TECHNICAL BULLETIN

Best Practices in Lightning Protection and Metal Construction

Objective

The intent of this Technical Bulletin is to educate the industry concerning good installation techniques that should be followed when installing lightning protection systems involving metal construction. Another goal is to dispel myths about metal construction attracting lightning. In addition to the information provided in this document, specific installation requirements are discussed in several important industry sources including NFPA 780, UL 96A and LPI-175. These documents should be referenced for additional important information.

Overview

We live in an electronic age, with computers and other sensitive electronic equipment present not only in every workplace, but also in most households. The element of personal safety notwithstanding, a significant number of people are considering lightning protection for their home or business. When metal roofing is employed on a project, it seems to heighten owner and designer awareness of lightning and there are sometimes questions about whether the use of metallic roofing increases the risk of lightning strike.

Metal roofing does not in any way increase this risk.

Lightning, by way of a simple explanation, is a giant spark of electricity in the atmosphere that sometimes connects to the ground. While using metal construction does not increase the chances of a lightning event, lightning protection products can make any building less prone to damage in the event of a strike. Lightning rods (air terminals, terminals, or strike termination devices are the preferred terms in the trade) are commonly made of copper or aluminum. (Use copper only with stainless or copper roofing to avoid galvanic corrosion discussed later in the paper.) Structure location and materials used are factors that should always be discussed with a professional installer and considered when choosing lightning protection in accordance with NFPA 780.

Air Terminals and Lightning Protection

Air terminals, or simply terminals, traditionally come in a variety of designs and styles. Traditionally, terminals consist of a minimum 3/8" diameter copper or 1/2" diameter aluminum and are at least 10" tall. Additional shapes can be used, but professional consultation is advised prior to making a final decision. Terminals are installed at the highest point(s) of a structure to intercept a lightning strike prior to that strike hitting the structure. On larger structures, terminals are used in redundant fashion and may also be located at other areas of the roof, such as perimeters and even midpoints of the roof plane. Terminals are interconnected to a common lightning conductor lead (woven wire cabling) of copper or aluminum (taking galvanic corrosion into account), which connects directly to two or more ground electrodes. This gives the current of a lightning strike a direct path to the ground, largely bypassing the structure and protecting it from damage.

Lightning Protection Installation for any Metal Roof

Installation of both air terminals and conductor leads are key considerations when installation takes place on a metal roof. Installation must be planned and executed prudently to provide a long lasting system and preserve the integrity of a long-life roof. The lightning protection system (LPS) is often installed long after the roofing contractor has completed work. While the installing contractor may be expert in connecting the components of the LPS, he may not be expert in weatherproofing, metals compatibility and generally preserving the integrity of modern metal roofing, as the acceptable methodology and standards of practice are different than for other roof types.

LPS Installation is normally done on the exposed surface of the roof. Conductors and air terminals should always be installed with care to ensure that the painted and metallic coating finishes on the metal roofing are not damaged. Do not drag metal conductor leads across roof surfaces. In the case where a painted roof surface has been damaged, it is not easily restored (refer to the MCA White Paper on Field-Applied Touch-up Paint Systems 10/17).

Once in place, conductors and air terminals should be adequately fastened to anchor them during wind and snow events. Wind can cause conductors to "slap" and flutter against metal panel surfaces, abrading the panel finish which leads to corrosion. Damage to a metallic-coated panel may be very difficult or impossible to appropriately repair, causing irreparable harm to roof appearance and integrity.

Snowpack on a metal roof tends to load the conductor with "sliding weight" not generally included in the system design. This snowpack can potentially tear the conductor and its anchorage from the roof and/or pull the conductor across the roof leaving finish damage that can lead to corrosion causing roof attachment failure. Metal roofs are "slippery roofs" as defined by ASCE-7. Snowpack migrates and slides easily on this surface. The forces involved can be substantial, and conductor attachments often are not be designed to resist those forces, especially when the conductors are located near building eaves.

In northern climates, many metal roofs are equipped with snow retention systems (snow guards) to mitigate the hazards of rooftop avalanche. If such a system is already installed on the roof, it can provide opportunity for convenient and effective attachment of the conductors. If not already in place, and especially if conductor lead is located near building eaves, it is highly advisable to install snow retention to protect conductor leads from being torn from their anchorage and causing permanent damage to the roof.

Any attachment brackets, bases and conductor retainer clips should be mechanically attached to the roof using appropriate techniques for the installed metal roofing. The specifics of fastening will vary with the metal roof type as explained below. Adhesively attached components, while generally popular within the LPS industry should not be used as such methods of attachment have consistently demonstrated adhesive failure on metal roof surfaces within a few years.

Metal roofs are typically of two types: either "face-fastened" or "standing seam". Specific recommendations for each follow.

Face-Fastened Metal Roofs

Face-fastened (also called direct-fastened) metal roof types are easily identified. The fasteners that attach the roof panels to the structure are quite visible, plentiful, normally in straight rows across the roof surface and can be easily seen from the roof topside. These roof types are installed either over open structural framing in most commercial, industrial and agricultural applications or over solid (usually wood) decks in residential and light commercial applications.

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When installing an LPS to the exterior of this metal roof type, appropriate screw fasteners and sealing methods are vital to ensure durability of the finished installation and preservation of roof integrity against water penetration. Consult MCA TB "Fastener Compatibility with Profiled Metal Roof and Wall Panels" for fastener compatibility and durability. When possible, the attachment of LPS components through the roof and into structure or deck is preferred, but alternatively components may be attached solely to metal panel provided that proper fastener type and frequency is also observed as well as adherence to other guidelines within this document.

Use butyl co-polymer sealant at the attachment of terminal base or conductor lead retainer clip to roof panel. Note that butyl co-polymer sealants must be protected from UV, hence not externally applied, but "sandwiched" between the metal panel and the terminal base. Do not depend upon exposed sealants applied to the top side of any assembly to prevent water infiltration.

Standing Seam Metal Roofs

The standing seam roof, offered in many varied but proprietary profiles always have a common denominator: Face-fastening is minimized or excluded altogether. Hence exposed fasteners, visible from the roof topside will not exist at all, or may only exist at limited locations such as the ridge, eave or panel endlap locations.

These premium roof types are often accompanied by extended warranties of 25 years or more and expected services lives that may double the warranty period. On this roof type, penetration of the roof surface is strictly prohibited and violates warranties. In attempts to comply with this prohibition, LPS installers typically resort to adhered anchorages, however this must be highly discouraged due to the high failure rate of such attachments from normal weathering phenomena. Attachment should be made directly at the seams with a maximum interval between anchors of 3 feet (36") with non-penetrative seam clamps and the leads are run longitudinally down the seams. On conductor lead runs that traverse the seams, the lead spans from seam to seam well above the "flat" of the panels. Attachment is then made with seam clamps at roof panel seams.

The attachment methods of LPS to these roofs is at a higher standard of care with more unique challenges than attaching to a face-fastened roof type. Creating penetrations through such roofs is contrary to the design principle given that the whole objective of such roof design is to eliminate holes through its weathering surface.

Additionally, standing seam metal roofs (SSMR) are attached to the structure to permit thermal expansion and contraction along the length of the panels. This means that changes in the length of the panels induced by their temperature change is differential to the structure that remains at a relatively constant temperature. These systems in generally respond to such differential movement through slippage of the attachment to the structure and the panels are free to cycle thermally independent from the structure. This freedom of thermal cycling ***must*** be preserved when attachments are made to their surfaces.

Attachments of air terminals and conductor leads should only be done by using non-penetrating seam clamps. Generally, such clamps are anchored with stainless steel setscrews that pinch the seam and are provided with threaded holes for attachment of the desired ancillary LPS component. The protective metallic and paint coatings of metal panels are very thin and easily breached, so round-point setscrews should always be employed in the clamp design. This type fastening when executed correctly will last the life of the LPS and the roof panels. (See MCA TB "Fastener Compatibility with Profiled Metal Roof and Wall Panels".)

LPS Beneath Metal Roof Surface

On rare occasion, the LPS is installed beneath roof panels or components, such as a ridge or rake flashing. When installed beneath the roof panels the terminal must penetrate through the metal roof (or

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flashing). The anchorage of the terminal and conductors then are made directly to the underlying support structure (or roof deck). Any terminal penetration through the roof should be accomplished using an EPDM rubber boot with an aluminum flange that fits snugly around the air terminal and is attached to the roof or ridge cover using appropriate fasteners and sealant (see MCA TB "Fastener Compatibility with Profiled Metal Roof and Wall Panels").

The rubber boot is designed so the opening can be cut-to-size on-location and snuggly fit over the penetrating item. This snug seal provides protection from leaks. Care should be taken to ensure that fastening of the flashing does not pin the roof panel to the structure or deck violating the freedom of differential thermal movement. The base of the flashing should be sealed to the roof panel or ridge cover using butyl co-polymer tape.

Myths About Metal Construction and Lightning

It is a common misconception that lightning protection systems (or metal roofing) "attract lightning". Lightning protection systems simply intercept a lightning strike and provide a safe and effective path that takes harmful electricity to ground. Lightning may strike a given location whether there is lightning protection in place or not. Height, shape, and proximity to other structures are several of the dominant factors controlling where a lightning bolt will strike. The presence of metal (whether on a roof, wall, or structural framing) makes no difference to where lightning strikes.

While the structural steel frame of a building may conduct lightning, if properly grounded, it is not necessarily safe from a lightning strike. Bonding, interconnection and grounding provided by a lightning protection system is needed to direct lightning's harmful electricity safely to ground. Arcing and side-flashing may also occur without the continuous "path of least resistance" to ground provided by the lightning protection system. Without the presence of the protection system, lightning can surge through mechanical, electrical, plumbing, communication and HVAC systems. In many cases, this can result in catastrophe as these systems are not designed to provide a safe path to ground for lightning. Metallic siding, wall cladding and roof panels are designed to fulfill the mechanical function of weathertightness, but these metals are not designed for safe electrical continuity in the event of a lightning strike. A complete lightning protection system is required that connects the air terminals and conductor leads either to a recognized, adequate grounding source or to the structural steel which is then grounded at grade level to a recognized, adequate grounding source.

Due to the relatively thin nature of metal roofing, the metal panels should not be considered as adequate means of transporting the current from a lightning strike. Construction codes recognize that a metal thickness of less than 3/16" cannot generally handle the current and resulting increase in heat generated by a lightning strike.

In assessing the risk involved with lightning striking any structure, two different subject areas should be analyzed. The first area is the probability of a strike; the second area is the consequence of the strike. There is no measure known that can lessen the probability of a lightning strike, except, perhaps, physically moving the building location to a safer geographic position. However, the use of lightning protection systems may lessen consequence of a strike, should one occur. The probability of a lightning strike can be determined by a number of factors including:

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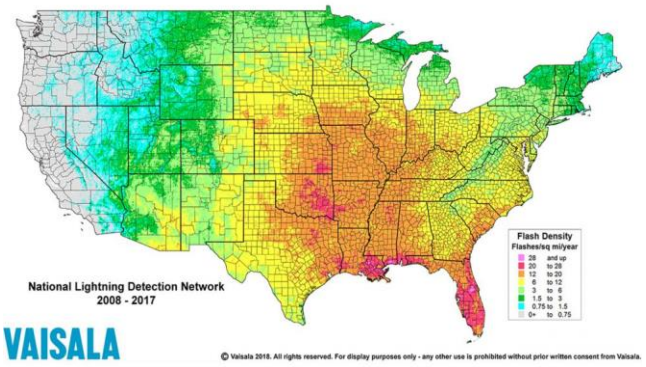
1. **The Measured Lightning Ground Flash Density for the region (Vaisala Map)**

Lightning Frequency Map, 2008-2017



https://www.vaisala.com/en/products/data-subscriptions-and-reports/data-sets/nldn

2. **Topography in the area of the subject facility**: The probability of a strike is higher if the project is located on a mountaintop or hilltop as opposed to a field without nearby structures or tall vegetation.
3. **Size and height of the subject structure**: A tall building or one covering large ground area is more likely to be struck than a short or small building. A tall, structure (such as a steeple or lighthouse) is also a more likely target for a lightning strike.
4. **Relative location of the structure with respect to nearby larger and taller structures:** The presence of a very tall structure in proximity to a small, short building will tend to further reduce the likelihood of a strike to the small building.

In order to adequately assess risks involved with lightning events, the consequence of a strike must also be studied. In other words, what if lightning *does* strike a subject building? What will happen?

Obviously, there is a potential threat to human life associated with a lightning strike in addition to the threat of damage to either the contents of the building, the building itself, or both. A related threat is that of fire. Lightning seeks the path of least resistance to find its way to ground. The more electrical resistance in that path, the more heat is generated by the passage of current through that material. If the material is combustible or in close proximity to other combustible materials the threat of fire is increased. These threats are affected by the following factors:

1. **Construction materials** used for both framing and roof coverings. If these materials are electrically conductive, the threat of fire is reduced, also reducing the threat to human life. If these materials are noncombustible, the threat of damage to them is reduced, and the framing and roof coverings will not contribute a fuel source to any fire resulting from a lightning strike.
2. **Physical contents** of a building. If contents are flammable or explosive, risks of the perils of fire are greatly increased. If contents are sensitive electronics or other equipment, valuable or irreplaceable items, then the consequence of loss is intensified.
3. **Human occupancy**. Buildings that are heavily occupied are considered to be at a higher risk than unoccupied or sparsely occupied buildings. Also, the type of occupancy has a bearing. If a fire results from a lightning strike, the risk to human life is greater if occupants are disabled or non-ambulatory and cannot be quickly evacuated.
4. **Remoteness of the building**. If the building is remote with respect to fire fighting and medical emergency response, the risks of physical loss due to fire as well as human perils are increased.

The largest benefit of using metal roofing related to a lightning strike is that the roof material generally performs as a noncombustible material, so the risks associated with the use of metal roofing during a lightning event make it one of the most desirable roofing construction materials available.

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LPS on a fire station in Texas. (Photo courtesy of Bonded Lightning Protection Systems Ltd.)

Installation and Choosing a Contractor

The electrical ground installed by your electrician is there to protect the internal workings of the electrical system in your building and to accommodate everyday electricity usage. The electrical ground is not designed to handle the mega electricity (100 million volts+ of power and 200 kA of electrical current) that a typical lightning strike can pack.

Lightning protection is a highly specialized trade that is governed by industry safety standards. There are many requirements that dictate installer's qualifications along with a host of NFPA, UL and IEC standards to which adherence is necessary. It takes an experienced design professional to specify the standards for installation, including installer qualifications, for a system that perform acceptably. Lightning protection systems are not for a weekend DIY project. Installers must consider many geographical, metrological, and practical scenarios to properly install a system. It is also very important for installers to exercise extreme caution when working around finished metal roof panels. Scratching of the high quality finish of metal panels can occur when braided cables, tools, or other materials are pulled across finished metal panels. This can compromise the panel finish and the integrity of the exterior envelope system as a whole.

In all cases, safety should be a priority when dealing with these installation practices. Wet roof panels can be hazardous to walk on. Reasonable safety practices must always be recognized and adhered to along with all applicable OSHA guidelines. (NFPA 780, UL 96A, LPI-175)

Aesthetics

What does the lightning protection system look like? Will it detract from the aesthetics of the structure? Entrusting your lightning protection system design and installation to a LPI-certified professional may help to ensure a safe and effective system that won't compromise aesthetics when installed in accordance with the issues raised in this document. In most situations, lightning protection systems are neat and inconspicuous when properly installed, components such as air terminals, conductor leads and grounding are barely visible to the untrained eye. Design and installation measures should always comply with foregoing recommendations and when followed, an LPI-certified professional will help to ensure that attention to detail is met for every structure and roof type.

To install this LPS on a ridge, the conductor was placed under the ridge cap, shielding it from the wind. Flashing was required where the air terminal penetrates the cap. (Photo courtesy of TL Smith Consulting Inc.)

Copper lightning rods and conductor leads are only compatible with stainless or copper roofing and will cause corrosive situations when combined with coated steel, zinc or aluminum roofing. Aluminum terminals and conductors are recommended when working with steel, zinc or aluminum roofs, regardless of the roof panel coating; see the Metal

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Construction Association's Dissimilar Materials Technical Bulletin for more information.

Galvanic Corrosion due to contact of dissimilar metals

Maintenance

Maintenance of lightning protection systems in conjunction with metal roof systems is often underestimated. Items such as making sure all connections are secure and that electrical continuity is as it should be are only two of the many important aspects for a sound maintenance program. Programs such as UL Master Label Certification and LPI Inspection Program Certification are two examples of third party inspection service programs that provide confirmation (Certification) that the Lightning Protection System (LPS) complies with national safety standards for lightning protection systems. When these certifications expire (typically in three or five years) applications can be made for a maintenance-style "re-inspection" to verify system integrity and standard compliance is up-to-date.

Conclusion

In view of the many variables that contribute to lightning risk, it may be prudent to consider lightning protection. A lightning protection system provides for a continuous conductor from earth to sky (and vice versa) so that the current is directed in a preferred path, thereby reducing the risk to buildings and human life.

For more information on lightning, reference the MCA Technical Bulletin on Lightning Strikes and Metal Roofing (6/18).

References

- LPI = Lightning Protection Institute
- NWS = National Weather Service
- NFPA = National Fire Protection Association
- UL = UL LLC (formerly Underwriters Laboratories)
- VAISALA = Vaisala Corporation's US National Lightning Detection Network, 2008-2017

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- Technical guidance
- Product certification
- Educational and awareness programs
- Advocating for the interests of our industry
- Recognition of industry-achievement awards
- Monitoring of industry issues, such as codes and standards
- Research to develop improved metal construction products
- Promotional and marketing support for the metal construction industry
- Publications to promote use of metal wall and roof products in construction

For more information, please visit the MCA Web site at www.metalconstruction.org

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