



WARREN LIGHTNING ROD COMPANY

2 RICHEY AVENUE • COLLINGSWOOD, NJ 08107

PHONE: 856-854-7000 • FAX: 856-854-1803

WWW.WLRC.NET

Galvanic Corrosion in Lightning Protection Applications – Problems & Solutions

By Simon C. Larter

Abstract: *Historically, copper and bronze components were used for lightning protection applications on all roof surfaces other than aluminum, from copper flashing to galvanized steel rooftop units to painted steel copings. Over time, localized corrosion will occur where galvanically incompatible metals are placed in contact in the presence of moisture. U.S. lightning protection standards now make explicit mention of avoiding such incompatibilities, and as such, lightning protection installations from as late as the 1990s are not eligible for recertification through nationally recognized testing agencies unless repairs are effected. This paper discusses the problems created by incompatible metal installations, and proposes solutions to ensure that both lightning protection components and rooftop equipment achieve maximum service life.*

Background

Historically, copper and bronze materials have been used in lightning protection applications on all rooftop surfaces other than aluminum, due to their excellent conductivity, thermal characteristics, and longevity. A properly installed lightning protection system (LPS) will last for decades, maintaining its integrity with only minor maintenance, in the absence of additions to the protected structure or reroofing projects. However, while the LPS materials retain their effectiveness even after oxidation, the same cannot be said of the roofing materials to which they are often attached. Indeed, copper and bronze components in contact with exterior galvanized or painted steel surfaces can cause significant corrosion over time (see Figure 1), an effect only partly mitigated by traditional methods such as repainting.

Published lightning protection standards in the United States have long recognized this issue. For example, the National Fire Protection Association's standard 78 (now 780, *Standard for the Installation of Lightning Protection Systems*), first published in 1904, makes clear



Figure 1: Copper and bronze in contact with galvanized steel.

that copper materials are not to be used in contact with aluminum surfaces, and vice versa. But it goes further, disallowing the use of materials that may form an electrolytic couple in the presence of moisture.

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

NFPA 780 (2011), 4.2.1

Underwriters Laboratories Inc.[®] (UL) says much the same thing in their standard 96A, *Installation Requirements for Lightning Protection Systems*.

Metals shall be used in combinations that are galvanically compatible.

UL 96A (1994), 5.2

This requirement was updated in the 1998 edition of the standard, to more closely conform to the language of NFPA 780.

Metals shall not be used in combinations that form an electrolytic couple (metals that are not galvanically compatible) that accelerates their degradation (corrosion or oxidation) in the presence of moisture.

UL 96A (1998), 5.2

While the subsequent paragraphs of both NFPA 780 and UL 96A had for decades made clear the prohibition against copper and aluminum materials being placed in contact, it was not until the 2007 edition of 96A that galvanized steel was called out as specifically incompatible with copper.

A copper lightning protection component shall not be installed directly on aluminum surfaces or external galvanized steel surfaces .

UL 96A (2007), 7.5

This revision rendered thousands of existing lightning protection systems non-compliant overnight. Furthermore, around the same time, UL placed a 5-year shelf life on their Master Label[®] certification, eliminating at a stroke any grandfathering for formerly-certified installations. And while only galvanized steel is mentioned in 96A, the standard interpretation for UL's field inspectors was that copper could not be placed in contact with any external painted steel surface at all.

Though this action on UL's part was unpopular with both installing contractors and building owners, it is clear that galvanic corrosion can and will occur where copper and steel in contact are exposed to an electrolyte fluid (which for our purposes is assumed to be rainwater). Figure 2 shows the deterioration that can occur when copper conductor is run on a painted steel coping.



Figure 2: Copper and bronze in contact with painted steel.

Discussion

The aforementioned corrosion issues often do not pose any threat to the functionality of the lightning protection system. Although the surfaces to which the LPS components are attached may degrade, copper being more noble than steel or aluminum (see Figure 5 below) means that there will be very little impact to the efficacy of the main conductor. However, lightning protection does not exist as a separate system, but as an integral part of the overall building envelope. As such, it cannot be viewed in isolation, and a building owner should not be asked to sacrifice the integrity of their roofing system for the sake of a lightning protection system whose value can only be realized in the event of a direct strike to the building—an event that may only occur once every few years.

For locations such as perimeter copings, degradation of the metal may not pose an immediate threat to the building contents. Roofing membranes typically wrap up and over parapets, providing a secondary layer of waterproofing, so that infiltration even in the event of corrosion through the coping will be nominal, at best. In the case of standing-seam roofs, on the other hand, the metal itself is the primary infiltration barrier. Holes corroded through this type of roof will expose equipment and personnel within the structure to moisture. The author has observed instances of almost complete corrode-through in systems less than 20 years old. Figure 3 shows the corrosion of a metal, standing-seam roof after less than 15 years of contact with bare copper conductor.

It should be noted that preventive maintenance can mitigate some of the issues associated with dissimilar metals. Regular inspection of the lightning protection

Solution

Since the 2007 change to UL 96A, most lightning protection contractors have adopted the practice of installing aluminum conductor and components on all non-copper exterior metal surfaces. While aluminum is less conductive than copper, with the result that the cable is larger and therefore more conspicuous, it has the advantage of being less noble than the materials to which it is attached (see Figure 5). Although this means that the aluminum will preferentially degrade over time instead of the substrate, in practice the effect on the lightning conductor will be minimal, and the performance of the LPS will not be significantly impaired.



Figure 3: Copper in contact with a standing-seam metal roof.

system can bring corrosion issues to light before significant deterioration occurs, and painting of affected surfaces can slow the oxidative process. As Figure 4 shows, though, painting will not fully prevent rust from forming. Because lightning conductor is generally braided, wicking of moisture through the interstices is impossible to prevent. There will always be infiltration, and therefore there will always be some amount of corrosion.



Figure 4: Corrosion between painted unit and painted conductor

Outside of the practicability issues, the fact remains that neither UL nor the Lightning Protection Institute Inspection Program (LPI-IP)—the second, and newest third-party LPS certification provider—will recertify a building where clear metal incompatibilities are present. Even if the corrosion is minimal, the language of the standards as they exist today is such that copper in contact with galvanized or painted steel will render a lightning protection system non-compliant, and therefore uncertifiable.

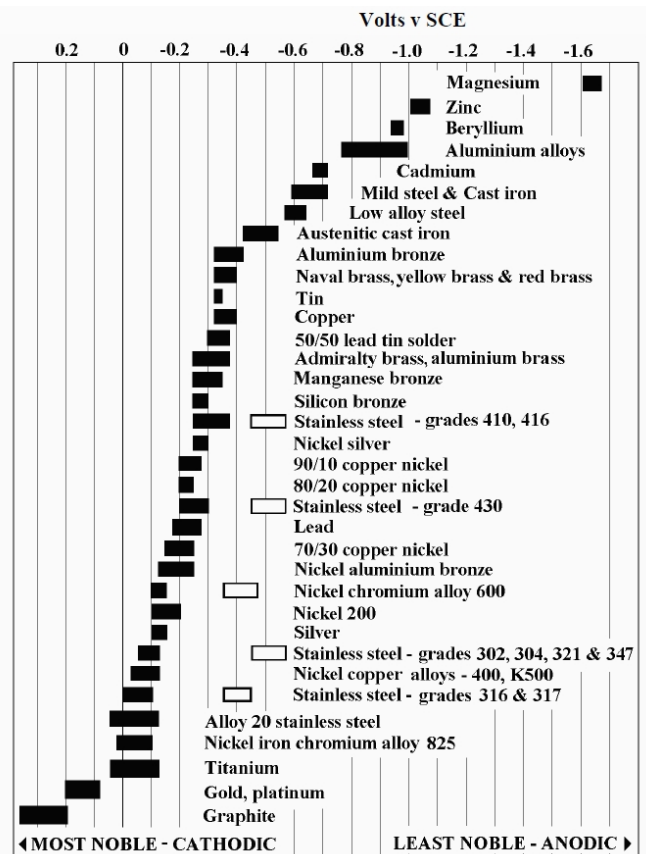


Figure 5: The galvanic series
(Source: [Atlas Steels Technical Note No. 7](#))

Applying this practice retroactively to buildings that require recertification of the LPS can unfortunately result in significant costs to the owners. Field evidence suggests, though, that replacing the copper with aluminum ensures that both the lightning protection components and the metal attachment surfaces will remain substantially intact for their expected service life.

The installation pictured in Figure 6 is a side-mount copper and bronze system affixed to a painted steel

coping. Even though the mounting surface is vertical, and offers little opportunity for moisture to accumulate, rust is easily noticeable where the conductor was held against the cap (the fastener in this instance worked loose, allowing the cable to fall away and expose the substrate).

membrane roofs, asphalt shingles, wood, concrete, brick, and other non-metallic surfaces, copper is the preferable material. It is also the only material permitted to be installed in contact with the earth, and in very wet locations. Aluminum conductor is recommended for certain specific applications, but is expressly prohibited in others.



Figure 6: Copper side-mounted on painted steel.

A counterexample is provided in Figure 7. Here, the installation is also side-mounted on a painted steel cap, but the materials are aluminum. We can see that despite the visible rust at the edge of the coping, there is no noticeable corrosion beneath the conductor, nor behind the air terminal base. The age of the system is similar in both instances.



Figure 7: Aluminum side-mounted on painted steel.

It may be worthwhile to note before proceeding that copper and bronze will always be the materials of choice in areas where corrosion is not likely to occur. On

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

NFPA 780 (2011), 4.5.3

Conclusion

While recertification of existing systems is sometimes tied to insurers' requirements, or corporate mandates, it is not always necessary to provide third-party inspections of upgraded installations. That said, a certification from LPI-IP or UL provides owners with an impartial assessment of their lightning protection system, and will result in proof of compliance with US ANSI standards. Where copper materials remain in contact with exterior galvanized or painted steel, no such proof will be forthcoming.

Despite the associated costs, it is advantageous in the long-run for building owners to replace copper components on exterior steel surfaces with aluminum when the opportunity presents. The copper and bronze materials pose no immediate hazard, and if left in place, will continue to provide protection for the structure, as long as the system as a whole remains in compliance with published standards. However, if significant roof work is expected (e.g., reroofing, HVAC upgrade, etc.), it is recommended that the lightning protection system be brought into full compliance wherever possible.

In the ideal case, both the LPS and the roofing envelope will retain full functionality for as long as possible. Installing or retrofitting lightning protection materials that minimize the chance of galvanic corrosion will ensure that both systems meet or exceed their expected service life. In this manner, both the structural integrity of the building and the safety of its contents and occupants can be assured.