Structural Lightning Protection

The third step in securing effective lightning protection is generally referred to as structural lightning protection. This term describes what is most readily recognized as the traditional lightning rod (air terminal) system, with its associated bonding and grounding systems.

It is important to note that the purpose of a lightning rod system is to keep the protected structure from burning down. That is why lightning rod systems are covered under National Fire Protection Association standards. That was fine back in the days of barns filled with hay and horses. Lightning would strike the lightning rod on the barn and be conveyed to ground. The barn would not burn down, and everyone would be happy, particularly the horses.

However, we have now taken the hay and horses out of the barn and installed computers. Lightning now strikes the structure, and the energy is conveyed to ground. The barn does not burn down, but now, none of the computers in the barn work. So everyone is not happy.

Since we cannot, with currently available technology, influence the formation of cloud charge or of stepped-leaders, if we want to influence the attachment of cloud-to-ground lightning, we must influence the formation of ground charge and of streamers. Hence, the introduction of streamer-influencing technology.

A good illustration of the general principle is found in the debate between the relative merits of a sharp lightning rod versus a blunt lightning rod. (Please refer to the lightning propagation section of this narrative for a review of lightning strike mechanism.) Assume we have a sharp rod and a blunt rod side-by-side with the axis between them perpendicular to, and directly facing, an oncoming electrical storm. As the ground charge reaches the two rods, the potential rises on both. The sharp rod will tend to break down into corona under a relatively low potential, leaking off some of the ground potential to the atmosphere. The blunt rod will hold it's charge, with ions accumulating on the blunt end.

As the ground potential builds, the corona builds around the sharp rod, while the blunt rod still tends to retain its charge. When the ground potential becomes very high, as when stepped leaders are on their way down from the cloud and there is going to be a strike in the immediate vicinity, the corona will build in density and elevation around the pointed rod. When the blunt rod finally breaks down, it breaks down catastrophically, and the accumulated charge jumps off of the blunt rod in a streamer extending well upward toward the stepped leaders.

Since the object on the ground which throws off the best streamer is the one most likely to be struck, the blunt rod is more likely to trigger a strike than is a sharp rod. Streamer-influencing technology uses this principle to influence strike termination likelihood. If you want to direct lightning to a preferred attachment point, do so with an early streamer emitting (ESE) air terminal. If you want to discourage lightning from attaching to a protected structure, use streamer-delaying air terminals. If you merely want to intercept a close proximity lightning strike, use a conventional lightning rod system. Lightning Master Corporation offers all three technologies, based upon the requirements of our Customers.

LIGHTNING STRIKE COMPLETION MECHANISM

Various mechanisms create a stratified charge in a storm cloud. The charge on the base of the cloud induces an opposite charge on the surface of the earth beneath it. (Remember playing with magnets as a kid? Like charges repel and opposite charges attract.) As the storm cloud builds, it increases the potential difference between the cloud base charge and the ground charge, with the cloud base charge trying to pull the ground charge off the surface of the earth.

As the charged storm cloud travels through the atmosphere, it drags its ground charge along beneath it. When the ground charge reaches a structure, the attraction of the cloud charge pulls it up onto the structure, and concentrates the ground charge on the structure. If, before it moves away, the charge on the cloud base manages to concentrate enough ground charge potential on and around the structure beneath it to overcome the dielectric of the intervening air, an arc, or lightning strike, occurs.

When the dielectric of the air is overcome and lightning is going to strike, the process begins with the formation of stepped leaders branching down from the cloud. These stepped leaders propagate in jumps of about one hundred and fifty feet. The next set of stepped leaders propagate through the first set and jump another hundred and fifty feet, and so on towards the

ground. These stepped leaders are the tendril-like branches extending down from the cloud which are visible in a photograph of a lightning strike. We see a lightning strike in two dimensions. The field of stepped leaders in three dimensional. It has depth too.

When the stepped leaders are within five hundred feet or so of the ground, the electric field intensity on the ground becomes so strong that objects and structures on the ground begin to break down electrically and respond by shooting off streamers upward toward the stepped leaders. When a streamer connects with a stepped leader, the ionized path becomes the channel for the main lightning discharge. The other streamers and stepped leaders never mature.

For the purposes of this discussion, it is not critical whether the cloud base charge is positive or negative. Indeed, it can vary, and the entire process can occur in the opposite direction.

Change in streamer initiation time, is a concept describing the influence air terminals have on the formation of streamers. ΔT is the change in time, as compared to a conventional lightning rod, of the release of the streamer from a particular air terminal. ΔL is the change in length, or more importantly height, of the streamer, and is derived from ΔT. The earlier a streamer is emitted, the longer it is relatively, and the more of a head start it has over other streamers from the same area. Therefore it has a better chance of reaching the stepped leaders first, and completing the strike to the air terminal. This positive ΔT is the basis of early streamer emitting technology, technology designed to attract lightning to a preferred point. Conversely, an air terminal which retards the formation of streamers, or exhibits a negative ΔT and ΔL, is less likely to complete the strike to itself.

EARLY STREAMER EMITTING TECHNOLOGY

Early streamer emitting air terminals are designed to emit a streamer early in the streamer-formation phase of a lightning strike, thereby becoming the preferred lightning attachment point.

As the ground charge builds immediately before the lightning strike, the ESE air terminal accumulates ground charge. In the instant before the strike, when the stepped leaders are branching down from the cloud, the ESE terminal emits a series of pulses of ground charge, forming a streamer from itself before streamers emit from other structures. Its streamer reaches the stepped leaders before competing streamers, thereby winning the competition.

Ground charge accumulation and streamer triggering may be either by air terminal geometry (shape) alone, or by electronic triggering in an electronically activated streamer emitting (EASE) air terminal. Lightning Master offers electronically activated ESE air terminals. Lightning Master ESE air terminals combine a US manufactured UL Listed air terminal with a triggering device designed by Laboratories de Physique des Gaz at des Plasmas, the French national laboratories.

Please see the "Product Showcase" section of this site for additional information.

STREAMER-DELAYING TECHNOLOGY

Lightning Master brand Streamer Retarding structural lightning protection technology is essentially an outgrowth of, and an improvement upon, conventional lightning protection technology. It employs the basic conventional system with modified air terminals which are designed to reduce the incidence of direct strikes to the protected structure. All of the components used in this type of system are UL Listed, and the system is designed to meet UL 96A and NFPA 780. As such, the completed system is eligible for a UL Master Label or Letter of Findings.

With the advent of microprocessors, it has become necessary to reduce the incidence of lightning strikes to protected facilities.

Lightning Master streamer-delaying technology secures the desired result by reducing the accumulation of static charge, and by retarding the formation of lightning-completing streamers from the protected structure.

This technology is not new. Patents covering the technology go back as far as 1839, with most progress on the subject reflected in patents issued in the late 1920’s and early 1930’s. The patents referenced in Lightning Master’s patent on the PP series products are those on aircraft

static wicks. Static wicks are an option available with an aircraft's avionics (radio) package, and have been in general use for many years.

Next time you board an airplane, look at the trailing edges of the wing and tail, and observe this technology in its aviation application. In its structural lightning protection application, it works as follows.

The operation of a Lightning Master ¨ brand Streamer-Retarding technology is based upon the point- discharge principal. The principal, as illustrated in this formula, holds that the smaller the radius of a dissipating element, the greater the electric field intensity.

$$\mathcal{E} = \frac{Q}{4\pi \in r^2} \qquad D = \frac{Q}{4\pi \in r^2}$$

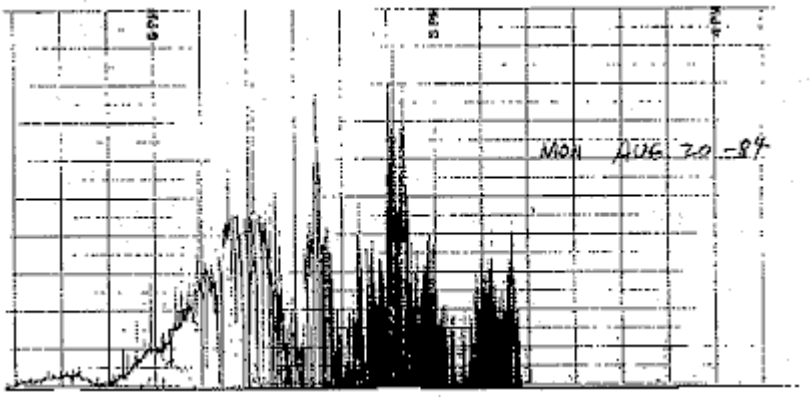
SPHERE

where: $\mathcal{E}$ = electric field intensity
Q = charge (in coulombs)
$\in$ = permittivity of space
r = radius

Point-Discharge Formula

The relationship is not direct, but an inverse square relationship. If one point is half the radius of another, the electric field intensity is not just doubled, but quadrupled. That is why Lightning Master employs the smallest radius dissipating elements feasible. Point radius is the most important factor in product performance.

Since charge accumulates on and streamers tend to form from a structure predictably according to the principles of point discharge, a structure properly blanketed by air terminals designed to delay the formation of streamers is thus protected, since streamers tend not to form from that structure.



This graph shows the current flow through a Lightning Master LS series dissipater installed on the WTOC-TV 425' self-supporting STL tower in Savannah, Georgia. The dissipater was isolated from the tower with insulators, and a twelve gauge copper wire run from the dissipater, through a 500 ohm resistor, to ground at the base of the tower. This graph, generated on August 20, 1984, shows time from 4 PM to 6 PM, right to left along the horizontal axis, and current on a fifty microamp scale on the vertical axis.

All objects have natural dissipation points. On a structure, charge tends to gather at, and streamers form from, the top of the structure (the ultimate point) and from edges and corners. The most effective way to mount a streamer delaying system, in terms of structure, weight, wind loading, cost and aesthetics, is to enhance this natural tendency by supporting the system from the structure itself at these natural charge accumulation points. In other words, the installation of the system should be tailored to the structure, not vice versa. How does a system enhance natural charge accumulation and dissipation? Keep in mind the nature of the static ground charge. Perhaps it is an oversimplification, but one way to envision system design is to imagine taking the structure, inverting it, and dipping it into syrup. When the inverted structure is raised from the syrup, the points from which the syrup drips will be analogous the charge accumulation and streamer formation points. These are the points at which the streamer delaying components

should be mounted.

Lightning Master uses NFPA 780 and UL 96A as its design and installation standard. Lightning Master products are designed for ease of installation. A variety of factory designed and supplied installation systems make it possible to easily tailor the Streamer Retarding system directly to the protected structure. Lightning Master designers will be happy to tailor a system design to your structure.

On a building or other structure normally protected by lightning rods and the associated bonding and grounding system, existing industry accepted lightning rod system design provides an adequate and proven method and arrangement for mounting Lightning Master ® brand Streamer Retarding air terminals. One may enhance a conventional system by installing dissipaters in place of, the conventional air terminals. Lightning Master PP-30 series products are Underwriters Laboratories listed air terminals, additionally offering streamer delaying properties.

Now a user can enjoy both the benefits of a "Master Label" installation to meet building codes and insurance carrier requirements, and the benefits of a true streamer-delaying static dissipater system.

Installing a Streamer Retarding lightning protection system upon one structure does not make another nearby object or structure more likely to be struck by lightning. Since a static dissipation system functions by retarding the formation of streamers from one structure, it has no effect on the formation of streamers from any other structure.

How well do the technologies really work? We sometimes hear comments from the pseudoscientific community that streamer-influencing technology does not work. However, remember what we are trying to do. We are not attempting to stop or redirect all lightning. We are only trying to influence the likelihood of a direct lightning strike to one relatively small geographical area on the surface of the earth. Therefore, we do not have to influence charge accumulation and streamer formation entirely. We only have to influence the behavior of the ground charge a very small percentage to affect streamer formation a fraction of a second from that specific point, so a competing streamer will be, or will not be, the first to complete the strike.

HYBRID SYSTEMS

An understanding of streamer influencing technology opens the door to many possibilities, including hybrid systems. Several years ago, Lightning Master was asked to design a lightning protection system for the new Advanced Launch System (ALS) at Cape Canaveral. There were several design constraints which made the use of a conventional system or a static dissipating system impractical. One of the options we suggested was a perimeter of early streamer emitting air terminals surrounding the complex to lower the overall ground charge making it onto the site by triggering strikes to the perimeter protection. This was to be complimented by a matrix of Lightning Master Streamer Retarding terminals inside the perimeter to retard the lightning

process in the protected site area itself. Working in conjunction, the two systems offered the possibility of a practical and effective solution, without compromising the ALS system design limitations. This approach highlights that one type of system is not necessarily better than another. Each has its applications, and there are applications which are best served by a combination, or hybrid, approach.

Structural lightning protection is the third leg of the three-part tripod of effective transient protection. By influencing the incidence of direct lightning strikes to the protected structure, you can reduce the incidence of stress on the bonding and grounding system and on the transient voltage surge suppression system. By doing so, by employing all three sub-systems in a complementary overall system, you can secure the maximum in personnel safety and optimize the environment in which your equipment operates.

Bonding And Grounding - **Transient Voltage Surge Suppression**