Evaluation of Early Streamer Emission Air Terminals

SCOTT D. McIVOR, ROY B. CARPENTER, JR., and MARK M. DRABKIN
Lightning Eliminators & Consultants, Inc., Boulder, CO

A perspective on early streamer emission air terminals is offered.

Background

Early Streamer Emitters (ESE) are sophisticated lightning collectors. They were developed to deal with the known inadequacies of the conventional lightning rod, and in particular, such factors as collecting range and angle of approach. Currently, there are about six different versions on the market. Claims made by their manufacturers are similar, with no further proof than those for conventional lightning collectors.

The claims were investigated by the U.S. Standards Committee NFPA 780 and its higher body, the U.S. NFPA Standards Council. The investigation culminated in an independent study funded by the Standards Council. The results were recorded in a final report, "Early Streamer Emission, Air Terminals, Lightning Protection Systems, Literature Review and Technical Analysis," dated January, 1996. Three hundred and three different works were reviewed. Of these, 301 rejected the ESE as no better than a conventional rod. The other two were authored by a manufacturer. Further, the study group pointed out that no ESE or conventional rod has been shown to be 100 % effective. As a result, the U.S. NFPA Standards Council rejected consideration of the ESE for a new standard and does not recommend their use.

The intent of this paper is to familiarize the reader with the different types of early streamer emitters and to evaluate their effectiveness.

ESE Types

An early streamer emitter is an air terminal (lightning rod) that is equipped with a device or formed in such a way that it supposedly creates an upward propagating streamer faster than a standard air terminal. This streamer connects with a downward propagating leader of a lightning stroke.

There are several different types of early streamer emitters on the market today. Each type is claimed to have a different protective radius as stated by its manufacturer. The earliest and most frequently used early streamer emitters are radioactive ESE terminals. The non-radioactive ESE terminals include sparking ESE terminals with special shapes and voltage- pulsing ESE terminals. Each type is designed to replace a number of conventional Franklin Air Terminal Systems with a lesser number of ESE terminals. The customer is led to believe that these devices will protect a greater area with fewer air terminals.

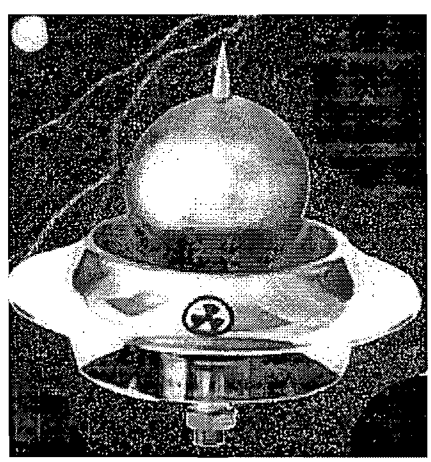


Figure 1. Radioactive ESE.

Radioactive ESE

A radioactive ESE is an air terminal equipped with a radioactive source positioned near the top of the terminal. The radioactive materials employed are weak alpha particle emitters with relatively long lifetimes. These air terminals supposedly ionize the air molecules in the immediate vicinity of the air terminal continuously, that is, with or without the presence of a storm cell.

One radioactive ESE in the U.S. is sold all over the world and marketed by a number of firms. The manufacturer describes the Preventor's function as follows: The radioactive isotope hits an atom and ejects an electron, leaving a positive ion. These positive ions are drawn upward to the cloud, causing a chain reaction which, by collision, increases the quantity of ions ascending from the source (Figure 1).

Criticisms

Several experiments have been conducted in various countries using radioactive sources in air terminals, some by independent scientists and some initiated by the manufacturers of early streamer emitters. In nearly all cases when the experiments were conducted by independent sources, it was found that these ESE were no better than standard Franklin Rods. In 1962, Muller-Hillebrand conducted a study showing that under storm cell conditions, the radioactive ESE and the Franklin Rod emitted equal currents in the presence of an electric field.[1] Tests by Golde, *et al.* arrived at the same conclusion.

Radioactive air terminals are banned in many countries as potentially dangerous to personnel. The English standard, BS CP 326:1965, states that "The protection of structures against lightning which says any method aimed at artificially increasing the range of attraction afforded by a lightning conductor is excluded." The German code specifically states that 'No significant effect is obtained by fitting radioactive material on to a lightning conductor."

The U.S. NFPA has recently rejected a section for early streamer emitters that include radioactive air terminals because of conflicting data and lack of substantial proof.

Laboratory Results

In 1988, Heary Brothers, a manufacturer, presented the results of a high-voltage laboratory test of air termination with and without radioactive sources.[2] These tests showed that the radioactive devices had a height advantage of 10 cm where the discharge leads were approximately 1 meter. They argue that this can be extrapolated to a height advantage substantially greater than 10 cm for real lightning conditions. In 1989, Wu Pu-san conducted a test and was unable to detect any height advantage for radioactive terminals in high-voltage laboratory tests of a radioactive air terminals using discharge lengths of about 5 meters. However, 10 cm or an extrapolation from that is no real advantage, as shown later in this article.

Non-Radioactive Terminals

SPECIAL SHAPES AND SPARKING ESE

Special shapes and sparking ESE are air terminals that are designed to have an increased protective radius due to the specific shape of the terminal or air terminals that discharge sparks at the point of the terminal when the air terminal is under the influence of a high electric field. These sparks are said to cause increased ionization to occur at the tip of the air terminal.

One such air terminal is the Prevectron, said to operate as a capacitor gathering charge as the electric field increases (Figure 2). According to product literature, when the leader is approaching the area, the electric field increases significantly. This causes the device to spark, creating corona and initiating a collective streamer. It is interesting to note that other ESE are designed to discourage the formation of corona (Figure 3). They claim that the presence of corona suppresses the formation of a collective streamer.

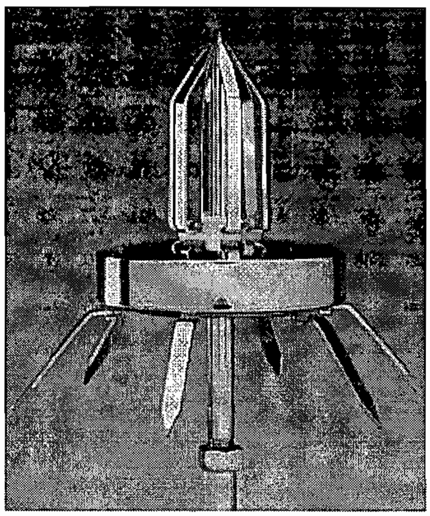


Figure 2. *Sparking ESE.*

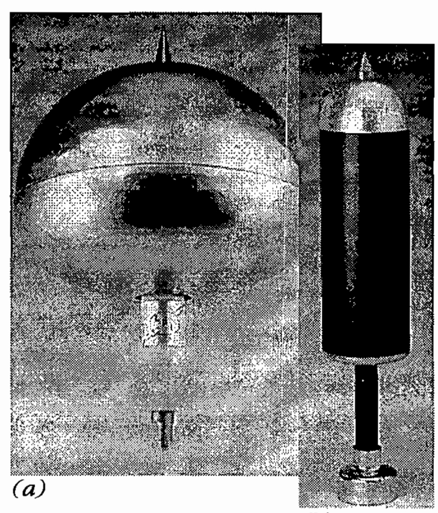
Another air terminal, the Dynasphere is described as "...a floating spheroid with [an] earthed central rod, the floating sphere being grounded via a very high impedance static drain. The floating sphere appears grounded to the static electric fields which are in existence prior to leader approach. In this mode, its geometric shape creates minimal field intensification and *there is little corona formed to distort the near electric field.* (Italics added.) The unit becomes active only in the few milliseconds of downward leader approach. At this time the outer sphere will rise in voltage due to capacitive coupling to the approaching leader and will create a spark discharge between itself and the nearby earthed rod."

However, the developer also states that "Insufficient data has been accumulated to provide positive conclusion...that geometric shape may create advantages over the Franklin Rod in both initiation time and relative current magnitudes."

This device was designed to attract lightning and safely conduct it to ground without damaging the terminal. The manufacturer states that this type of installation is typically 85% effective. That means that 15% of the time lightning will bypass the ESE and damage the object being protected, meaning that 15 out of every 100 strikes bypass this "collector." One customer in Malaysia reported seeing lightning strike a tower with the System 3000 on the opposite corner only 1 meter away. Figure 4 shows Dynaspheres that did collect the strike; however, note the severe damage they received from that lightning bolt.

Voltage Pulsing ESE

Voltage Pulsing ESE are air terminals that contain an auxiliary-powered apparatus which produces voltage pulses. The voltage pulses produce positive ions around the point of the terminal. The frequency of the pulses is de-



(a) *(b)*

Figure 3.
(a) Special-shaped Sparking ESE.
(b) Interceptor, Sparking ESE.

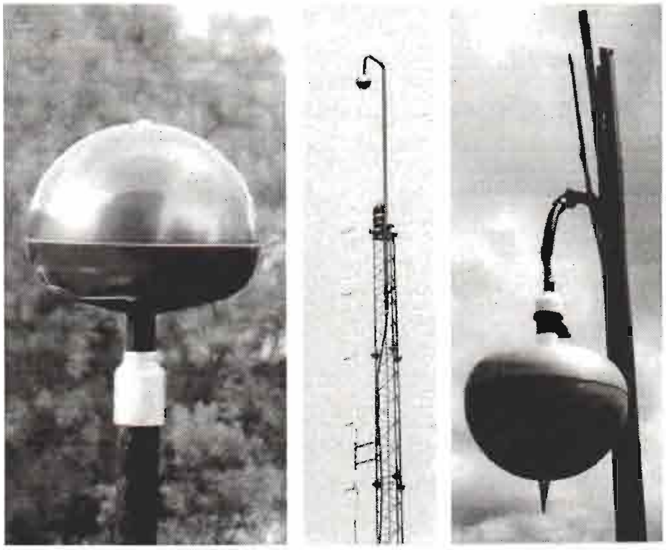


Figure 4. *Dynasphere Damaged Due to Lightning.*

signed to limit the formation of space charge (corona) around the air terminal. These ESE contain a tapered rod fixed to a shaft containing the high voltage transformer and an electronic module which detects the increase in field strength (Figures 5 – 7). These units are typically powered by batteries and photo cells. The corona produced is supposed to provide a channel of positive ions before a streamer is emitted. This is a copy of a U.S. patent filed by Roy Carpenter, Jr. but never used because of complexity.

ESE technologies are based on limited laboratory testing, studies by the Les Renardieres Group in 1977, and research from G. Berger.[3] In 1992, G. Berger conducted a test to compare the Helita Pulsar with a standard Franklin Air Terminal. The results from his laboratory test indicate that the Voltage Pulsing Air Terminal will produce a streamer 10 to 50 μs faster than a Franklin Air Terminal.

Analysis of Non-Radioactive Early Streamer Emitters

Several independent organizations have researched these types of ESE and have declared that they do not work. Papers by D. Mackerras and M. Darveniza discuss how it is "...physically unreasonable to expect an upward streamer to continue its progress towards the downward leader tip if it is unable to obtain enough energy from the electric field to do so. The condition for obtaining this energy is directly related to the average field between the downward leader tip and the point launching the upward streamer... All streamers (regardless of their source), once they have progressed into air beyond their launch point, are subject to the same laws governing their progress. It follows that the striking distance is a direct consequence of these laws and the properties of the air and is independent of the nature of the air terminal launching the streamer."

Additionally, for sparking and special shaped devices they state that "During the close approach of the downward leader, all prominent conducting earthed objects on the top of a building will be in a high ambient electric field environment and there will be local electric field enhancement (around all the objects within the leader's influence). Consequently, these objects will be emitting ions in corona discharges sufficient to prevent the local field adjacent to the objects from rising above the dielectric breakdown field for air, about 3 MV/m."

CIGRE (a French working group) states that they cannot support the use of any early streamer emitters based on the fact that: "The theoretical basis for the Early Streamer Emission technology appears technically incorrect for the following reasons:

- Even if a streamer from a non-conventional terminal can be initiated at an earlier time than a streamer from a conventional air terminal, once initiated it will require the same field strength to propagate as a leader from a conventional terminal.
- The assumed constant velocity of 1,000,000 m/s for the upward leader propagation is in contradiction with the available data for both natural lightning and long laboratory sparks, which show an average velocity of one order of magnitude lower."

Theoretical Basis for the ESE

In general, ESE manufacturers claim that their device will create the most competitive collective streamer for a given protective radius because they cause a streamer to initiate faster than the surrounding objects. Some suppliers claim

Figure 5. *Pulsar ESE.*

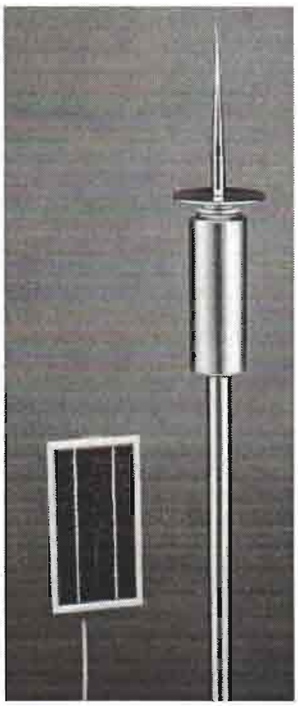


Figure 6. *Corona II ESE.*

Figure 7. *Satelit ESE.*

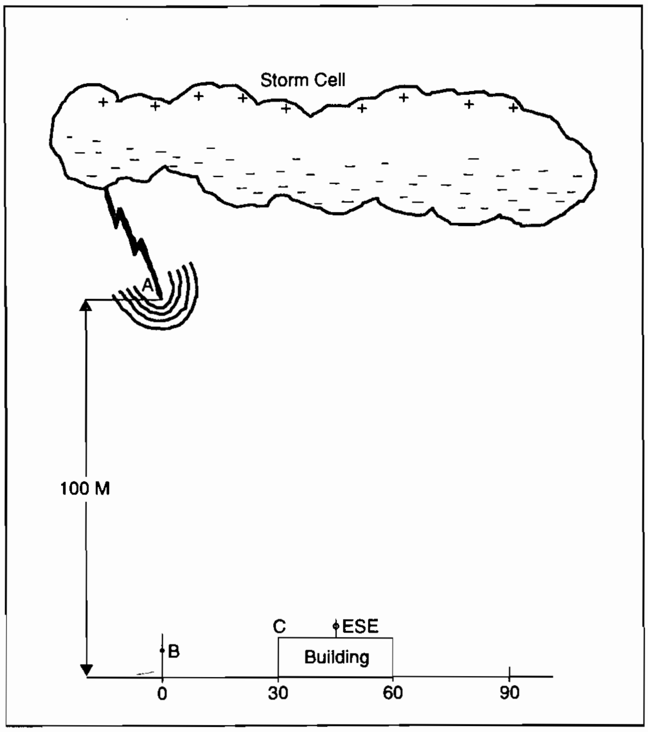


Figure 8. *Downward Moving Leader Approaches Earth.*

that this occurs because the ESE ionizes the air around the tip of the ESE just before the electric field is strong enough to initiate a streamer. This increase in ionized air will theoretically create a streamer before the other objects. However, when reviewing a curve with electric field strength versus the horizontal distance from the leader, it is clear that the electric field increases exponentially as the distance to the leader decreases. Further, other ESE suppliers claim that they suppress the formation of corona for the same reason.

Figure 8 illustrates a typical situation as a downward moving leader approaches earth. Using a position of 100 meters above flat earth, the electric field at any location above earth can be calculated. The resulting electric field at any location along a radial from that point directly below the step leader, taken as "0" can also be calculated (Figure 9). That electric field is calculated from data taken from the book, "The Lightning Discharge," by Dr. Martin Uman.[4] The actual value used for the voltage at the leader tip is not significant: it is the *relative value* of that field at any given location that is significant.

Using the foregoing data and the situation illustrated by Figure 8, the field strength at various locations and on the different devices at these locations can be estimated. These are approximated in Table I.

If the ESE were 30 meters away from the building, the difference would be in excess of $4.3\text{x}10^6$ v/m. Obviously, even with a poor collector, a part of the building will generate a collective streamer at Location C before the ESE. These factors, in and of themselves, prove that the ESE claims are unfounded and erroneous, regardless of the type considered. Even those with a voltage source would have to apply very high voltages (in the millions of volts) to compete with even a poor collector only 15 meters away.

Laboratory tests prove that the radioactive devices ionize air at 2 centimeters. They have not proven that the devices have the effectiveness that is claimed by the manufacturers. The non-voltage ESEs have been tested in laboratories where they were the only object, or one of a select few, creating streamers and space charge. In a natural environment, there are numerous objects creating space charge and competitive streamers. That object which is the most efficient streamer generator, and which has the highest voltage on it, will be the winning collector.

POSITION	FIELD STRENGTH
At the leader tip "A"	10^8 v/m
Just under the leader "B" on earth	Over 9 x 10^6 v/m
At the conventional rod "C" on the building	7.9 x 10^6 v/m
At the ESE, only 15 meters from the rod "C"	About 5.6 x 10^6 v/m, a difference of at least 2.3 x 10^6 v/m

Table 1. *Field Strength at Specified Locations in Figure 8.*

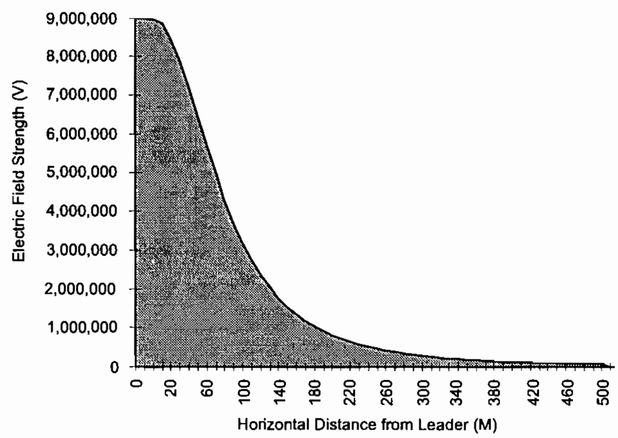


Figure 9. *Electric Field Strength with Q = 5C and Height of 100 m.*

Conclusion

There is limited test data on ESE performance, and no available data substantiates the suppliers' claims; conversely, the data collected by independent researchers prove otherwise. That is, the ESE performs no better than the conventional Franklin Rod.

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SCOTT D. McIVOR *has an engineering degree from Embry-Riddle Aeronautical University. Scott is experienced in the areas of lightning protection, grounding and surge suppression. He is currently an engineering sales manager with LEC. (303)447-2828.*

MARK M. DRABKIN *has nearly 40 years experience in electrical and electronic systems engineering experience. About 30 of these years have been devoted to work in the field of lightning and transient protection of power systems, and installations, data and telecommunication networks. Recently he served as a member of the team working on power interfaces for the Russian segment of the International Space Station. (303) 447-2828.*

ROY B. CARPENTER, JR. *has more than 50 years of experience in electrical and electronic systems engineering. The last 24 have been devoted to the study of lightning protection requirements and the development of protection products that satisfy the needs of contemporary lightning related problems. Mr. Carpenter has worked for the USAF, NATO, and NASA, and is the founder of Lightning Eliminators & Consultants, Inc. (303) 447-2828.*