royal

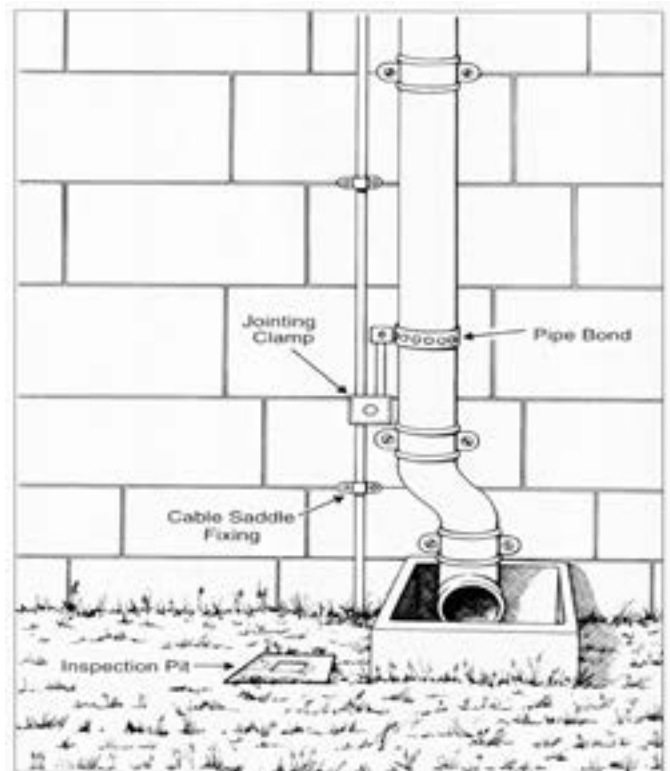


Figure 5. Bonding of conductive material on a structure to the lightning protection system is important to deter damage from side flashing. In this drawing, the metal downspout has been bonded to the down conductor. Unless bonded, metal gutters and downspouts provide a good path for an electrical discharge to side flash and cause damage to a building. Drawing: English Heritage©

Society of London, Franklin described his experiments and observations on electricity. Published together in London in 1751, these letters soon led Thomas-Francois Dalibard and a colleague, collaborating in Paris, to experiment with a tall metal rod that was insulated in the ground. Their experiment in May 1752 was based on a proposal described by Franklin in his letters and succeeded in drawing sparks, helping to confirm that thunderclouds are electrified.

Franklin probably conducted his famous kite experiment shortly thereafter, unaware at that point of the earlier French experiment. He did publish in his *Poor Richard's Almanac* a description of a lightning protection system in 1753, and, in the same year, he was awarded the prestigious Copley Gold Medal by the Royal Society of London for his "curious experiments and observations on electricity." Franklin had envisioned a means to protect a structure from being struck by lightning. Yet he soon came to realize that rather than preventing strikes, lightning protection systems functioned to provide a safe path of travel for the electrical discharge.

In a letter written in 1762, Franklin provided a detailed description of a lightning protection system:

Prepare a steel rod 5 or 6 feet long, half an Inch thick at its biggest End, and tapering to a sharp Point; which Point should be gilt to prevent its rusting. Let the big End of the Rod have a strong Eye or Ring of half an Inch Diameter: Fix this Rod upright to the Chimney or highest Part of the Building, by means of Staples, so as may be kept steady. Let the pointed End be upwards, and rise three or four Feet above the Chimney or Building that the Rod is fix'd to. Drive into the Ground an Iron Rod of about an Inch Diameter, and ten or twelve feet long, that has also an Eye or Ring in the upper End. It is best that the Rod should be at some Distance from the Foundation of the Building, not nearer than ten feet, if your Ground will allow so much. Then take as much Length of Iron Rod of about half an Inch Diameter, as will reach from the Eye in the Rod above to that in the Rod below; and fasten it securely to those Rods, by passing its Ends thro' the Rings, and bending those Ends round till they likewise form Rings.

This Length of Rod may be in one or several Pieces. If in several, let the Ends of the Pieces be also well hooked to each other. Then close and cover every Joint with Lead...that there should be considerable Quantity of metalline Contact between Piece and Piece: For if they were only hook'd together, and so touch'd each other but in Points, the Lightning in passing thro' them might melt and break where they join. The Lead will also prevent the Weakening of the Joints by Rust. To prevent the Shaking of this Rod by the Wind, you may secure it by a few Staples to the Building till it comes down within ten feet of the Ground, and thence carry it off to your Ground Rod; near to which should be planted a Post, to support the Iron Conductor above the heads of the people walking under it.

In such a remarkable short time, the basics of today's lightning protection system for ordinary structures were in place, and this invention became popularly known as

the Franklin system. It is still the most commonly used lightning protection system for structures throughout the world. Yet even Franklin acknowledged that he and his colleagues benefited from some luck in arriving so quickly at a lightning protection system that worked.

In the second half of the 18th century, lightning protection systems were being installed from Boston to South Carolina. Yet this was a pioneering period and installations were far from common. Relying principally on descriptions provided by Franklin rather than first-hand experience, early installers operated with some trial and error. A number of the known early installations seem to have worked reasonably well in providing a safe path to the ground for the charge from an electrical strike, establishing for the first time that buildings could be protected from significant damage caused by lightning.

When strikes to a protected structure occurred, damage to the lightning protection system still could result due to material deficiencies or improper installation. The "Electric Rod and Conductor" on Christ Church in Philadelphia was struck by lightning in June 1777, and rendered useless, although additional damage to the church seemingly did not occur. System damage reported at other buildings included the narrower pointed end of the rod at times melting and needing to be replaced; large metal staples securing a down conductor to the building dislodging and having to be reattached; and down conductor sections joined with hook and eye connections needing to be rejoined. Failures did occur as a result of undersized conductors, too few lightning rods, or lack of bonding to nearby metal objects, with resulting damage to buildings. It soon became clear that thicker conductors needed to be used; connectors needed to be more secured and, where possible, reduced in numbers; and, to avoid damage to foundations, more extensive grounding was required, depending upon soil condition.

Evidence of late eighteenth-century installations have survived, including ones in Franklin's hometown. A section of a hand-forged, wrought-iron conductor remains inside the stair tower of Independence Hall and would have been joined in a series of sections using hook-and-eye connections to form the down conductor. In Portsmouth, New Hampshire, a system was installed in 1767 on the Warner House, purportedly under the personal inspection of Franklin. An early system still survives on the Warner House, consisting of a long forged-welded piece of wrought iron (Fig. 6). A hook-and-eye section of the ground has even survived and is now on display inside the building.

In Europe, individuals that shared Franklin's scientific interest in lightning protection helped to guide early installations on buildings. Despite some initial resistance on religious grounds, lightning rods soon appeared on many larger steeple-topped churches that had a propensity for being struck by lightning.



Figure 6. Lightning protection was installed on the Warner House in Portsmouth, New Hampshire, in 1767, purportedly under the personal inspection of Benjamin Franklin. An early system still survives on the building, consisting of a long forged-welded rod of wrought iron which extended up and above the chimney, comprising both the conductor and the air terminal. The conductor was joined to a separate, buried, iron ground rod by a forged hook and eye connector. Photo: Peter Michaud.

Specialized applications soon followed such as for powder magazines and lighthouses.

The installation by 1788 of the lightning rod on the dome of the Maryland State House in Annapolis, Maryland, represented a superb example of a building-specific application of the Franklin system. Still in place and fully functional, the historic wrought-iron lightning rod measures 28 feet in height and is 2 1/2 inches square at its base, its thickest point. This lightning rod has a decorative flare, including a weathervane toward the top and an acorn and pedestal at its base. As part of a 18th-century renovation of the State House, Joseph Clark, a local architect and builder, erected the large dome and installed the lightning protection system, essentially using the Franklin system (Fig. 7).

Despite no real manuals or standards, the early installations of the “Franklin rod” often proved effective. The experience derived from the early applications provided for an enlightened learning process. Still, there were failures that reinforced the belief among some that lightning rods actually attracted lightning and should not be used.

By at least the early 19th century, individuals were marketing lightning protection, sometimes with little or

no understanding of the working of the Franklin system. In 1824, the newspaper *New England Farmer* reprinted a letter attributing many of the recent failures to improper grounding and installation, stating that “*Lightning rods are generally made and put up by persons wholly unacquainted with the principles of electricity and what is necessary to constitute a safe conductor.*”

The letter goes on to provide instructions for proper installation that include the use of five or more points at the end of the rod, with points sharpened, tipped with silver, and elevated five or six feet above the highest part of the building. The writer specified that the rod (and conductor) should be at least 3/4 inch in diameter, with a continuous weld rather than linked where possible, and should terminate in the earth six or seven feet deep, set in a bed of two or three bushels of wet charcoal. The letter’s author noted that the expense for one rod on a two-story building would not exceed \$50, still a considerable sum for the time



Figure 7. The c. 1788 wrought-iron lightning rod on the Maryland State House dome measures 28 feet in height, 2-1/2 inches square at its base, and is pointed at its top. The rod passes through a decorative copper-paneled wood acorn that is nearly 4 feet in diameter. The acorn helps provide stability to the rod that, in turn, is secured to the pedestal or base of the acorn. While based on the Franklin system, this rod had a decorative flare, including a weathervane and ornamental base. Prominently located in Annapolis along the Chesapeake Bay, an area of frequent summer lightning storms, the building has been struck by lightning as recently as 2016, surviving undamaged. Photo by Niagara (Own work) [CC BY-SA 3.0 (<http://creativecommons.org/licenses/by-sa/3.0/>)], via Wikimedia Commons.

According to the writer of the aforementioned letter, a single rod could protect a building for 20 feet on each side. Practice and observation were still guiding lightning protection work.

As to the number and placement of the lightning rods, in 1823 the French Academy of Sciences carried out scientific investigations and proposed that the protection zone (cone of protection) of an air terminal was a radius twice its height. This provided a framework needed to determine the placement and number of air terminals. Included along with other detailed information in the report entitled "Instruction sur les paratonneres," it was adopted by the French government and gained wide distribution in the United States.

Information on how to protect structures from lightning was shared through newspapers and other means, reaching not only an urban audience but farmers as well. Because of their typical large size, location in open areas, and their use to store flammable hay and

grains, barns were recognized as being high risks for lightning strikes. A description for proper installation of lightning protection on a New England barn appearing in an 1848 issue of *The Cultivator*, a New England farm journal, reflects the prevailing view that multiple rods/terminals and ground components were needed for most structures.

In applying the conductor to the barn, begin at the northwest corner, by inserting the rod far enough into the ground to always insure its contact with the moist ground; carry it along the gable end to one end of the ridge pole, thence along the ridge pole to the other end of the ridge pole, thence along the other gable end, and down the southwest corner continuing into the ground.... There should be a point at the eaves on each corner, and one on each side of the ridge pole, which should be covered with a coating of silver to prevent them from rusting....

It was common practice to locate the conductor on the outside since most systems were installed on existing buildings. However, installations that ran down the interior still were occurring. An 1847 article in the *Burlington Gazette* refers to a church in Philadelphia that recently was destroyed as a result of lightning: "It was provided with a conductor, but it ran down from the steeple inside the church!.... Such blundering ignorance as that of setting a rod to conduct the lightning into the house, we have seldom heard of. The precise reason for the failure was not stated."

By the mid-19th century, the collegial nature of the pioneers of early lightning protection system was giving way to a competitive field and proprietary products. This change came at a time that fostered a growth in the marketing and sales of lightning protection across an expanding country. New lightning protection products and patented systems could get ready exposure as a result of the proliferation of newspapers and manufacturing trade catalogues. The New York firm of Marshall Lefferts & Brothers, manufacturers of galvanized and iron building products, marketed in their 1854 trade catalog the sale of galvanized iron for lightning protection systems that eliminated the degrading effects of rusting. Galvanized steel soon became, along with copper, the common materials used for components.

About the same time, David Munson of Indianapolis, Indiana, purportedly invented a copper tubular spiral lightning rod, using copper because of its greater conductivity than iron. Made of sheet copper for affordability, the distinctive tubular spiral shape provided needed rigidity and became a popular type for years. In the 1858 publication, *A Chapter on Thunder and Lightning, Their Causes and Effects*, numerous advantages of the Munson Rod were touted, including that it did not rust. Conducting rods came in 5-foot lengths with connections made by lapping and wiring. The lightning rod also was made of copper with a terminal consisting of multiple points.



Figure 8. Church steeples, roof turrets, and chimneys were identified early on as being susceptible to lightning strikes. Finials, weathervanes, and other such ornamentation in these locations could often serve as lightning rods when connected to down conductors and grounds. The cupola on the Home Moravian Church in Winston-Salem, North Carolina, is an excellent example. Old Salem, Inc., has a number of Moravian buildings where early lightning protection systems are still in place. Photo: Sunni L. Goodson.



Figure 9. While plain round, 4-inch to 5-inch, color-glass lightning rod balls were most common in the late nineteenth and early twentieth centuries, balls also came in more decorative patterns and shapes such as the pleated round balls shown here in a variety of colors. Courtesy: Ferdinand Meyer Collection.

By the 1850s, patents were appearing for glass insulators to secure cables running between air terminals and to secure the main conductors, enabling cables not to directly touch the building. The use of different styles of glass and porcelain insulators became common, all in a perceived effort to help direct a lightning discharge.

With the Industrial Revolution, lightning protection products became mass-produced at affordable prices and shipped by railroad across the country. For the Franklin system, there now were many different parts that were available, such as specialized insulators and connectors, and a variety of shapes and sizes available for air terminals—some utilitarian and others quite decorative.

The westward movement onto the Great Plains following the Civil War contributed to the Golden Age of lightning protection, as this included areas thought particularly prone to turbulent lightning. The long stretches of flat land made buildings on isolated farmsteads and grain storage containers along railroad sidings at risk.

A 4-inch to 5-inch glass or ceramic ball became a common feature on many late 19th and early 20th-century rods. They came in different patterns, colors, and shapes, with plain round colored balls dominating the landscape. Balls could be added to one or more of the lightning rods on the roof. Folklore has it that the balls were functional, designed to break when lightning

struck, thus giving notice to the building owner that the system both had worked and should be inspected for any possible damage. In fact, the glass balls were purely decorative and intended to aid sales (Fig. 9). Additional decoration could be added to a lightning rod. Multiple, color glass balls and custom-crafted metalwork were two ways to accent it. A directional weather vane attached to one of the rods could in turn be embellished with colored glass or a metal animal or sailboat, reflecting the building use or owner's interest.

The longer length of air terminals of this period typically required a sturdy stand for stability and attachment to the roof. The height of these stands varied widely, commonly ranging from one to three feet, meaning that the rods could measure as high as five feet or more. Three-foot stands with five-foot rods were the most prevalent size. The rod would usually have a point, with common shapes being a shell point or a bayonet shape. A rounded point was also available, though not as popular in the U.S. as in Europe.

In an unusual application, and the first use of aluminum as part of a lightning protection system, a pyramid-shaped cast of aluminum was selected to be the top of the Washington Monument and was installed in 1884. It was later augmented with lightning rod points (Fig. 10).

By the 1880s, the commonly accepted measurement that helped determine the number and placement of

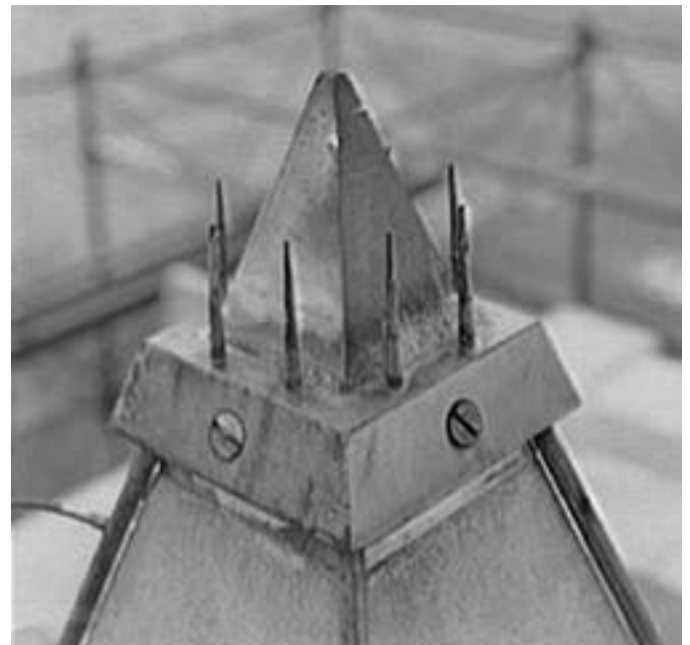


Figure 10. When the Washington Monument was completed in 1884, it was capped with a pyramid made of aluminum. Though intended to function as a lightning rod, it proved within the year to be deficient. After lightning struck, a crack appeared under the top stone. As a remedy, copper rods attached to a copper band were placed around the base of the aluminum apex. The band was directly connected to the iron elevator shaft inside the monument that was part of the otherwise functioning system. The cap is the first use of aluminum as a lightning rod in the United States. Photo: Theodor Horydczak, Library of Congress.

lightning rods was a cone of protection served by each air terminal that had a radius of the circle at the base measuring the same height as the air terminal—a 1:1 ratio. At such a ratio, more lightning rods were typically needed than was common prior to the Civil War.

Scientific investigation in lightning protection continued throughout this time along with a growing need for professional standards. In Great Britain, "rules [recommendations] for those who installed lightning protection systems" was published in 1882 in *The Report of the Lightning Rod Conference*. One of the conclusions of the conference was that there was "no authentic case on record where a properly-constructed conductor failed to do its duty."

In the United States, the National Fire Protection Association (NFPA) drew upon this report when they developed and published in 1904 *Specifications for Protection of Buildings against Lightning*. Though more conservative than the British report in terms of the ability of a properly installed lightning protection system to be effective in all cases, they concluded that lightning protection systems materially reduced the risk of fire loss to structures where prone to such damage. They noted that within a 5-year period, 3,842 dwellings, 9,375 barns, 328 churches, and 59 ice houses had losses from fires due to lightning.

By 1908, the Underwriters Laboratories in the United States began the independent testing and certifying of certain lightning protection equipment. Such specifications and quality assurance were sorely needed. Traveling salesmen hawking lightning protection to unsuspecting homeowners, farmers, and small merchants too often were more interested in a quick sale rather than whether the system was properly installed.



Figure 11. Two salesman kits used by F. B. Renak operating out of Racine, Wisconsin. He was a reputable agent for several companies including the Security Lightning Rod Company, which offered a reasonable 10-year guarantee upon installation at a time when some unscrupulous companies offered essentially worthless hundred-year or lifetime guarantees. The kits included sectional pieces of a twisted copper conductor and two styles of air terminals—one was a bayonet shape and the other came in a shell or bullet shape. The shell terminals were available in several materials, including copper and nickel-coated copper. Courtesy: Charles Fisher Collection.

In many communities, particularly in the Midwest, popular opinion turned against the salesman and the potential benefits of lightning protection. Ironically, this came at a time when there was general support among the scientific community as to the effectiveness of properly installed lightning protections (Fig. 11).

Using scare techniques, parlor tricks to simulate lightning, testimonials, and flashy advertising, unscrupulous traveling salesmen frequently gave little consideration as to whether a structure was at risk and merited lightning protection. Going hand-in-hand with aggressive sales techniques was often over-priced, shoddy work. Where grounds were not functional or conductors improperly connected, flashy air terminals on a roof provided no protection and written guarantees were of little value.

The "Golden Age" of lightning protection came to an end by the 1930s, a victim of the excesses of so many traveling salesmen and the Great Depression. Many of the lightning protection manufacturers ceased production. Fortunately, a few of the companies did survive and continue today to offer various traditional components that meet modern standards.

In the decade after World War II, a number of important changes occurred. Aluminum became an alternative to the use of more expensive copper for terminals and cables and remains, along with copper, one of the two most common materials available today. Since aluminum is a better conductor than galvanized steel, does not rust, and was competitively priced, it generally replaced the use of galvanized steel.

The older method of determining placement of air terminals—the "cone of protection"—became less used. The 150-ft Rolling Sphere Model, developed in the 1950s, has gained more common acceptance. Except for some historic reproductions, air terminals are now shorter than many of their predecessors and are available in both pointed and blunted (rounded) tips.

"Surge protectors" or surge protective devices (SPD) have become a significant part of modern lightning protection work, reflecting our increased reliance on electronics and technology (Fig. 12). Besides providing for surge protection at the main electrical service box, second-stage or point-of-use surge protectors are needed to protect sensitive electrical devices such as computers. These surge protectors must be rated for lightning protection. With the proliferation of service lines to a structure, proper bonding of these service lines to the common ground of the lightning protection system remains important.

Risk Assessment

The majority of buildings in this country neither have existing lightning protection nor may they be



Figure 12. A surge protector covering the electrical lines in a house, barn, or other such structure is relatively inexpensive to have installed. With two or more electrical service boxes, each will need one. The surge protector includes one or more LED lights which indicate whether or not it is properly functioning. In areas of frequent thunderstorms, the unit may need to be replaced after a severe or repeated number of power surges in the line. Photo: Independent Lightning Protection Company.

in real need of such protection. Nevertheless, there are significant number of structures, including many historic ones, at risk of loss or damage due to lightning strikes and which merit protection. Local building codes or fire marshals may require certain buildings being rehabilitated or undergoing a change in use to install lightning protection. In most cases, the decision to install or maintain an existing lightning protection system for a historic building is voluntary. If an owner elects to install one, many local building codes do set

forth installation standards, often drawing upon the National Fire Protection Association's *Standard for Installation of Lightning Protection Systems* (NFPA 780).

The frequency of lightning strikes varies considerably across the country (Fig 13). Coastal areas in the southeast are particularly prone to high numbers of lightning strikes, while the west coast has few. Even within a single state, the number of lightning events each year can vary considerably by location. Lightning activity and lightning strikes are tracked on a continuing basis by companies providing fee services for weather forecasts, insurance claims, and other business purposes. These companies are the best source of data for a specific area where such information is not publicly available.

In Annex L to NFPA 780, information on lightning risk assessment is provided. The described method takes into account the building environment, type of construction, structure occupancy, structure contents, and lightning stroke consequences. Among the examples that NFPA 780 cites, and where the need for protection should be given serious consideration regardless of the outcome of the risk assessment, are structures located where there is high lightning frequency, tall isolated structures, buildings containing explosive or flammable materials, and buildings containing irreplaceable cultural heritage. While most historic structures by their very nature may be considered irreplaceable, practical constraints, including financial ones, often result in an informed owner having

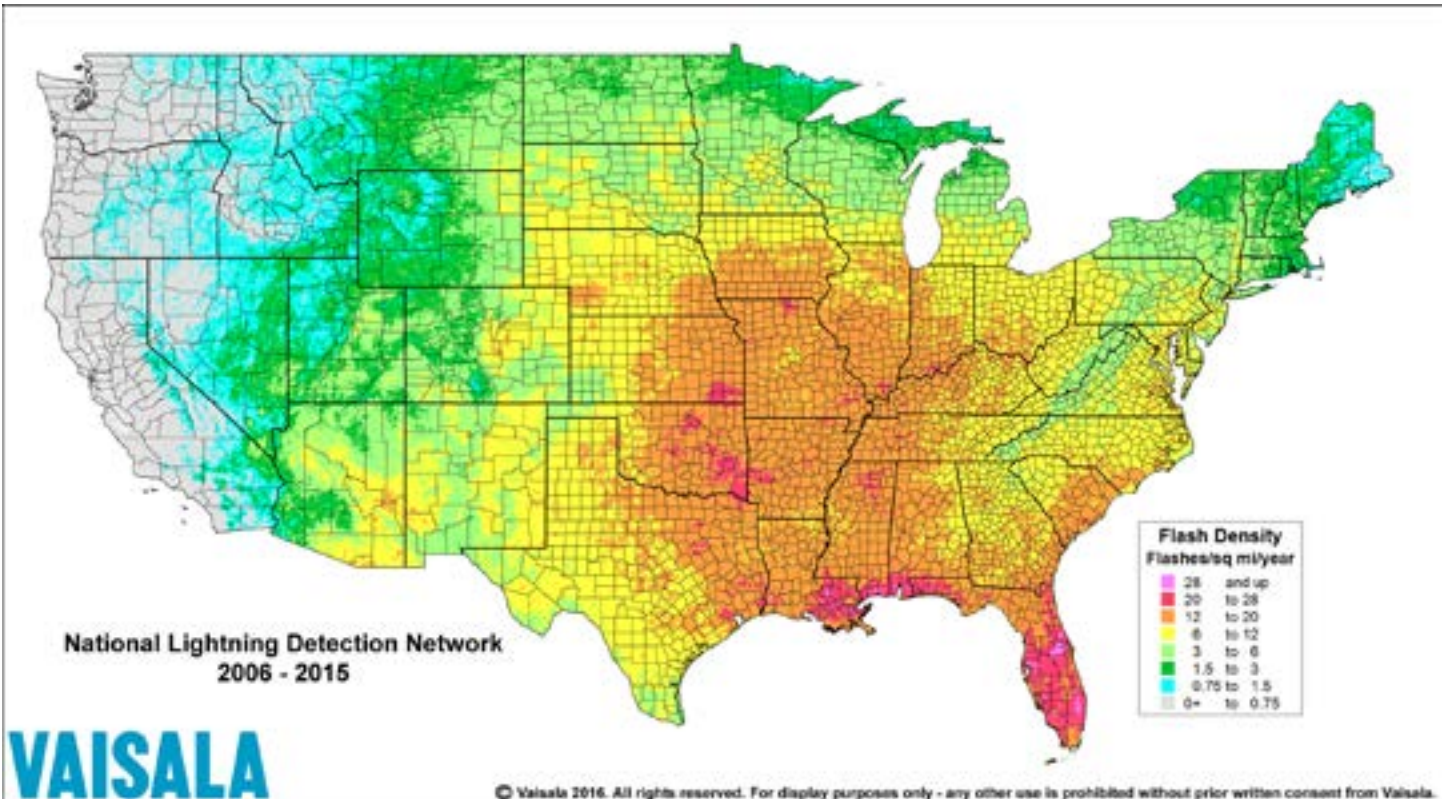


Figure 13. The frequency of lightning strikes varies considerably across the country and is tracked and reported nationwide. States with a high number of cloud-to-ground flashes in 2016 included Louisiana and Kansas with over one million each; states with a low number included Maine and New Hampshire with each around 10,000. Ben Franklin's home state of Pennsylvania had 182,071 cloud-to-ground flashes in 2016 while across the country, California had 48,958. Courtesy of Vaisala.

to weigh the risks of not installing a lightning protection systems—in other words, the likelihood of lightning striking a building and the resulting damage and potential loss of life that could occur.

Buildings with towers or spires such as historic courthouses and churches are at greater risk because of their height and since they are often the most prominent buildings within a small community. On the other hand, a downtown historic building, even one with a tower such as a firehouse, set among much taller, newer buildings, is less likely to be struck by lightning. Structures such as lighthouses that are tall and in exposed locations are at high risk when located where lightning strikes occur. Similarly, an isolated building on a hilltop is more prone to a lightning strike than a rowhouse in an urban district.

The type of construction is another factor taken into account, particularly the structural framework and the roof type. For example, a wood roof has a higher risk value than a fiberglass shingle roof because of its greater flammability; a structural steel-frame building with a metal roof that is electrically continuous is at a lower risk than a concrete building with a composition roof. Another factor is the occupancy use and damage that may occur. With theaters, schools, and large retail stores, a lightning strike may cause both fire and panic with loss of life. For farms, there is the risk of fire and loss of business, and for museums there is the additional irreplaceable loss of cultural heritage.

A lightning risk assessment should be undertaken by a qualified, experienced individual, usually an architect or engineer, who operates independent of any lightning protection company. For structures that have been previously struck by lightning, and where conditions have not changed that otherwise would significantly lower risk, remember that lightning can and has struck twice in the same place.

Inspection, Evaluation, and Maintenance

Whether old or quite recent, lightning protection systems need to be periodically inspected and maintained. Systems can be impacted by changes to a structure, as with an addition of a dormer, attachment of a new metal blade sign, or installation of a new roof. Fasteners and certain other components degrade over time, requiring cleaning, securing, or replacement. Components may also suffer from man's careless or unintentional actions. While performing as intended, a system might even incur some damage, such as to the tip of an air terminal or damage to a surge protector, as a result of a lightning strike.

The inspection should either ensure that the system is fully functional or identify components that are broken, dislodged, or otherwise deficient (Fig. 14). Historic components needing conservation work should be identified. While today's lightning protection standards



Figure 14. Lightning protection systems should be visually inspected every year and once every five years be inspected by an experienced professional. Note the break in the down conductor at the top of the photograph and the lack of a bonded connection to the cable at the bottom, which goes to one or more grounds. The old ground rod should be bonded to the new ground. Photo by author.

do not classify older systems as obsolete, even functional systems may merit some upgrading, and this should be noted in the inspection.

The recommended number and placement of air terminals needed for coverage today usually will exceed that of older systems. Also, some old lightning rods may be connected to only one conductor, rather than today's required two or more conductors and grounds. It is important to check whether pertinent objects and service lines are properly bonded to the lightning protection system. As part of the inspection and evaluation process, existing surge suppressors and arresters should be checked, and those locations lacking adequate surge protections should be identified.

On older systems, new ground rods usually need to be installed and connected to the old ground rod. Even under normal conditions, grounding components decay and usually will need replacement within 30 years or less, depending upon soil conditions (Fig. 15). The inspection should also indicate whether additional ground rods need to be installed. Particular attention should be placed on recent site work, such as trenching for cable lines or installation of landscape features like

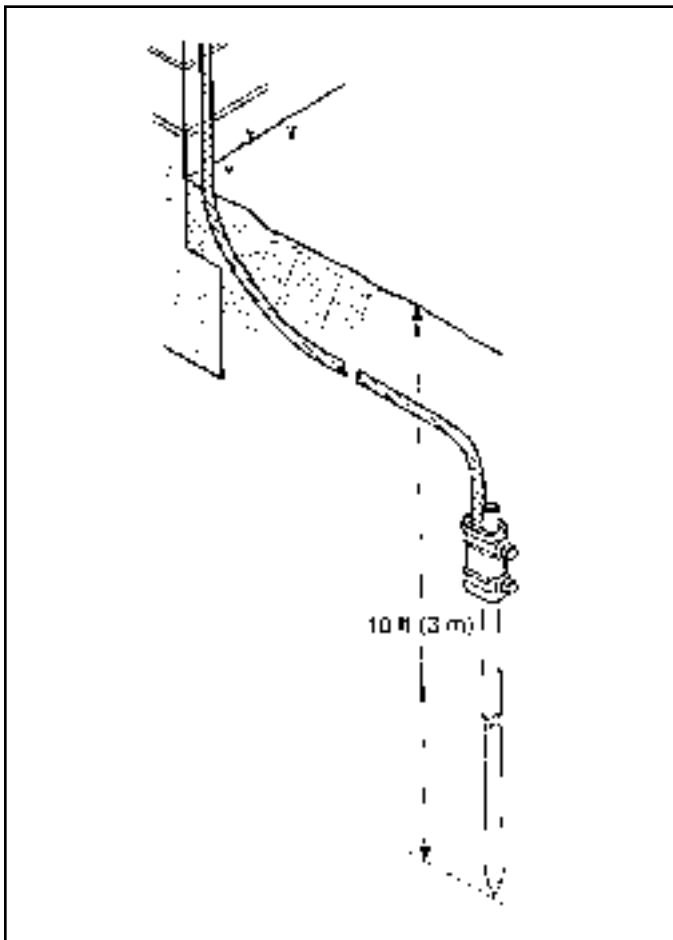


Figure 15. Ground rods decay and may need replacement within 30 years or less depending upon soil conditions. Ground rods should be copper-clad steel, solid copper, or stainless steel. They should be 8 feet long and no less than 1/2 inch in diameter. Reprinted with permission from NFPA Standard 780, 2017, *Standard for the Installation of Lightning Protection Systems*, Copyright © 2016, National Fire Protection Association, Quincy, MA. This reprinted material is not the complete and official position of the NFPA on the referenced subject, which is represented only by the standard in its entirety.

a metal flagpole, which may have cut or otherwise disturbed a previously functioning ground.

Besides visual inspection, a ground resistance test can help establish if an existing ground is working properly. If a visual inspection of certain components is not possible, as with concealed conductors, a continuity test can be run instead. A visual inspection by an individual familiar with lightning protection systems should take place annually and at least every five years be undertaken by a professional who also tests the ground and the system's conductivity. Where roof replacement or repairs to chimneys, parapets, or similar features has occurred, a visual inspection should immediately follow.

With an older system, an assessment should be made at the outset as to its overall historic significance and that of individual components. A lightning rod with a colorful glass ball and crafted weathervane dating to the turn-of-the-twentieth century can easily be appreciated, yet early connectors, conductors, and glass insulators,

while more utilitarian in function, may be significant as well and merit preservation considerations.

There are additional considerations when an older system is determined to be a historic feature of a building. If a lightning rod is rare or quite distinctive and exhibits deterioration, it may be appropriate in some cases, particularly with museums and public buildings, to replace it with a replica, conserving and retaining the original piece for display or storage inside. Examples include a deteriorated rod that exhibits high quality craftsmanship and specifically designed for a structure; a rod that is of unusual design and is considered valuable folk art; or a surviving 18th-century lightning rod.

Where historic lightning rods and other components can function properly and are in fair to good condition, identifying steps to conserve and secure them in place is usually the preferred preservation approach. When repairs are necessary, finding certain parts for old systems may be more difficult and may necessitate utilizing reproduction parts that may not have been UL-certified, but are otherwise serviceable. If the existing system is in poor condition and needs substantial upgrading, replacement may be the only alternative. Recommendation of the inspector should be explained in the evaluation, including a discussion of alternatives.

With serviceable pre-Civil War lightning rods, and even with more common decorative rods of the Golden Era, special attention is needed where there is a risk of vandalism or theft. If a building is being mothballed or is undergoing major repairs and is not in a secured location, historic lightning rods with any decoration usually should be temporarily removed. If the risk is high for lightning strike, an interim system with modern terminals may need to be installed.

Traditionally, the most common threat of vandalism is due to a glass ball or weathervane being used for target purposes, particularly on vacant and isolated buildings. While rarely preventable, glass balls broken as a result of vandalism can often be replaced, since a number of the common designs and colors are still available today as moderately priced reproductions using original tools (Fig. 16). Theft occurs as well, since historic lightning rods with glass balls or decorative weathervanes are



Figure 16. This three-piece vintage mold for a round pleated-glass lightning rod ball is still used to make accurate reproductions today. Photo by author.

valued by collectors, and copper conductors can be sold for scrap metal.

Proper maintenance of historic lightning protection systems includes some similar tasks associated with modern systems. Attachment hardware and connectors may become loose and simply need to be retightened. On a common tripod stand, excessive rust on a steel or iron screw, or water leakage where the screw is attached through the roof, will over time cause one or more of the legs of the stand to detach from the roof. As a result, the rod usually will bend or deflect to one side. Thus, it is important to re-secure the stand and ensure that the roof is watertight at the connection.

Historic hardware may need to be cleaned to ensure proper function and longer wear. Where historic hardware is severely corroded or broken, has suffered from past abuse, or is otherwise seriously deficient, replacement parts should be used.

With replacement hardware even as simple as screws, care must be taken to avoid use of dissimilar metals that have different electrical properties which can result in galvanic corrosion. If the existing conductors are copper, the connectors should be copper or brass. Similarly, only aluminum connectors should be used with aluminum conductors. Because of appearance and durability, plastic anchors and connectors should generally be avoided for historic buildings. Parts designed for lightning protection installations should be used in replacement work.

It may be necessary to clean iron and steel parts of the lightning rod. Particularly with decorative weathervanes and directional signs, care must be taken to avoid unnecessary damage when cleaning. Where the object appears to be discolored, this can be the result of a natural patina that provides some protection, and the object may be prized for this visual quality and undisturbed nature. With copper and brass, cleaning to an as-new appearance should generally be avoided except where repairs are made at connectors.

Decorative objects, such as a fish or horse on a weathervane, were typically formed from relatively thin sheet metal, as opposed to heavier weight castings that also were sometimes used. Where cleaning is appropriate, use the gentlest means possible, avoiding unnecessary abrasion or etching. The best cleaning approach is to use methods suitable for the cleaning of similar art and historic objects. If the decorative objects have vestiges of early paint, it may be appropriate to take steps to conserve the paint since it adds to the historical value. More than one metal material may be used in a single lightning rod assembly, so it is important to identify the metals on each part and to use an appropriate cleaning method for each type.

Iron and later steel used for stands to support a lightning rod are somewhat more forgiving in terms of cleaning methods than softer metals like aluminum, copper,

nickel, bronze, and brass, which generally should not be cleaned. Gentle hand scraping, soft wire brushing, and sanding with medium grit emery paper can remove rust on iron and steel, except for where fine detail requires more delicate work. Because iron and steel easily rust, support stands and applied decorative objects that are to be painted should be cleaned and treated with a zinc-based metal primer on the same day. Air terminal stands, connectors, and cables can be painted without impeding the flow of electricity in case of a lightning strike.

Historic and reproduction glass balls are a fragile component of the lightning rod and should be handled carefully. Glass can inadvertently be scratched or etched when in contact with certain metal cleaners used on adjacent metal parts. Cleaning to remove bird waste and other harmful residue should be done by washing with a soft cloth, warm water, and a mild non-ionic detergent. Because of their outdoor exposure, cleaning glass to an as-new appearance is not recommended so as to avoid unnecessary risk of breakage.

Glass and porcelain insulators used to fasten cables to a building are no longer made for lightning protection work. The cable typically ran through or was secured to the side of a glass insulator, which came in a wide range of colors. The insulator was in turn attached to the building in a variety of ways, typically with a metal bracket or ring. By the early 20th century, porcelain insulators became prevalent, replacing the glass insulator. They can still be used in place when maintaining or upgrading older systems (Fig. 17). Where existing insulators have major cracks, are broken, or missing altogether, they can be replaced with appropriate metal fasteners. As historic insulators



Figure 17. Glass insulators were attached to a structure in a variety of ways using metal rings, staples, wire, or similar fasteners. Where old insulators are damaged and no longer functional, they can be replaced with appropriate metal fasteners. Photo by author.

are replaced, samples should be retained for record purposes and future reference.

Conductors can be cleaned and painted to inhibit corrosion or reduce their visibility. Since the exterior walls of many historic buildings were periodically painted, special cable mounts were often used in the past that allowed the cable to be secured approximately one inch off the wall.

Repair

Repairing and augmenting an existing lightning protection system on a historic building follows some of the same basic principals, whether the system is historic or more contemporary, yet there are also some key differences. With historic systems, there is a greater emphasis on retaining old materials through repairs and, where necessary, augmentation. An 1870 system that has survived on a building would most likely be considered deficient today in terms of the number and placement of air terminals. For example, there is the current requirement that one or more terminals be used at each chimney, depending upon chimney size—a practice not always common in the past.

Historic lightning rods can often be repaired and coverage augmented where needed with smaller, plain contemporary air terminals. The taller lightning rods typically used in the past were usually set on individual stands. Misshapen or bent stands can usually be straightened, while fasteners securing the legs of the stand to the roof often need to be replaced. It is also important to check that the roof is sound where the legs are attached and to correct any wood rot or other roof decay prior to reattaching the stands. Where lightning rods are partially concealed in the roof, it is important to renew seals where they penetrate the roof (Fig. 18).

Particularly on late 19th and early 20th-century buildings, accurate reproduction lightning rods often can be used where a historic terminal is missing or to augment for proper coverage where historic ones exist. There are both some age-old companies as well as newer ones that not only manufacture a number of the traditional lightning rods, but also offer cables, connectors, and other hardware for lightning protection systems that are very similar, and at times, a true match to various older designs. Besides cost, factors influencing the decision whether to use traditional replacement parts or those of more modern design include the historic significance of the existing system; the preservation approach as to whether maintain, restore, or rehabilitate a building; and the visibility of a particular component.

Where historic lightning rods are of galvanized steel or iron, it is possible to retain them in place, depending upon condition. These rods usually were connected in the past to conductors of the same or similar material. While iron or steel does not meet code today for conductors and rods, there are tests that can be run

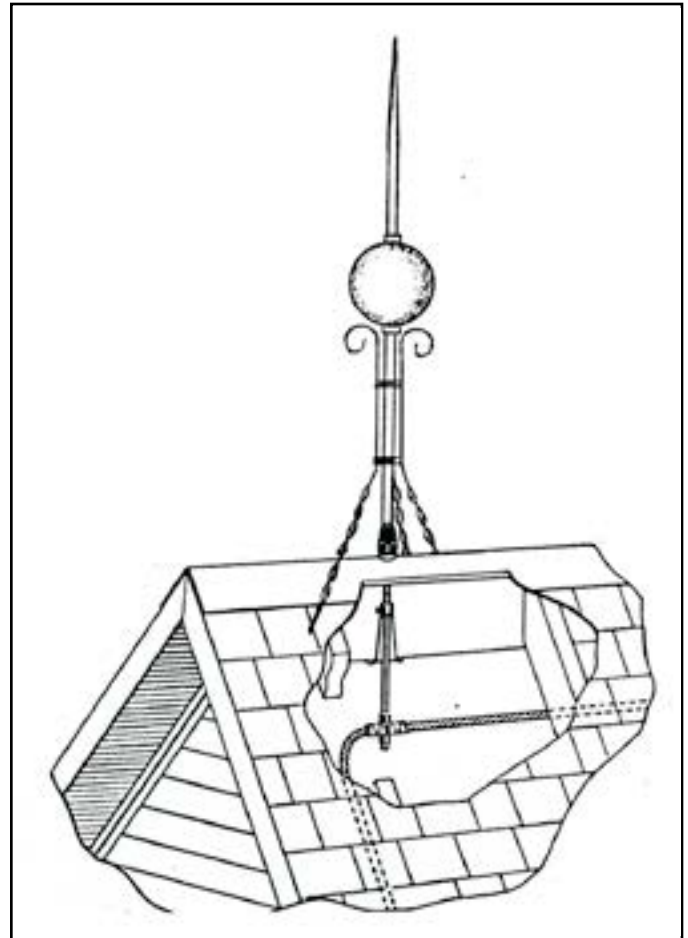


Figure 18. With concealed lightning protection systems, cable wire connecting lightning rods and conductors are partially or totally concealed on the exterior by running most of the lines within the structure. Where the lightning rod stand is attached to the roof, as well as where the concealed cable is attached on the outside to the lightning rod, are all areas that need to be routinely inspected and repaired as needed. The roof seal at the junction of the cable through the roof will need to be replaced over time. Drawing: Courtesy of Independent Lightning Protection Company.

for continuity in a circuit (but not for capacity). As in the case of the Maryland State House, the historic iron lightning rod was repaired and retained as an essential part of a functioning system.

Where historic lightning rods and conductors are determined to be comparable or equivalent with modern ones in terms of functionality, they can be treated as integral to the lightning protection system. Where functionally deficient, they can be retained in place and bonded to the updated system. Such old terminals or conductors would thus not be essential to the system, but rather retained as a historic feature.

Where one or more existing terminals are connected by a cable to only one down conductor, installing a second path to an additional ground is important. In the case of old conductors, an inspection may find that they are not working properly. Historic conductors may be undersized, frayed, or otherwise degraded and need to be replaced with appropriately-sized modern wire cable that is U.L.-approved for lightning protection.

Case Study

Upgrading old lightning protection on a historic building

Mumma House, Antietam National Battlefield, Sharpsburg, Maryland

Located within the Antietam National Battlefield, the historic Samuel Mumma farm house had lightning protection devices installed some years after the Civil War. As part of an exterior stabilization of the wood-framed residence in the 1990s, the National Park Service also provided for a newly-functioning lightning protection system.

The existing system, which appeared to date to the late 1800s, included four tall ornamented lightning rods on the terne-metal roof, each consisting of a galvanized- steel point with a sunburst air terminal on top. The tall rods had been bent over time and the three-legged galvanized steel braces were twisted and loose from the roof. The two original steel down conductors, consisting of twisted section rods, were still in place and connected to ground rods. There were several above-grounds breaks in the down conductors, rendering the system inoperable. Most of the original glass insulators used to attach the down conductors to the masonry walls remained, though a number were broken or missing altogether.

For its time, the original protection system would have been considered a proper functioning system with a correct placement of lightning rods, use of two down conductors securely attached to grounds, and cables correctly connecting to lightning rods appropriately sized. While this building feature had acquired historic significance over time and was visually prominent on the roofline, it no longer served its intended function. Besides breaks in the conductors and damage to the lightning rods, there were other deficiencies by today's standards, including the lack of air terminals at the chimneys and the distance between existing terminals being too great. Furthermore, replacement steel air terminals and steel conductors are no longer used.

In assessing whether the system should be repaired and upgraded or be replaced altogether, a number of factors were considered. After the National Park Service was in contact with a long-established,

Figure C. The historic down conductor with its original insulator attached to the house just above the stone foundation is still connected to the old ground while bonded to the new conductor and new ground rod.

Photo by author.



Figure A. Rear view of the Mumma House showing three of the four tall reproduction lightning rods placed close to the same locations as the historic ones, which were too deteriorated to reuse. Running down the left side of the house below the chimney is one of the two historic down conductors, which were saved in place and bonded to the new system. Photo by author.



Figure B. Photo shows one of the reproduction tall lightning rods being secured in place. New cables connected the reproduction lightning rods and the modern air terminals to the down conductors that lead to the grounds. Photo: Independent Lightning Protection Company.



lightning protection manufacturer in Goshen, Indiana, it was determined that the historic air terminals and a number of the connectors could still be easily replicated using old molds that the company had for casting of new parts. Since the historic terminals were in poor condition and mounted high on the roof, it was decided to replace the four lightning rods with matching designs. Replacement steel terminals were not considered a suitable option, so lead-coated copper was selected for its durability and similar coloration to the original terminals.

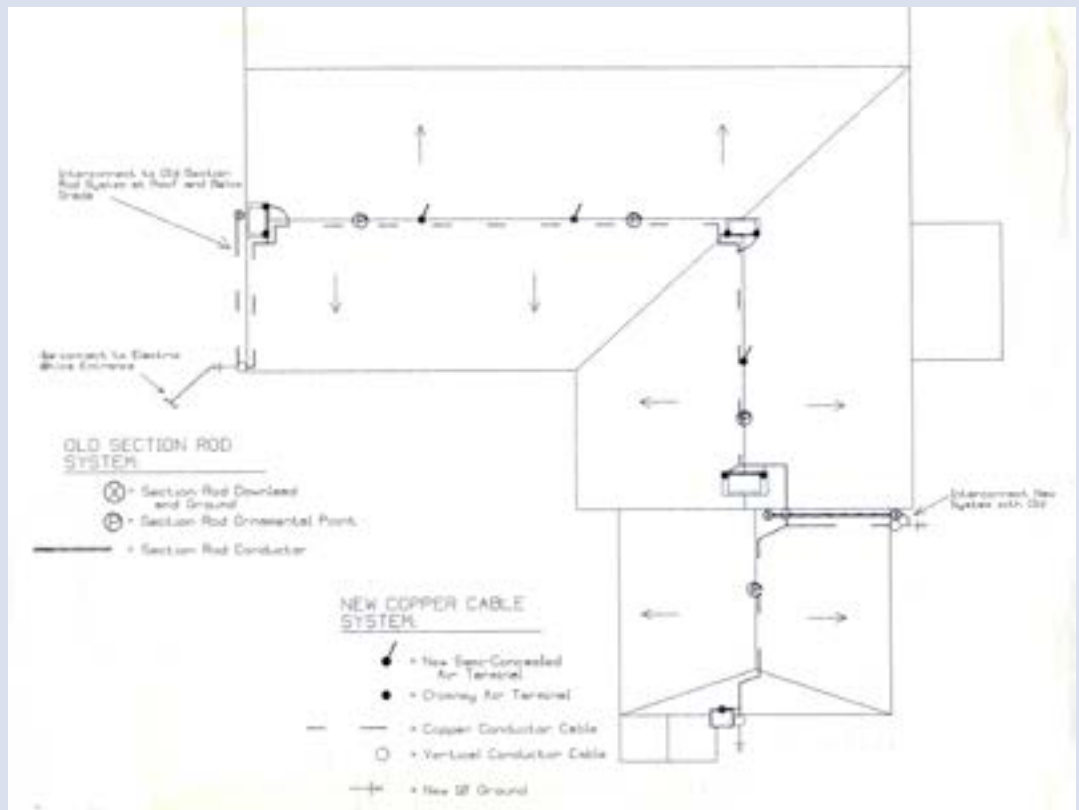
The four reproduction lightning rods were installed close to the original locations. To augment and ensure proper coverage, additional contemporary terminations were installed. There was no effort to conceal the new connecting cables since visibility was a historic feature of the old system. New copper down conductors were placed at needed locations, including where two historic steel conductors existed. The new conductors were connected to new grounding rods. Both of the historic down conductors with their glass insulators were retained in place and bonded to adjacent new conductors, providing an informative way to preserve in place part of the old system.

Upon completion of the work, the visual prominence of the historic lightning rods had been re-established while integrating non-obtrusive additions to the system in order to meet code. A distinctive rooftop feature, the large reproduction lightning rods are part of a fully-functional lightning protection system.



Figure D. Tall lightning rods once again stand out on the Mumma House. These reproduction rods along with retention of the historic down conductors have been incorporated into the modern lightning protection system that was installed. Much smaller, contemporary air terminals located on the roof are barely discernible from below. Photo by author.

Figure E. Plan for the installation of the new system. Note that the historic systems did not include any lightning rods at the chimneys, while today's code requires two air terminals on each side of this size chimney. The required new air terminals were much smaller than the historic ones and were relatively inconspicuous along the ridge of the roof. Drawing: courtesy of the Independent Lightning Protection Company.



Depending upon age and significance, if a historic down conductor or the cables connecting the air terminals are to be replaced, one or more sections should be saved; tagged as to its function, location, and date of removal; and stored with the structure's historic artifacts for future reference. Remember, it may be possible to retain in place an inadequate historic down conductor by simply bonding it to a new down conductor (see case study on page 14).

When installing new down conductors, each should be fitted with a purpose-made test clamp at an accessible location to permit periodic testing. Where conditions permit, new ground conductors on masonry structures should be attached only at joints rather than to masonry units (Fig. 19).

Any sharp bends in conductors require attention since they raise the risk of flashover problems. Sharp bends can be either reworked so as to form a minimum bend radius of eight inches, or, if that is not possible, the

section of the conductor should be replaced and the alignment changed.

In most cases, repair work involving neglected systems includes new ground rods being installed. Most old grounding rods do not merit special historic preservation considerations and can be left in place and bonded to the new ground rods. When installing new grounding rods, avoid where possible any archeological resources. All service lines should be bonded to the new lightning grounds.

Surge protective devices that are not functioning properly should simply be replaced with modern units and, where lacking, new ones should be added. Metal objects and features at risk that lack proper bonding to the lightning protection system should be connected as well.

Installing a New System

Installing a new system on a historic structure requires a number of special considerations. Depending upon the nature of the structure, such as its height, complexity of the roof, internal access, type of structure, historic significance, and use, the decision has to be made whether to conceal as much as possible or surface mount the new terminals and conductors. On a high-rise building with a continuous steel structure, it is common practice to tie the lightning protection system to the steel structure. High-rise buildings are prone to be struck by lightning (Fig. 20). The Empire State Building in New York City is struck on the average of more than 20 times a year. Small modern air terminals mounted on a high rooftop usually have little visual impact from below.

Most historic buildings, however, are much lower in height and their roofs are often readily seen. For these buildings, the decision as to the extent of concealment may involve consideration of two or more possible options, with the most common options being:

1. Elect to place modern air terminals and conductors in a manner that minimizes their visual impact yet remains fully exposed on the outside.
2. Select an installation approach that conceals within the structure as much of the lightning protection system as possible.
3. Choose to install reproduction lightning rods appropriate to the period and type of the structure, augmenting with contemporary terminals as needed, and elect not to conceal the system.

Some of the earliest 18th-century installations concealed part of the down conductor within the building such as at Independence Hall and Christ Church in Philadelphia. This approach fell out of favor for a number of years, as systems generally were surface mounted on the outside. Since the Golden Age, there are a multitude of products

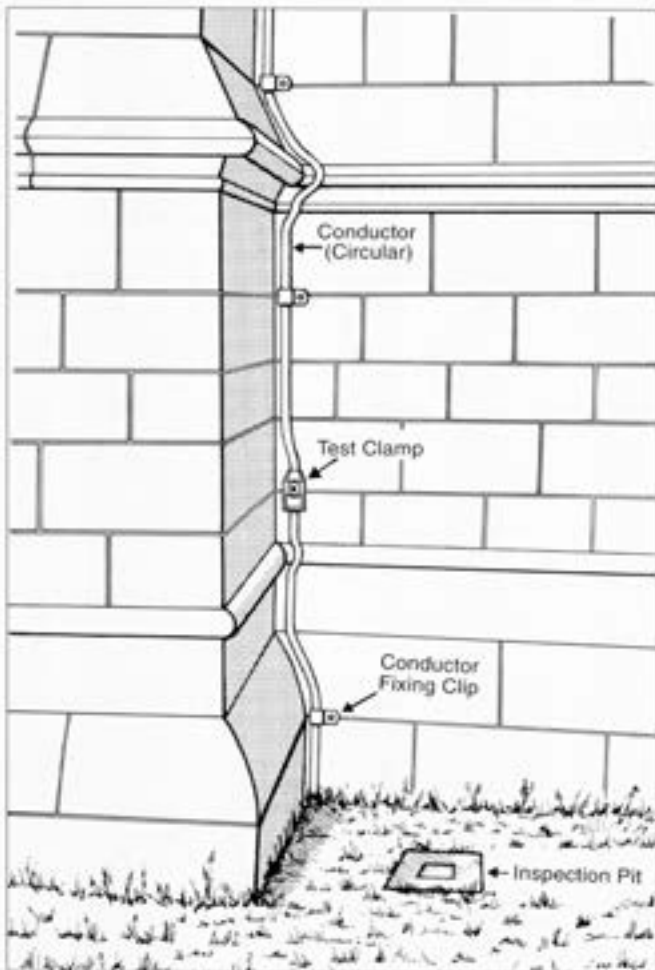


Figure 19. Placement of down conductors along inside corners or adjacent to downspouts helps minimize their visibility. This conductor has been placed on an inside corner. Other good installation practices shown in the drawing include the use of clamps to attach the conductor at mortar joints, rather than damaging the stones; the avoidance of sharp bends in the conductor; and provisions for a test clamp and an inspection pit accessing the ground connection which can be used during periodic inspections of the system. Drawing: English Heritage©.



Figure 20. High-rise buildings in cities such as New York, Chicago, and Atlanta have a higher risk of being struck by lightning, and it is not uncommon for some structures to be hit multiple times during a year. Multiple strokes from a single lightning occurrence can strike more than one building at the same time as shown in this photograph of the Atlanta skyline during a thunderstorm. Photo: David Selby©.

and installation techniques that permit concealment of the conductors or cables connecting lightning rods. Current standards and building codes generally allow the use of either exposed or concealed systems.

With concealed systems, the exposed air terminals run through the roof and are typically attached below to a ridge board or other part of the inside roof structure, permitting the connecting conductors to run inside the roof. The terminals require a good weather seal at the roof. The connecting conductors can be attached to outside ground conductors or to concealed ground conductors that are either set in a wall cavity on finished interiors or, on some utilitarian structures, left partially exposed on the interior side of outside walls. At grade, the inside ground conductors can then be run to the outside and be joined to the grounding rods.

Concealment applications exist for specialty features even as mundane as metal rooftop ventilators commonly found on small manufacturing buildings and barns.

With ventilators, the air terminal would extend from inside the vent up through the center top and be secured inside the vent to the conducting cables.

One of the factors when considering concealment methods is how much initial disturbance is required on the interior of a structure. For historic buildings, such an approach may not be advisable if historic interior finishes and distinctive features are adversely impacted. On the other hand, if such disturbance is not necessary or the interior is undergoing considerable work, concealment techniques are a plausible option.

In many cases, the most practical approach is to design a modern system that is largely an outside mount, but where special attention is placed on utilizing appropriate techniques and materials that help minimize the visual impact of the cabling and multiple air terminals. Fortunately, today's smaller air terminals accommodate simple, unobtrusive attachment methods, unlike the taller stands commonly used in the past. While roof

Reroofing a Structure that has Lightning Protection

Most reroofing work necessitates temporary removal of portions of the lightning protection system. With some small simple roofs, a roofer may be capable of undertaking the reinstallation work, subject to an inspection by a qualified lightning protection professional upon completion of the work. In most cases, however, the removal and reinstallation should be done by a qualified lightning protection contractor. If the work must be undertaken during a season of high lightning risk, every effort should be made to closely coordinate the overall work in order to minimize the time when the building is left unprotected.

While reroofing, it is often important that certain aspects of the lightning protection systems unaffected by the roof work remain functional. This particularly applies to surge protection. Where there is a high risk, any components of the lightning protection system remaining in place during the roof work should not create unintended paths for electrical discharge from a potential lightning strike. If the reroofing stems in part from related new construction that will affect the design of the existing lightning protection systems, as with the construction of a large addition or a new dormer, services of a qualified lightning protection professional should be used.

Common Questions about Lightning Protection Systems

By installing a lightning protection system is there a greater risk of a lightning strike? *No.*

Is a licensed contractor required for installation? *Even though many of the components of a traditional lightning protection system are readily available to the public and contractors, licensed and certified installers should be used in most cases.*

In a lightning-prone region should a weather-vane on a building be bonded to a lightning protection system? *Yes. Where no system exists, it may be best to leave the weathervane ungrounded rather than undertake a do-it-yourself project.*

What to do with an old decorative rod on a building where the system has not been functional for years? *If the building is considered to be at risk, repair and upgrade the lightning protection or remove the rod and store for possible later reuse. If the area is not highly prone to lightning and the building risk is low, probably no immediate action is needed.*

What about the use on a historic building of one of the non-conventional types of lightning protection systems that have been marketed in recent years? *NFPA and UL safety standards for lightning protection only apply to the widely accepted Franklin system. The conventional/traditional Franklin system remains effective and has stood the test of time.*

With a working lightning protection system, are there any precautions to be taken during a lightning storm? *There are still the normal precautions to be taken such as avoiding metal water pipes (no baths) for personal safety, disconnecting sensitive electronics when possible, and staying indoors.*

Can landscape features like trees be protected from lightning damage? *Yes. Lightning protection can be installed on trees.*

mounted terminals are typically connected by conductor wires running along the roof top, down conductors can often be placed at inside corners, beside or behind downspouts, or on less prominent elevations for reduced visibility. On chimneys and rooftop features such as parapets, the small terminals can be placed on the least prominent side or in a way that best minimizes their visual impact while providing the necessary protection.

Both lightning protection systems that primarily use copper components and ones that use aluminum are available today. With copper terminals and cables, some of the connectors and fasteners usually are made of bronze. For historic buildings, copper systems often are preferred because they have been traditionally used in the past and may be a good visual match where replication is desired. While copper is more costly, aluminum as a material is a slightly poorer conductor, requiring heavier gauge cables and components. As a replacement for galvanized cables and terminals, aluminum or sometimes lead-coated copper may be preferred over copper for a closer color match.

The choice as to whether to use copper or aluminum is at times dictated by the existing roofing material. Copper should not be used for lightning protection on old galvanized steel or corrugated iron roofs, as it will tend over time to stain and erode the roofing due to galvanic corrosion. Aluminum should also be used on steel, iron, and zinc roofs. For such commonly-found historic roofing materials as slate, wood, asphalt shingles, and rolled roofing, either copper or aluminum may be used.

While the installation of lightning protection should always be done by a certified lightning protection contractor, there are projects where a roofing contractor needs to be involved as well. Such close coordination is important, especially on membrane roofs, to ensure both that the lightning protection is properly installed and that the integrity of the roofing and flashing is not impaired. The appropriate means of attaching air terminals to the roof and securing the connecting cables without reducing the service life of the roof depends on a variety of factors. The use of specific sealants, adhesives, cap sheet materials, and metal fasteners to secure cables and terminals to the roof depends in part on the type of roof, roofing material, and other building specific conditions. Fasteners must be attached in a manner that minimizes the risk of future water leaks.

For smaller historic structures such as most residences and barns, there is the option of installing a new system, utilizing period reproduction air terminals where appropriate and augmenting with modern smaller air terminals at chimneys and other locations where dictated by today's standards (Fig. 21). This approach can be used to replace a missing system, or where it is simply the preference of the property owner, providing the intent is not to create a major new visual feature where one did not historically exist. Care should be

taken to select a design that is compatible with the historic character of the building, especially in regards to any ornamentation. Because of availability, the best building candidates for reproduction terminals are those dating to the Golden Age. Even some of the manufacturers' cables and connectors available today for general installations are a match to historic ones.

Although lightning protection can be added to a structure anytime, the best time is when a roof is being replaced. Existing surge protection that is deficient should be upgraded or replaced whenever needed. For building uses such as museums with special climate controls, businesses with vital data equipment, or even homes with expensive home entertainment centers, up-to-date protection from power surges is important. Such surges may be caused not only by lightning but also by electrical malfunctions. If the installation of a traditional lightning protection is being postponed or because of low risk not being considered, appropriate surge protective devices still should be installed and care be taken that electrical service, cable, and similar systems are properly grounded.

The locations for down conductors are usually derived as a result of requirements of standards and codes and aesthetic considerations. For historic buildings of special significance, particular care in the installation of the grounds should be taken so as to minimize disturbance and risks to historic landscape features and damage to any archeological resources. Furthermore, location of drain pipes and underground utility lines should be marked prior to grounds being installed.

Codes, Standards, and Contracts

For large or complex structures, special applications, certain uses, or buildings of high historic significance, the services of an architect or engineer experienced with lightning protection is usually desirable to assist with major upgrades or new installations. A number of the major manufacturers of lightning protection systems



Figure 21. Small air terminals have been used in this more recent installation and have little visual impact. If a partially concealed system was desired, the cable and the mount for two of the air terminals could have been concealed within the ventilators. Photo by author.

also provide helpful design assistance. In more common building cases where design services independent of the installation contractor are not used, the property representative needs to check with the local building department as to relevant code provisions. While the National Electrical Code, which includes general references to lightning protection may be cited, the most commonly referred to safety standard specifically for lightning protection work is that issued by the National Fire Protection Association and entitled, *NFPA 780 Standard for Installation of Lightning Protection Systems*.

The Underwriters Laboratories, Inc. (UL), has a similar standard covering the installation of lightning protection, *UL 96A Standard for Installation Requirements for Lightning Protection Systems*. In addition, UL has requirements that cover the components used in the system, *UL 96 Standard for Lightning Protection Components*. These standards can be specified in a contract document along with NFPA 780.

Where a historic system is being repaired or undergoing upgrades using specialty reproduction parts, all functional replacement parts, unlike ornamental pieces, should be UL-listed products. UL-listed products help provide quality assurance, but it does not necessarily mean that non-UL-approved parts are unsafe to use. For new installations and for some older systems, UL also offers an optional Inspection Certificate Program through UL-listed installers. A UL Certificate assures that a lightning protection system installed on a structure has been inspected by a UL-field representative and is in compliance with UL, NFPA, or U.S. government standards.

The Lightning Protection Institute (LPI) is a voluntary membership association for lightning protection manufacturers and contractors that provides training and certifications for designers and installers. They offer different levels of certifications for installers. A membership list can be found on their website. The Institute also administers a quality assurance program that certifies an installation meets their quality assurance program through a third-party inspector.

For most projects, competitive proposals from experienced lightning protection installers are desirable. However, with historic systems, the choice of installers may be more limited. Depending upon the historic resource and conditions, it may be important to use a contractor both with experience in lightning protection systems and historic buildings. Work on historic buildings often requires knowledge of older building materials and construction; an appreciation of the importance of installing a lightning protection system that does not unnecessarily impact the structure's historic appearance or damage historic materials; and a commitment to the highest quality of work.

The cost of a new system varies according to many factors such as the size of a structure, roof type, and

materials. Features that require individual protection, such as dormers, chimneys, and metal skylights, will add to the cost. Porches and lower additions to a building may necessitate additional work to ensure full protection coverage. The type of materials to be used affects costs, with copper and copper alloys being more expensive than aluminum. Copper cannot be used on structures with aluminum siding or most metal roofs, and similarly aluminum cannot be used on a copper roof. The extent of required bonding of nearby objects and the level of surge protection coverage desired are also cost factors.

The cost of a new system installed on a simple monument, house, or barn with a small footprint and plain roofline tends to be relatively inexpensive. A new system on a medium-sized residence or commercial building with multiple dormers, chimneys, and numerous features that need to be bonded to the system will cost considerably more. Among some other factors affecting costs are whether conductors are concealed or run exposed, the ease of access to the building, and where the building is located.

Summary

The use of lightning protection systems to protect structures and provide for public safety is scientifically accepted. Various government entities require such installations on their buildings and local building codes in areas of frequent lightning may require such systems depending upon the use of a structure. While there are no special requirements simply because a building is historic, as an irreplaceable cultural resource, historic structures at risk of damage or loss from a lightning strike merit protection.

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