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Lightning Protection Basics

Pitfalls to Avoid in Lightning Protection Design and Installation

A properly installed lightning protection system performs the simple, yet invaluable task of providing a network of low resistance paths for lightning current to follow in preference to other parts of a structure. While the concept behind lightning protection is relatively simple, the requirements for proper installation are specific and often complex. The single best way to ensure proper system design and installation is to specify compliance with the nationally recognized safety standards for lightning protection, maintained by the National Fire Protection Association (NFPA 780) and Underwriters Laboratories (UL96A). Strict compliance with the requirements of these standards is essential to proper system performance. As is true with any safety system, ensuring correct installation the first time is a must, since waiting for nature to send down a bolt of lightning to test the system's quality can have catastrophic results.

Essential System Components

A lightning protection system that complies with national standards must include all of the following elements:

a) a network of roof-top air terminals
b) a network of ground terminations
c) a network of conductors interconnecting the air terminals and grounds
d) interconnections with metallic bodies
e) surge suppression devices on all incoming power and communication lines

The first three elements serve to intercept, conduct and dissipate the main lightning discharge. The fourth element addresses the secondary effects of a lightning strike by limiting the dangers of the harmful current jumping or sideflashing within a structure. The last element protects power lines and connected equipment from damaging currents traveling on utility lines. Each of these elements is essential to proper system performance. Failure to make proper provisions for any of these five elements can result in inadequate protection.

Discussed below are some specific aspects of lightning protection system design to consider to help ensure standards complaince. Paying close attention to these potential trouble spots can help increase the quality and performance of lightning protection systems.

On the Roof

Air Terminal Placement – The parts of a structure most likely to be struck by lightning are those that project above surrounding parts. Such projections include chimneys, spires, railings, gables, dormers, ridges, parapets and rooftop equipment. Ridge ends as well as the edges and corners of flat or gently sloped roofs are similarly considered most likely to be struck. These factors in addition to roof pitch and overall roof area influence air terminal placement. National standards take these structural factors into account and have established guidelines for air terminal placement. The guidelines call for terminals to be placed at regular intervals not to exceed twenty feet along ridges and perimeter roof edges. They also mandate that air terminals be placed no more than two feet from ridge ends, roof edges and outside corners of flat roofs. Failing to keep terminals within this twenty four inch maximum requirement is a fairly common violation that leaves the most exposed portions of the structure vulnerable to a lightning strike bypassing the air terminal.

Standards also mandate that flat or gently sloping roofs that exceed fifty feet in length or width shall have additional air terminals installed at 50 foot intervals on mid-roof areas. Conductors connecting these midroof terminals must be connected with perimeter roof conductors or down conductors at intervals not exceeding 150 feet in length. Designers or installers unfamiliar with the requirements of the standards are likely to omit or improperly place these mid-roof terminals.

Other rooftop features must also be taken into account when designing a lightning protection system. National standards mandate that metallic rooftop equipment, such as ventilators, skylight frames and railings be incorporated into the lightning protection system. Just how these objects need to be connected to the system depends on the constuction and location of the equipment. For example, standards permit that exposed metal objects such as ventilators constructed of continuous metal with a thickness that exceeds 3/16 of an inch need only be interconnected to the lightning protection system through a bonding connection. Much rooftop equipment however, is constructed of metal that fails to meet this minimum thickness requirement and therefore must, not only be connected to the lightning protection system but also be equipped with conductors and air terminals for adequate protection. Failure to take the thicknesss of the metal skin of rooftop equipment into account can lead either to over design or conversely under protection.

These basic rooftop design provisions may sound simple enough but can actually become quite complex to interpret when dealing with complex roof layouts and/or composition. Strict compliance with air terminal placement and spacing requirements is critical to proper system performance. Familiarity with lightning protection standards will eliminate incorrect air terminal placement as well as over or under specification with regard to interconnecting rooftop equipment.

On the Ground

Just as important as a properly installed roof circuit is proper ground circuit installation. Lightning protection ground terminations are typically made either with individual ground rods in multiple locations or with a buried ground ring that encircles the structure. NFPA 780 mandates that each lightning protection down conductor shall terminate at a ground terminal dedicated to the lightning protection systems. The standard also contains “common ground” provisions, mandating that all grounding media in and on a structure be interconnected. This provides for common ground potential between objects in a structure. All lightning protection, electrical, telephone and antenna grounds must be interconnected. These grounds must also be interconnected with underground metallic piping systems including water lines, well casings, gas piping, conduits, etc. All of these grounding system interconnections are to be made with full size lightning conductor. Failure to make all of the required ground system interconnections is a common trouble spot.

Conductor Coursing -

Lightning protection systems require heavy cables to interconnect the roof-top terminals, creating the roof circuit, and to join the roof circuit with the grounding system. Guidelines for proper conductor coursing include:

- maintaining two paths to ground from each air terminal
- maintaining a path toward ground that is either horizontal or downward
- avoiding up and down bends in conductor referred to as “U” and “V” pockets
- avoiding tight or sharp bends in conductor, 8”radius turns at a minimum.

The cables that connect the roof circuit to the ground circuit are referred to as down conductors. All structures, no matter how small, require at least two down conductors. Structures exceeding 250 foot in perimeter will need additional down conductors for every 100 foot of perimeter, spaced at intervals not exceeding 100 feet on average. These cables should be as widely separated as practical. Determining the exact location for down conductor cables can depend on the following factors: 1) location of air terminals, 2) providing a direct path 3) earth conditions, 4) security against displacement, 5) location of large metallic bodies and 6) location of underground metallic piping systems. Advance planning for lightning protection installation can include provisions for raceways to simplify down conductor coursing.

National standards also permit the use of structural steel framework itself as the main down conductors for the lightning protection system, provided the framework is electrically continuous. Using the steel has several advantages including lower material costs, less maintenance over time and in many cases an increased level of system performance, given the massive conductive capacity of the structural steel and its inherent bonding to other building components. Specific provisions for properly connecting the roof circuit and grounding system to the structural steel are contained in the national standards and should be adhered to closely. Designing a system that utilizies the structural steel should be done during the planning phase of a project, as it is rarely feasible to install this type of system on an existing structure.

Bonding

According to NFPA 780, metal bodies within or on a structure that contribute to lightning hazards because they are grounded or help provide a path for lightning currents need to be bonded to the lightning protection system. Bonding to these metal objects, which are often referred to as metal bodies of inductance, is another essential and often tricky element of proper lightning protection. When determining whether or not a metal body within a structure needs to be tied in to the lightning protection system there are several factors to consider. NFPA 780 contains formulas for calculating the need for bonding based on a object's size and proximity to the lightning protection system. Bonding distance requirements depend of a technical evaluation of the location and number of down conductors and the existence of other system interconnections to grounded objects. The requirements for bonding are derived from the concept of potential equalization which is not everyday subject matter for many. A close reading of the provisions for bonding and an accompanying appendix section of 780 can help provide a basic understanding of the concepts. A lightning protection system for even a relatively simple structure will typically require some bonding connections in order for the system to comply with safety standards. Some common bonds include interconnections with downspouts, railings, water pipes, door tracks, etc. Failure to fully understand and implement bonding requirements can lead to under protection or conversely, an attempt to connect the lightning protection system to every metal object in a building without regard for its relative potential. This linking of every window, door and switch plate is not necessary and needlessly drives up the cost of the system.

Surge Suppression

Standards require the installation of lightning arrestors on all incoming lines. This includes electricity, cable television, telephone, antenna feed, satelite dish lines, etc. Arrestors provide protection from overvoltage travelling on these lines as a result of a nearby lightning strike. Lightning arrestors are an essential first line of defense to protection electrical systems and connected equipment. In many cases to fully protect sensitive electronic systems and components, along with the required arrestors, transient voltage surge suppression (TVSS) devices need to be installed at subpanels and at the point of use. The requirements in national standards are limited to the installation of the lightning arrestors. TVSS is outside of the scope of the standards and should be included in specifications as an additional provision.

Using the Right Stuff

Those inexperienced with lightning protection often assume that electrical system fittings and lightning protection system components are interchangable. Materials requirements established by UL and NFPA take into account the extremely large and short duration currents that a lightning protection system is expected to carry. Electrical system components are typically not adequately sized to handle such large currents. Undersized components can contribute significantly to system failure. Examples of the size requirements established by national standards include a minumum of eight square inches of contact for primary bonding connections and at least 1 ½" of contact along the conductor axis when making a conductor splice. Standards also mandate that ground rods are joined to conductor with a minimum of 1 ½" of contact and at least two bolts, making lightning rod ground clamps significantly larger than the clamps used for electrical grounding. Lightning protection components should be listed and labeled for compliance with UL Standard 96 – Lightning Protection System Components. These products are not typically available through electrical supply houses but are rather the products of manufacturing firms that specialize in lightning protection. These manufacturers should be listed with Underwriters Laboratories as lightning protection equipment manfacturers. UL's lightning protection program requires manufacturers to submit product samples for initial compliance verification along with submitting to quarterly on-site inspections by UL representatives to verify continued product compliance.

UL Master Label Program

While most people are familiar with Underwriters Laboratories programs to certify whether electrical cords and appliances meet safety requirements, many are not aware that Underwriters Laboratories offers a Master Label Program especially for Lightning Protection Systems. This third-party quality check helps ensure that the lightning protection materials, design and installation are in compliance with national safety standards. The program includes the factory

inspection of lightning protection components described above as well as an inspection program for lightning protection contractors. Only contractors that are listed with Underwriters Laboratories for lightning protection can obtain UL's Master Label inspection for a project. In the event of system non-compliance Underwriters Laboratories issued notices of variation to the lightning protection installer and withholds the project's Master Label until the system is in compliance. Installers whose systems repeatedly receive notices of variation are put on probation by UL and must have each and every installation they perform inspected until their record of compliance increases. Requiring that lightning protection installers provide a UL Master Label is a good way to ensure that a system meets national standards.

Buyer Beware

There are several products currently marketed in the United States as "innovative" lightning protection systems, that fail to meet the requirements of NFPA and UL standards. These non-standard lightning protection systems, which are marketed under various brand names, are similar to one another, in that they point to some pseudo-scientific theory to prop up fairly outlandish claims of either attracting or deflecting lightning. These products lack independent scientific validation yet occassionally find their way into job specifications and have been known to cause confusion and headaches for architects, engineers, project managers and building owners, who have unwittingly purchased the systems believing that they meet nationally standards. There is currently only one method of lightning protection that complies with national standards and it is devoid of outlandish claims. The method of protection prescribed by NFPA and UL is also adhered to by standards setting bodies around the world and is strongly supported by organizations with extensive lightning protection experience inlcuding the FAA, NASA, the United States Departments of Defense and Energy.

Who Does the Work?

To help make certain that lightning protection systems are designed and installed in compliance with national safety standards, keep in mind that lightning protection systems are typically installed by experienced contractors that specialize in lightning protection. Lightning protection specificiers often require that contractors performing lightning protection work are participants in UL's Master Label lightning protection program. Lightning protection is regarded as a specialty discipline, that is often not within the scope of expertise held by electrical contractors, general contractors or roofers. Electrical contractors typically recognize their lack of expertise in lightning protection system design and subcontract lightning protection work to a lightning protection specialist. Experienced lightning protection installers are experts on the provisions of the lightning protection standards and can design a system that is aesthetically pleasing without compromising safety standards for installation.

Following Up

Once an effective system is in place, it make sense to take measures to ensure that it stays in compliance. NFPA 780 recommends establishing periodic maintenance programs for all lightning protection systems. A good maintenance program need not be complicated or expensive and can be easily incorporated into other building maintenance programs. Some of the events that can effect the integrity of the lightning protection system include, structural modifications, reroofing, maintenance that involves digging near the foundation, or the addition of antennae, satellite dishes or transmitters on the roof. Possibly the single most common interference with lightning protection system integrity however, stems from repairs and changes made to roof-top fixtures such as HVAC equipment and roof hatches. Very often when changes are made to these fixtures the lightning protection is inadvertently disconnected. Since any of these events can compromise the efficiency of a lightning protection system it is worth making provisions for verifying system in compliance on a regular basis.

by Jennifer A. Morgan