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LIGHTNING PROTECT ION THEORY: MORE FUEL FOR THE DEBATE

A clear understanding of the operational theory of streamer-delaying products might lead the technology's opponents to take another look and to devote some of their energy to figuring out how and why it works.

Six years ago there raged in these pages a debate over the benefits of static dissipation as a lightning protection technology. One side were manufacturers and user that claimed static dissipation technology worked well, and on the other side were several manufacturers and users that claimed the technology could not (in theory) and did not (in practice) work at all. The proponents based their position on what they evaluated as successful experience. The opponents cited negative test results and asserted that satisfied users either had misinterpreted their results or had attributed an actual reduction in lightning damage to dissipation technology when other factors, such as grounding and bonding, were really responsible.

Large companies with sophisticated employees and managers who otherwise were generally acknowledged to the objective in their evaluation and purchasing decisions were considered by the opponents to be somehow less capable when it came to evaluating static dissipation technology. Sophisticated users were convinced the technology worked, yet others presumably objective in motive, were equally convinced the technology could not possibly work.

OPERATIONAL THEORY

Why the discrepancy? One major weakness in the proponents' position that creates confusion and also contributes to the basic misunderstanding was the operational theory presented by many static dissipation device manufacturers. The theory, as expressed in both patents and promotional literature, was that the devices dissipate, or "leak off," ground charge, maintaining the protected structure's electrical potential below the critical flash point of lightning. Moreover, it was claimed that the devices actually discharged any storm cloud overhead.

This cloud-discharge theory first appeared in patents issued in the late 1920s and early 1930s, and it appeared in a patent issued as recently as 1979. Other patents and sales literature repeated the early theories, and much product design has been influenced by an attempt to implement cloud discharge. Until the 1990s, there were no new theoretical advances, and as a result, no new developments in product design since the 1930s.

MANUFACTURERS' CLAIMS

Static dissipation technology opponents focus on certain manufacturers' claims that their products discharge storm clouds. They have gone to great lengths to prove that such discharging is not technically possible. Because it is not possible to discharge a storm cloud, they reason that static dissipation technology cannot work.

This reasoning is beside the point though, because static dissipation technology does not work by discharging a storm cloud charge.

Instead, it works by influencing the formation of lightning-completing streamers from the protected structure.

Various mechanisms within an electrical storm produce stratified charges within the storm cloud, resulting in an electrical charge at the cloud's base. This cloud base charge induces beneath it on the earth's surface a shadow of opposite charge commonly referred to as the ground charge.

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As the charged storm cloud moves, the corresponding ground charge moves with it on the earth's surface. When the ground charge reaches a structure, the cloud charge's attraction pulls the ground charge up onto the structure and concentrates it on and around the structure. If before the cloud moves away, the cloud base charge concentrates enough ground charge potential on and around the structure beneath it to overcome the dielectric (the electrical insulating quality) of the intervening air, an arc, or lightning strike, occurs.

STEPPED LEADERS

When the dielectric of the air is nearly overcome and lightning is about to strike, the stroke begins with what are called "stepped leaders" that branch down from the cloud. These stepped leaders propagate in jumps of about 150 feet. The next sets of stepped leaders propagate through the first set and jump another 150 feet, and so on toward the ground. These stepped leaders are the tendril-like branches extending down form the cloud that are visible in many photographs of lightning.

When the stepped leaders are within 500 feet or so of the ground, the electric field intensity on the ground (the ground charge) becomes so strong that objects and structures on the ground begin to break down electrically and respond by shooting off streamers up toward the stepped leaders. When a streamer connects with a stepped leader, the ionized path they form becomes the channel for the main lightning discharge. The other streamers and stepped leaders never mature.

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

Because current technology cannot influence the formation of cloud charge, or of stepped leaders, influencing cloud-to-ground lightning requires influencing the formation of ground charge an of streamers.

CHARGE AND STREAMER FORMATION

To illustrate the general principle, consider the relative merits of a sharp lightning rod vs. a blunt lightning rod. Imagine a sharp rod and a blunt rod side-by- with the axis between them perpendicular to and directly facing an oncoming electrical storm. As the ground charge reaches the two rods, the electrical potential rises on both. The sharp rod breaks down into corona under a relatively low potential. The blunt rod holds its charge, with ions accumulation on the blunt end.

As the ground potential builds, the corona builds around the sharp rod, while the blunt rod holds its charge. When the ground potential becomes quite high, such as when stepped leaders are on their way down form the cloud, the corona builds 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 the blunt rod in a streamer extending well up toward the stepped leaders.

Because the object on the ground that throws off the best streamer is the one most likely to be struck by lightning, the blunt rod is more likely to trigger a strike than is a sharp rod. Static dissipation technology uses the point discharge principle to produce corona and to reduce arcing or streamer-forming.

AIR TERMINAL STANDARDS

Streamer-influencing technology has matured to the point where the National Fire Protection Association (NFPA) has formed a committee. NFPA 781, to write standards for the application of early streamer-emitting air terminals. The change in streamer-initiation time (ΔT) describes the influence air terminals have on streamer formation. ΔL is the change in length, or more importantly height, of the streamer, and is derived from ΔT. The earlier a terminal emits a streamer, the loner the streamer, and the greater its head start compared to other streamers emitted nearby. Earlier, longer streamers have a better chance of reaching the stepper leaders first and completing the lightning strike to the air terminal. This positive ΔT is the basis of early streamer-emitting technology.

Conversely, an air terminal that retards streamer formation or exhibits a negative ΔT and ΔL is less likely to complete the lightning strike to itself. Because an electrical charge accumulates on- and streamers tend to emit from – a structure according to the principles of point discharge in a predictable manner, a structure properly blanketed by such air terminals is protected because streamers tend not to emit from such a structure.

Once the static dissipation family of products is recognized as a form of streamer-influencing air terminal, it becomes apparent that their successful operation is a function of the air-terminal portion of the system. Subsystems such as grounding and bonding, as long as they are included, become less significant in explaining successful product performance.

PRODUCT ADVANCES

A correct understanding of operational theory has resulted in advances in product design, application and approvals. Indeed, when the theory was correctly understood, some manufacturers won Underwriters Laboratories listings for their products by presenting them as simple air terminals. Their streamer-influencing properties simply defined where they fell in the spectrum of air terminals, a spectrum that ranges from early streamer-emitting to streamer delaying.

Understanding the technology also opened the door to other possibilities, including hybrid systems. Several years ago, the project management at the National Aeronautics and Space Administration's Cape Canaveral, FL. Facility asked for a lightning protection system for its Advanced Launch System (ALS). Several design constraints made the use of a conventional system or a static-dissipation system impractical.

One option was a perimeter of early streamer-emitting air terminals surrounding the complex to lower the overall ground charge on the site. These terminals were to be complemented by a matrix of static-dissipation air terminals inside the site to retard streamers in the protected area. Working conjunction, the two systems would have offered the possibility of a practical and effective solution, without compromising the ALS system design limitations. This approach highlights the idea that one type of system is not necessarily better than another. Each has its applications, and some applications are best served by a combination, or hybrid, approach.

SCIENTIFIC TESTING

Opponents of static dissipation technology sometimes call for scientific testing and proof that the technology works. Proponents of conventional lightning protection technology cannot call too loudly, though, because conventional lightning rod technology has never been subjected to the same level of scientific testing that some of them demand of static dissipation technology.

The limited tests of static dissipation products performed by the industry, by users and by others have concentrated on the charge current-dissipating properties of the product under test. Acknowledging the streamer-influencing nature of the technology would call for measuring the products ability to retard streamer formation. A direct lightning strike to the product under test would indicate the maximum possible discharge current flow, so it does not make sense to claim that “the higher the discharge current, the better the product.”

Recent, incomplete studies show that different types of air terminals display dramatically different behavior in the short interval during which streamers form. It is hoped that continued testing will allow results to be quantified and compared among the various technologies and will lead to developing specific concepts to optimize air terminal design and installation configurations.

A step that could reduce confusion would be to cease referring to the technology as static-dissipation technology and to begin describing it as streamer-delaying. A clearer understanding of the operational theories and a cleaner name for the products might lead the technology’s opponents to take another look and to devote some of their energy to figuring out how and why it works.

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