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# STRUCTURAL LIGHTNING PROTECTION

*"May not the knowledge of this power of points be of use to mankind, in preserving houses, churches, ships, etc., from the stroke of lightning, by directing us to fix, on the highest parts of those edifices, upright rods of iron made sharp as a needle...Would not these pointed rods probably draw the electrical fire silently out of a cloud before it came nigh enough to strike, and thereby secure us from that most sudden and terrible mischief!" Ben Franklin.*

There are three common approaches to structural lightning protection, loosely grouped as follows :

- Lightning interception systems - the common Franklin lightning rod technology
- Lightning attraction systems – Early Streamer Emission (ESE) or Electronically Activated Streamer Emission (EASE) technology
- Lightning prevention systems – typically called Charge Transfer Systems (CTS) and/or Dissipation Array Systems (DAS)

The first two types of systems protect structures by providing zones of protection over that structure. The zone of protection is defined as the space adjacent to a lightning protection system that is substantially immune to direct lightning flashes. Think of it as a volume of space around a lightning rod wherein lightning will attach to that lightning rod in preference to anything else around it. Conventional lightning protection consists of a network of lightning rods interconnected by conductors leading to a grounding system. As long as the entire protected structure is located within a lightning rod zone of protection, the claim is that lightning will always attach to a lightning rod and be harmlessly conveyed around the protected structure to ground, thereby sparing damage to the protected structure.

It is helpful to remember that the primary purpose of a conventional lightning rod system is to keep the protected structure from burning down. That is why lightning protection is covered under the National Fire Protection Association standard, NFPA 780. This technology was introduced by Ben Franklin, and goes back almost 250 years, essentially unchanged since then.

The third type of system claims to protect a structure by reducing the difference in potential between the cloud and ground sufficiently to prevent a strike or through creating a space charge above the structure, creating a shield through which lightning cannot travel. This system is based on patents going back to the 1830's, including one issued in 1918 to Nikola Tesla. Many of these patents addressed lightning protection for petroleum storage tanks. However, the systems described in these early patents never achieved general acceptance. Lightning prevention systems described in more recent patents have not enjoyed general acceptance, and are the subject of much controversy.

Let's look at these systems in more detail.

## LIGHTNING INTERCEPTION SYSTEM

The first and oldest type of system is the Franklin lightning rod system as described in National Fire Protection Association NFPA 780. NFPA 780 is the United States "Standard for the Installation of Lightning Protection Systems". Underwriters Laboratories (UL) converts NFPA 780 into Standards for Safety materials and installation guidelines. UL 96 covers Lightning Protection Components and UL 96A covers Installation Requirements.

UL is the Nationally Recognized Testing Laboratory (NRTL – pronounced to rhyme with "turtle") in the lightning protection industry. Organizations such as Lightning Protection Institute (LPI) and United Lightning Protection Installers (ULPI) are not. They are simply membership organizations for manufacturers and installers. They have no standing in the industry.

This type of system basically just "gets in the way" of any strike to a protected structure and conveys the lightning energy to ground. It consists of a system of lightning rods arranged around the perimeter of the structure, particularly on outside corners, with additional lightning rods in the center of the structure and on elevated features, such as stairway or elevator penthouses. Lightning rods are installed on the likely lightning strike locations on the structure.

The ancient Chinese recognized that lightning was most likely to attach to corners and edges of a structure. If you look at an old Chinese building such as those found in the Forbidden City, you will notice a parade of small, fearsome looking figurines arranged along the edges. The purpose of these figurines was to frighten away lightning. They unintentionally comprised the lightning strike interception component of the first lightning protection systems.

Layout requirements for individual lightning rods call for the zone of protection of each one to overlap the zone of protection of an adjacent rod. If the entire structure is contained within the zone of protection of one or more lightning rods, the theory is that lightning should always attach to a rod in preference to the protected structure. Once it is intercepted by a lightning rod, it is conveyed to ground over the conductor system.

**LIGHTNING ATTRACTION SYSTEM**

These systems work the same way as a conventional Franklin rod system, attracting lightning to a preferred point(s), then conveying it to ground. They employ air terminal(s) that are claimed to have a larger lightning attraction or collection area than a conventional lightning rod, thereby providing a larger zone of protection. As such, fewer air terminals are required to protect any given structure. The air terminals used in these systems employ either geometry (ESE – early streamer emitting) or electronics (EASE – electronically activated streamer emitting) to trigger the formation of a streamer before natural streamers begin to form. As such the ESE streamers have a head start ($\Delta T$) over natural streamers. This time advantage is claimed to make them appear longer ($\Delta L$), thus reaching the stepped leaders first and triggering the strike to themselves.

There is no US recognized standard covering this type of system, although they are commonly used by major US theme park operators to provide protection for crowds.

**LIGHTNING PREVENTION SYSTEM**

The third type of system is the Dissipation Array System (DAS) or Charge Transfer System (CTS). This system claims to reduce the electrostatic potential between the protected structure and passing clouds to a level that a direct lightning strike is prevented, or by creating a space charge (ion shield) above the protected structure isolating the site from the charged clouds. The patent describing this type of system claims to collect ground charge with a "ground charge collector" surrounding the protected structure or site. It further describes a hemispherical or linear array of dissipation elements (hence Dissipation Array System) located above the protected structure to transfer the collected ground charge to the atmosphere above the protected structure (hence Charge Transfer System). Service wires convey the ground charge from the ground charge collector to the dissipation array.

This system does not meet the requirements of NFPA 780, UL 96A, or any other recognized standard. It uses undersized conductors, undersized strike termination devices and other undersized system components, none of which are listed by UL or any other NRTL for lightning protection purposes.

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## A FOURTH TYPE OF SYSTEM

There is also a fourth type of system, the Lightning Master streamer-delaying system, also called a streamer retarding air terminal (SRAT) system. This system builds on the concepts of the Franklin rod system approach but uses enhanced air terminals (lightning rods) to delay the formation of lightning-completing streamers.

Each air terminal is equipped with a plurality of small radius dissipation electrodes extending from its tip. These electrodes greatly enhance dissipation of ground charge to the atmosphere. Lightning attachment is determined by streamer formation. Whichever object emits the best streamer, wins. These small radius points break down into corona under a much lower potential (voltage) than a rounded or even pointed conventional lightning rod, dissipating the ground charge to atmosphere.

In its primary mode, the SRAT dissipates the ground charge that would otherwise form a lightning-completing streamer, reducing the likelihood of direct lightning attachment.

If the ground charge rises too quickly or too high, the dissipation ability of the air terminal may be exceeded. In that event, the air terminal reverts to its secondary mode of a conventional lightning rod. Since the SRAT is located at the top of the structure as required by both NFPA 780 and UL 96A, and it is already saturated with streamer constituting ground charge, the SRAT then emits a streamer, reliably collecting any strike and conveying it to ground over the lightning protection system.

The effectiveness and reliability of this approach has been documented by numerous users over the past 30+ years this system has been available.

### MEETING INDUSTRY STANDARDS

Lightning Master SRAT's are designed and intended to be used as part of a NFPA 780 or UL 96A system. This system employs all of the components of a NFPA 780 system, meets the requirements of both NFPA 780 and UL 96, and uses all UL Listed components. As such, a completed installation is eligible for a UL Master Label, the gold standard in lightning protection.

Underwriters Laboratories, the lightning protection industry NRTL, has confirmed that Lightning Master streamer delaying air terminals meet the requirements of NFPA 780, are UL Listed to meet the requirements of UL 96, and provide a zone of protection exactly the same as any other lightning rod.

### EXPLANATORY MODELS AND EXAMPLES

To explain this phenomenon, we sometimes use one or more of the following examples or models. Sometimes it helps to envision taking the protected structure, turning it upside down and dipping it in syrup. When the inverted structure is lifted from the syrup, the syrup tends to drip off the outside edges, corners, and any protrusions. These points are analogous to the charge accumulation points of that structure, and can help make it clear why those points are most likely to be struck by lightning. It also explains why NFPA 780 and UL 96A locate lightning rods at those locations. It follows that the SRAT's, being lightning rods also be installed at those locations, to dissipate charge off, and delay streamer formation from, the locations most likely to be struck by lightning.

When talking with engineers, it is sometimes helpful to use a variation of Coulomb's law showing that the smaller the radius of a point, the greater the electric field intensity surrounding it. This explains the greater dissipation current from a SRAT than from a conventional lightning rod.

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At trade shows, we sometimes use a Van de Graaff generator to show the difference in dissipation between objects of various shapes. Where a car key or conventional lightning rod may arc 1/2" to 1" or so to a 200,000 volt Van de Graaff, a Lightning Master SRAT may be touched to the generator ball without arcing. We also use the Van de Graaff to show the ability of an electrical field to induce current in a piece of metal. That piece of metal then arcs to any other piece of metal brought into proximity to it demonstrating a common cause of ignition, particularly at oil production facilities.

## COMMON MISCONCEPTIONS

The SRAT does not protect only itself, allowing nearby strikes to the protected structure. In our experience, this is actually more of a problem with conventional lightning rods than with Lightning Master streamer-retarding air terminals. Two cases in point, Lightning Master's original exposure to structural lightning protection for buildings was at the Veterans Administration Hospital in Bay Pines, Florida. The building had suffered a direct lightning strike to the roof between lightning rods. The strike punctured the roof, melting the roofing material. Building maintenance had heard about Lightning Master, and asked us to see if we could develop a solution to their problem. At that time, Lightning Master provided lightning protection mostly for broadcast and communications towers. In response, we developed an air terminal employing streamer-delaying technology that slipped over and crimped on to a conventional lightning rod. In order to obtain a UL Listing, we later modified the product so it no longer slipped on to, but replaced a conventional lightning rod.

Several years later, a conventional lightning rod system was installed on a data center in Lake Mary, Florida. This system was designed by a well-known and influential engineering company specializing in the design of conventional lightning rod systems. Because the data center was considered critical, the system was designed and installed using a system with decreased spacing between lightning rods to enhance its level of protection. Some time after the installation was completed, the structure suffered a direct lightning strike to its roof near, but not to, a conventional lightning rod. After an investigation, no one could explain why it occurred or how to keep it from happening again. The installer of the original system suggested replacing the conventional lightning rods with Lightning Master streamer-delaying air terminals. The customer did so, and there have been no incidents since.

We have been asked how it is possible for a SRAT system to dissipate the millions of volts and thousands of amps of a lightning strike. It is not necessary to do so. Actually, only a small percentage of that energy need be dissipated to lower the streamer emitting threshold of the protected structure.

Neither is it necessary to discharge the storm cloud. A SRAT system has no effect on the storm cloud. It only affects one small area of the surface of the earth.

## ADVANTAGES FOR INDUSTRIAL FACILITIES

According to both NFPA 780 and UL 96A, certain conductive metallic components of a structure may be substituted for LPS components. An industrial facility normally consists of metal process vessels supported by steel frames. The I-beams and frames that comprise the top of the structures are greater than 3/16" thick. Therefore, they may be substituted for lightning rods. The horizontal and vertical framing is also greater than 3/16" (or arguably 0.064") thick, so it may be substituted for the main and down conductor system. The frames are grounded to the plant grounding system at their bases, meeting the requirements for LPS grounding. Therefore, these structures are considered self-protecting under both NFPA 780 and UL 96A. According to those standards, no lightning protection is required and there is no point in installing a lightning rod system.

However, based on experience with lightning damage, these plants are obviously not self-protecting. Fire is not the issue. A lightning strike is highly unlikely to burn down a steel structure. These plants run on microprocessor-based communications and control systems, and suffer damage, interruptions and outages during electrical storms. In addition to equipment damage, other problems occur ranging from momentary data interruptions to plant emergency shut down (ESD). These problems are generally the result of secondary or electromagnetic pulse (EMP) effects of direct or nearby lightning strikes. The solution may be to install SRAT's atop the plant. Using UL Listed stainless steel bases, the air terminals simply attach to the I-beams or frames, and use the plant structure as the conductor and grounding system. The effect of the SRAT system is two-fold. First, they act as simple static wicks, similar to those on an airplane, to reduce static charge on the structures. Second, by dissipating the ground charge, they act to delay the formation of streamers from the protected structure, thereby lowering the likelihood of a direct lightning strike. No strike, no secondary or EMP effects, so less damage and down time.