Copper Applications

A Case Study

POWER QUALITY

A Tale of Two Churches

Lightning protection and robust grounding essential for steeples, roof structures

Photo curtesy of *Richmond Times-Dispatch*

The near-total destruction of Richmond, Virginia's historic St. James Episcopal Church by a 1994 lightning strike is believed to have resulted when the strike hit the ungrounded, copper-clad steeple, from which energy traversed the wooden roof structure, setting it ablaze, rather than being directed safely to earth. An alternative explanation sees the strike initially contacting a distribution transformer behind the structure.

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Strike termination devices, also known as Franklin rods and air terminals, are familiar sights atop barns, public buildings, and even some residences. The tapered, 3/8-inch-diameter copper or other metal rods are a foot or so tall, interconnected and grounded. When properly positioned and installed, they comprise the business end of a lightning protection system. Connected to a robust copper grounding system, *as they must be*, they have saved many a structure, directing lightning energy harmlessly down to earth.

Unfortunately, there are plenty of other pointed rooftop structures that aren't always protected properly, if at all. Worse yet, they may be *several dozen feet* tall, making them very attractive lightning targets. They're steeples, of course, and their vulnerability generates millions of dollars in lightning-related damage annually.

Why would anyone not protect such an obvious lightning target, especially on a church? Mainly, it's ill-founded complacency; churches that have never seen a serious lightning incident tend to adopt the mistaken assumption that their spires are adequately protected and grounded. A good example is the Richmond, Virginia church described later in this case study. It had survived since 1905 without a single recorded "hit" before disaster struck.

In other cases, there's the understandable aesthetic reluctance to mount air terminals near religious symbols atop a steeple, or even expose down-conductor cables at all.

The good news here is that safety and fire-avoidance issues can be addressed successfully by today's standards-based lightning protection practices. Aesthetic considerations in particular are routinely dealt with by skilled, certified installers.

Here are two examples:

A Baptist Church's History of Electrical Problems

The Mount Ararat Baptist Church complex in Stafford, Virginia occupies a multi-acre site containing roads and parking lots, walkways, and even a small cemetery. The church's two-story construction stands out prominently, but that, unfortunately, increases its vulnerability to lightning (**Figure 1**).

Figure 1. The "new" structure at the Mount Ararat Baptist Church complex stands out prominently among parking lots and roads on the church's large lot, making it especially vulnerable to lightning strikes. Two towers on the structure, one shown at center, were found to be inadequately grounded.

Mount Ararat is a contemporary community-oriented church whose architecture combines traditional worship space with an assortment of classrooms, meeting rooms and offices, plus youth, recreational and athletic facilities. Its two principal buildings are well protected by Code-approved fire and safety systems and equipment, much of which is computer controlled or monitored.

Daniel Lutsky, Mount Ararat's facilities manager, knows the complex well and understands the lightning-based problems it faced as well as anyone.

"The church started in 1907, and there have been lots of tear-downs and additions over the years," he explains. "We're currently a little shy of 100,000 square feet total in two buildings. The older section was built in 1957 and the newer section went up in 2009.

"I started working at Mount Ararat three-and-a-half years ago, and we were having lightning-related electrical surge problems from the day I got here. Finally, in 2013, the older building itself got hit, and it got hit in a big way. The strike by-passed the short steeple in favor of a nearby chimney (**Figure 2**). Lightning is just gonna go where it wants to go!

Figure 2. The 2013 lightning strike destroyed a chimney on the "old" structure that stood to the left of the short belfry. From there, it entered the complex via telephone lines, severely damaging or destroying $100,000 worth of HVAC equipment, an elevator, computers, telephone equipment and important safety devices. Several of the new lightning protection system's rooftop air terminals and their ground conductor connection can be seen in the foreground on the "new" structure's parapet.

"We lost about $100,000 worth of equipment in that single strike, including the chimney — there were bricks blown everywhere! — and all kinds of HVAC equipment and controls, one of our passenger elevators, all of our computers and telephones, and a lot of life-safety stuff. We just recently found out that a fire light pull-down station was damaged. It's not a device that ordinarily goes bad. We also lost the mini-annunciators that we have all throughout the building. That was rather costly.

Bringing in a certified installer

"I certainly didn't know much about lightning at the time, and I wanted the repairs to be done right. The Loehr Lightning Protection Company had installed the lightning rods on the chapel some years ago. The chapel wasn't damaged this time, and Loehr's nameplate was on the wall, so I gave them a call.

The person Mr. Lutsky contacted was J. J.Loehr, president of Loehr Lightning Protection Company, a nearly 70-year-old, Richmond, Virginia-based family business. Mr. Loehr is also a master installer/designer as certified by the Lightning Protection Institute (LPI).

The first thing that struck Mr. Loehr was that although *portions of* both structures were grounded to earth, the buildings' electrical and grounding systems weren't connected to each other. Mr. Loehr concluded that this situation stemmed from the church's incremental growth history.

In fact, the churches grounding systems were a hodge-podge waiting for trouble. "For example" Mr. Loehr recalled, "the older portion of the church, which has a gable roof, had steeple protection only, and even that was questionable. The new building and its flat roof had some lightning protection but only in scattered locations. There was some grounding to earth here and there, but none of those systems were interconnected, so a lot of the surge and stray-current problems the church had been experiencing over the years were likely due to differences in potential between the various grounding systems and between the two buildings themselves.

"What we did to correct this situation was to install a new rooftop lightning protection system on the new building and use that system as a facility-encompassing bus to tie all of the various grounding and electrical systems together, exactly like one would do with a conventional buried ring-ground except that it was at roof level. That made sense in any event, first, because we had to connect all the air terminals on the roof anyway, and, second, because placing the ring on the roof avoided having to install a buried ring-ground through parking lots, roads and sidewalks, not to mention the cemetery, (**Figure 3**). We installed additional driven electrodes per UL Standard 96A, then bonded them and all existing ground electrodes to the roof-top ring.

Figure 3. A small cemetery remains adjacent to the Mount. Ararat Baptist Church. Along with roadways and paved parking lots, the cemetery made the installation of a conventional buried ground ring impractical.

Ground Resistance Not a Problem

"We're lucky here in central Virginia because we have good, moist, conductive clay-bearing soil. We'll typically get ground resistance readings lower than two ohms for systems like Mount Ararat's. We don't have to drive deep electrodes or augment the electrodes chemically.

Down-conductors extend from the roof's perimeter ring to grade, then they turn away from the building underground approximately two feet to clear the foundation. At those points, they're exothermically welded to 3/4-in X 10-ft copper-clad ground rods. The 10-ft ground rods are standard in the industry. NFPA 780, the standard for installation of lightning protection systems, specifies that the tip of the rod must be 10 ft below grade. You can dig a 2-ft hole and use an 8-footer, but we just go with a 10-ft electrode."

There are two low architectural towers on Mount Ararat's newer building, (**Figure 4**). The architect had specified an air terminal atop each of the two towers, and that down-conductors should connect the terminals with building steel. That's just what was done. *But there was no mention in the construction spec about grounding the building steel.* As a result, the towers and their inviting air terminals weren't really grounded at all.

Figure 4. The weathered copper down-conductor leading from the Franklin terminal on one of the church's two towers blends well against the roof's reddish shingles. Attention to aesthetic details such as this helps make externally mounted lightning protection system components unobtrusive elements of the building's appearance.

Mr. Loehr's fix was to bond the two tower-mounted air terminals to the rooftop lightning protection system and, by way of a heavy-gage, buried copper conductor, connect the grounding systems of the old and new structures. Doing that ensured that the facility's entire grounding and electrical systems were finally at one common potential.

"Technically, we installed a perimeter Class I system on the new structure — that's for installations less than 75 feet above ground. A perimeter ring runs along the parapets. The ring is bonded to the air terminals, the HVAC system equipment and all other metallic bodies on the roof. What is important in a lightning protection system is the interconnection of all metal bodies to the system. You don't want a side flash from a grounded metal body to an ungrounded body. Consequently, metal bodies like air conditioning systems, exhaust fans, vent pipes, railings, are bonded to the equipment and other metal objects that are on the roof.

"With all the roof-top elements now connected and bonded, we then ran copper down-conductors to grounding electrodes placed at the required average 100-ft spacing around the building. We also interconnected selected down-conductors to the building's phone, water, communications and electric systems by way of wall penetrations. Now everything that involves electricity or grounding is at the same ground potential" (**Figure 5**).

Figure 5. Rooftop lightning protection system on Mount Ararat's "new" building. Note Franklin rods mounted on all metal bodies on the roof, whether grounded or not. All equipment is bonded to a network of grounding conductors that, in turn, are bonded to a conductor ring encircling the structure at the roof's parapets. The ring serves the same purpose as a conventional buried ring-ground on properties where excavation is practical. From the rooftop ring, copper down-conductors lead to driven 10-ft grounding electrodes.

Has the fix worked? So far, and despite the passage of several severe thunderstorms, there has been no evidence of any electrical surges in the buildings, and no equipment damage. Mr. Lutsky, who works in the building every day, says it best: "I do feel safer about the building since we've had the new protection system installed. We're not experiencing any more surges. We went through a storm the other day and nothing happened! It was great. At the end of the storm I felt secure."

Connections to Indoor Systems

The ground conductors of interior electrical, communications and safety systems, as well as water lines, were connected to common grounds that terminate at copper grounding buses located at convenient spots throughout the structures. The buses were located near to down-conductors at the outside of the building so that through-wall connections could be made between the down-conductors and the grounding buses. (**Figure 6**). In this manner, all interior and systems were now common to the rooftop ring and the driven earthing electrodes, placing the entire complex at the same ground potential. It was this feature of the lightning protection and grounding system that ended the surges and electrical damage the complex had experienced for years.

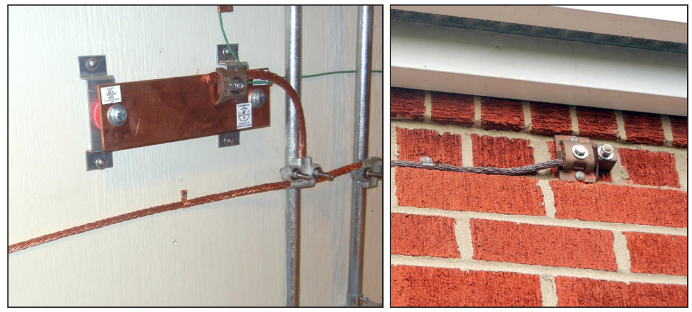


Figure 6. Indoor grounding bus with wall penetration (left); the right-hand photo shows one of several outdoor wall penetrations, from which the heavy-gage copper conductor to the left of the penetration lug leads downward to a driven earthing electrode.

"Tricky" Aesthetic Considerations

"The folks at Mount Ararat were sensitive to aesthetics," recalled Mr. Loehr, "and so are we!. When you're working with new construction, you can hide conductors in conduit or elsewhere, but you don't have that luxury with existing structures, like those at Mount Ararat. You have to match the existing conditions. Here, the older building and the towers on the newer structure have dark brown shingle roofs, and copper blends in well with that as the conductors oxidize, (**Figure 4**). They have brick walls, particularly on the older structure, that also tend to hide the copper. We also ran down-conductors next to downspouts to make them less conspicuous, less obvious, (**Figure 7**), and we ran cable along edges and corners. If you do it carefully, the cables are almost invisible.

"When it comes to gutters and downspouts, we could have just run the down-conductor over the gutter and down the downspout or leader. That meets the standard, but it really doesn't look that great. What we do is run the cable *through* the overhang or the gutter with a solid rod enclosed in a water-tight fitting. It eliminates the awkward looping and it's a lot less conspicuous, (**Figure 7**).

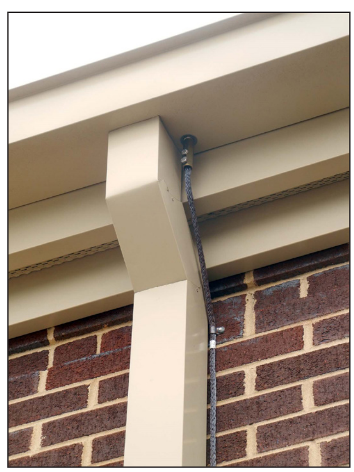


Figure 7. Rather than looping down-conductors over gutters, Loehr Lightning Protection Company routes them through the overhang when necessary, sealing the penetration with a solid copper rod enclosed in a water-tight fitting. The result is a cleaner, less conspicuous installation.

Mr. Loehr has strong opinions regarding grounding connections: "You might want to use a mechanical connection where you have to construct a ground path at a disconnect, and you don't have the luxury to use an exothermic weld. But generally, as part of a system like this, we like to go with an exothermic weld. Also, our protection systems utilize only Franklin rods, I've never been a believer in lightning 'preventers' and I've never seen convincing evidence that they do what they say. In fact, I witnessed a failure of such a system on a building in Newport News in 1996. Franklin systems have a proven track record and comply with national safety standards, so that's what we recommend and install for our clients."

Pleased with the cost

Mr. Lutsky was very pleasantly surprised at the cost of the lightning protection system. "In the end, it was only a small fraction of the cost to repair the building and its systems, and we should continue to avoid those repair costs from here out. The lightning protection system is very cost-effective."

"Devastating" Lightning Damage to Richmond Church

St. James Episcopal Church is one of Richmond, Virginia's most stately houses of worship. It was founded in 1838 as a small Sunday school at what was then the western edge of the city. The sanctuary of the current church, which opened in 1913, was built at a new location selected in keeping with the then-population center of its congregation. The church's brick-and-stone walls support a wood-timbered roof. A 160-ft, steeple, the top 40 feet of which are clad in copper, stands at the narthex (front) end, (**Figure 8**). The totally enclosed far end of the church faces an alley.

Figure 8. St. James's 160-ft, copper-clad steeple stands at the front of the church. Although a 1994 lightning strike probably hit the steeple, destroying the church, the steeple itself remained relatively unharmed. The steeple was not grounded before the lightning strike. Now, the steeple, the periphery of the church's roof and all rooftop equipment are protected by strike termination devices (Franklin terminals), all bonded to a securely grounded, 100% copper lightning protection system.

The church had never been struck by lightning, giving rise to a belief that the steeple was adequately grounded. A metal staircase was known to run up to the chimes inside the steeple, but no knowledge of its connection with any grounding system exists.

In July, 1994, a thunderstorm that spawned more than 1,000 cloud-to-ground lightning strikes throughout the city sent a massive bolt into the church, leading to its near-total destruction (**cover photo**). Two scenarios have been posited: the first proposes that lightning initially struck a pole-top distribution transformer located in the alley behind the church, and that the explosion of that transformer engulfed the rear of the church, destroying it and setting the roof afire. An alternative scenario offered by J. J.Loehr is based on his analysis of the damage some days later. Mr. Loehr suggests that lightning first struck the steeple and that, running out of vertical grounding conductor at or near the base of the steeple, it turned horizontally to run along the gable of the roof, igniting its wooden rafters. According to Mr. Loehr's analysis, the strike then blasted through the rear wall of the church, finally finding earth via the alleyway transformer's ground connection.

Mrs. Betty Mostler was a St. James parishioner at the time and lived only a few blocks from the church. She did not witness the strike itself, but saw its results shortly afterward. "My impression is that it was devastating," recalled Mrs. Mostler. "The whole roof caved in on the church.

Inside the church, the balconies at the sides of the apse had fallen but, fortunately, not all the way to the ground. They were all left tilting inward, in which position they protected the stained-glass windows, including several designed by William Comfort Tiffany (**Figure 9**).

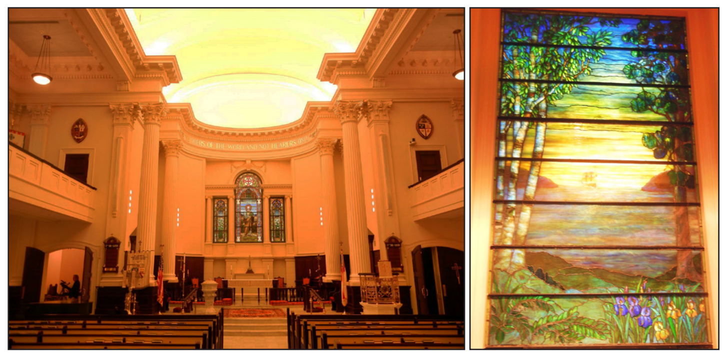


Figure 9. (Left) Restored interior of St. James Episcopal Church, Richmond, Virginia. Almost everything visible in the figure was destroyed by the 1994 fire save the baptismal font and the brass lectern and pulpit. The balconies, left and right, fortunately sagged rather than collapsing completely, thereby shielding priceless Tiffany stained-glass windows from damage, (Right).

"The volunteers managed to salvage a few pews, from which exact duplicates could be copied. Miraculously, they were also able to save a large wooden carving containing an image of Jesus. It was badly charred but now stands in our chapel. On the night of the fire, people formed a line to bring out silver and brass and anything that they could carry. The baptismal font and the brass pulpit and lectern were salvageable. Best yet, deep in the church, in a small basement, they found the molds for the plasterwork: the ceiling, tops of columns, that sort of thing. All of that went back the way it was. It was amazing.

"One of the best things that happened was that the next week after the fire, the Jewish synagogue located right beside us gave us a place to meet in their facility, and for three years that is what we did.

"The total cost of the restoration was six or seven million dollars, and insurance covered close to five million of that. The church's foundation was deep enough to allow us to dig a full basement to give us a lower floor that we didn't have before, and the cost of that addition accounted for the difference. It took three years to rebuild and restore the church." Mrs. Mostler ought to know: she served as chairperson of the rebuilding committee throughout the entire operation.

For Mr. Loehr, the rebuilt church presented an opportunity to install a robust, standards-based lightning protection system that would shield the structure well into the future. "The church had no lightning protection beforehand," said Mr. Loehr, "So we installed an all-copper, Class II lightning protection system, beginning with a Franklin electrode at the top of the cross atop the steeple. We used 28-strand, 0.066-in copper lightning cable as down-conductors, connecting them to ¾-in X 10-ft driven electrodes wherever we were able. The cables are practically invisible from street-level. We installed additional air terminals along the periphery of the new roof and on all exposed conduits and structures on the roof itself. Everything, including the building's electrical and water systems was interconnected, and everything is also now at the same ground potential."

Despite the passage of more than a decade of thunderstorm seasons, St. James has suffered no further lightning damage. Mrs. Ostler, for one, believes that her church is now safe: "We thought the church was protected, and it wasn't. Now, it's very clear to me that lightning protection is important. We never want to go through a fire like that again."

Kimberly Loehr, Communications consultant for the Lightning Protection Institute.

The Lightning Protection Institute (LPI) is a not-for-profit nationwide group founded in 1955 to promote lightning safety, awareness and education and is a leading resource for lightning protection installation in accordance with national safety standards of NFPA and UL.

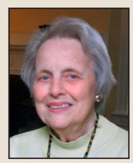
LPI emphasizes that "steeple only" lightning protection does not meet industry standards for safe and effective lightning protection. Steeple grounding and partial protection methods have been found to cause more harm than good, leaving structures vulnerable to lightning side-flash, surge problems and structural damage, and even fire.

LPI certifies individuals for the installation of lightning protection systems through a Master Installer testing program to qualify competence. LPI supports lightning protection quality control and assurance through third-party inspection. Information about follow-up inspection services can be found at www.lpi-lp.com. For a list of certified contractors visit the LPI website at www.lightning.org

The Principals

Daniel Lutsky is facilities manager at Mount Ararat Baptist Church, Stafford, Virginia. He experienced the frequent lightning-related damage to church electrical systems leading up to the massive 2013 strike. Mr. Lutsky can be reached at dlutsky@mtararat.org

J. J. Loehr is president of Loehr Lightning Protection Company, Richmond, Virginia. Mr. Loehr is a Commonwealth of Virginia Class A contractor and an LPI-certified master installer/designer. Mr. Loehr can be reached at loehrlp@aol.com



Betty Mostler witnessed the 1994 fire that destroyed most of St. James Episcopal Church, Richmond, Virginia. She was subsequently appointed and hired to direct the three-year, multi-million-dollar restoration project.

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