# THE APPLICABILITY OF LIGHTNING ELIMINATION DEVICES

# TO SUBSTATIONS AND POWER LINES

Abdul M. Mousa, Fellow, IEEE
British Columbia Hydro
Burnaby, British Columbia, Canada V3N 4X8

Abstract - Unlike the Franklin lightning rod which achieves protection by providing a sacrificial point for the termination of lightning flashes, special devices employing the point-discharge phenomenon have been marketed since the early 1970's with the objective of eliminating lightning strikes. The application of those devices has been mostly limited to communication towers and other tall structures, with the manufacturers claiming success and the scientific community expressing strong scepticism. In recent years, the manufacturers have been attempting to sell those devices to electric utilities for use in substations and on power lines. This paper presents a new theory which reconciles the apparent success of such devices in minimizing/eliminating lightning damage to many tall towers with the established scientific position regarding their inability to eliminate lightning. This paper also shows that lightning elimination devices would not benefit power lines nor substations.

Keywords - LIGHTNING, LIGHTNING PROTECTION: Dissipation Arrays, Lightning Elimination, ELECTRIC LINES: Lightning Protection, ELECTRIC SUBSTATIONS: Lightning Protection.

## 1. INTRODUCTION

The idea of using multiple point discharge to neutralize cloud charges was first suggested by Czech scientist Prokop Divisch in 1754 and has since been periodically advocated and abandoned (Golde, [14]). In 1930, that idea was the subject of a patent issued to J.M. Cage of Los Angeles, who applied it in the form of point-bearing wires suspended from a steel tower to shield petroleum storage tanks against lightning (Hughes, [15]). The systematic commercialization of the concept started in 1971 by a company which still exists but has since changed its name. That company is referred to hereafter as Manufacturer "A", and its first dissipation array installation was commissioned in November 1972 (Carpenter, [9]). Manufacturer "A" was subsequently followed by a few other companies. Devices claimed to be able to eliminate lightning strikes were originally marketed for use on tall communication towers. In recent years, the manufacturers of those devices started promoting their use on power lines and substations, and they often produce what appears to be an impressive list of satisfied customers. On the other hand, the suggestion that lightning can be eliminated has been soundly rejected by the scientific community based

on an evaluation which was quite rigorous. That evaluation was based on both theoretical and field studies which were commissioned by the Office of Naval Research, the US Air Force, NASA (National Aeronautics and Space Administration) and FAA (Federal Aviation Administration). Results of that evaluation were presented and discussed during a conference which was held on 6 November 1975. (The proceedings were published in 1977.) The invalidity of the concept of lightning elimination has since been confirmed by other field studies. However, the existence of a long list of "satisfied customers" is somewhat at odds with the above scientific finding, even though the subject lists are rather misleading as will be shown hereafter. · This suggests that the subject devices may be succeeding for a reason other than that postulated by their manufacturers. To assess the applicability of the so-called "lightning elimination devices" to power systems, which is the subject of interest herein, this document presents the following:

1. A summary of the findings of the 1975 lightning conference mentioned above and other field studies which have since been conducted.

2. A critical review of the lists of "satisfied customers" which are being circulated by the manufacturers.

3. A discussion of a possible mechanism through which the subject devices may have been contributing to protecting some tall structures against lightning.

4. A discussion of whether the limited success encountered on tall structures is relevant to the case of substations and power lines.

But first, a brief description of the commercially available charge dissipaters is given hereafter; a main point of interest being the dimensions of such devices:

1. The charge dissipater types presently used by Manufacturer "A": Figs. 1A and 1B show the umbrella dissipater which is used for towers up to 100 m in height. As an example of the related dimensions, the unit which was used on a 30.5 m (100 ft) tower at the NASA satellite tracking station on Merritt Island, Florida, was about 6 m in diameter with about 300 m of barbed wire wrapped spirally around the frame of the umbrella (Bent et al., [4]). The barbed wire typically has four points spaced every 7 cm along the wire; the four points are separated by approximately 90° around the wire and are 2 cm long. Fig. 1C shows a ball dissipater which is being promoted as a "hybrid terminal which will prevent most lightning strokes and collect all others". Fig. 1D shows the barbed wire conical array which is used for the taller towers. This is larger at the base than at the top by a factor of up to 6:1. The conic array can be used to protect a ground area rather than a tall structure by installing a dedicated pole in the middle of the subject area and attaching the barbed guy wires to it. For power
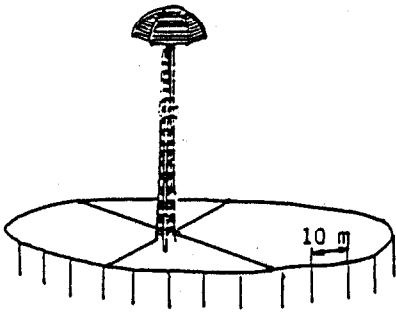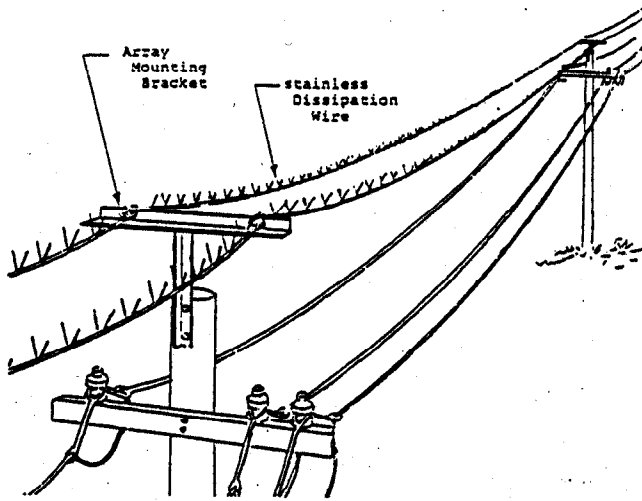
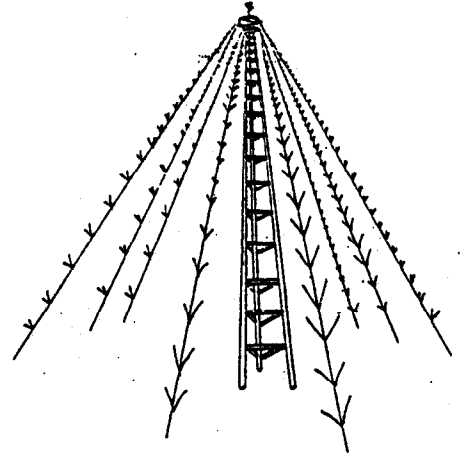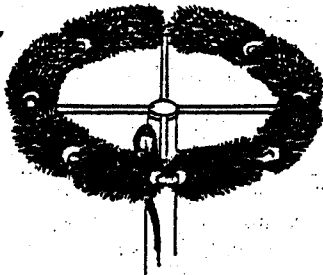A) Umbrella dissipater installation
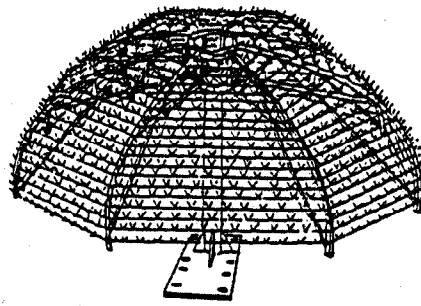
B)   Details of umbrella dissipater
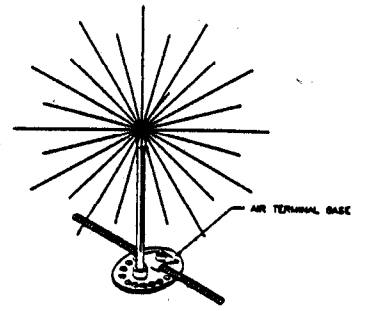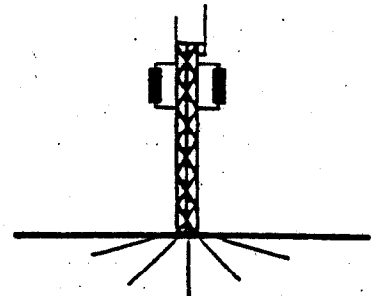
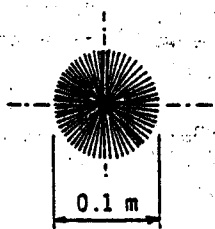C) Ball dissipater

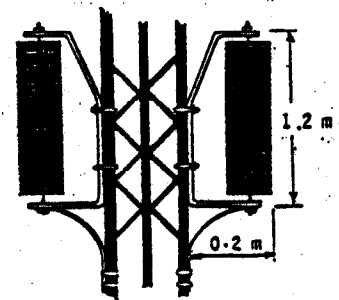E) Barbed shield wires

D) Conical barbed wire array

F) Doughnut dissipater

G) Cylindrical dissipater installation

I) Cross-section of a cylindrical dissipater

H) Close-up of cylindrical dissipaters

Fig. 1. Configurations of charge dissipaters

lines, the traditional shield wires are replaced by barbed wires as shown in Fig. 1E. In addition to the above configurations, Manufacturer "A" earlier used rigid metallic panels with protruding sharp points (panel dissipaters) which are similar to what one might expect in a "fakir's bed of nails". The material is conducting and typically has 4 cm high sharp points separated by 6 cm (Bent et al., [4]).

2. Fig. 1F shows a doughnut dissipater built by Manufacturer "B". The circular core is a solid stainless steel wire and ranges from 0.75 m (30") to 3.6 m (12 ft) in diameter. Extending from the core are hundreds of stainless steel needles ranging in length from 7.5 to 35 cm (3 to 14") (Bell, [3]).

3. Figs. 1G, 1H and 1I show a cylindrical dissipater system built by Manufacturer "C". This consists of three units installed at or near the top of the structure, spaced 120° from each other, and each having about 14,000 points.

In addition to the above, a fourth manufacturer builds a skinny version of the doughnut dissipater which is shown in Fig. 1F, and a fifth manufacturer markets a panel dissipater (fakir's bed of nails) similar to the device earlier used by manufacturer "A" (Drabkin and Carpenter, [10]).

It should be noted here that the manufacturers of charge dissipaters usually require that extensive grounding be also installed. For the cylindrical array system of Manufacturer "C", a typical configuration would be a ring made up of #2/0 stranded copper wire located outside the footings of the tower by a distance of about 1 ft (0.3 m); anchored by six 3/4"x10 ft (19mm x 3.05 m) copper-clad ground rods, and connected to an 8-arm radial counterpoise made up of #10 solid copper wire and having a length equal to about 1/3 of the total height of the tower. For the dissipation arrays of Manufacturer "A", the typical grounding consists of a copper ring which encircles the protected site, and is enforced with 1 m long ground rods located at 10 m intervals around the circumference of the ring. For high resistivity soils, Manufacturer "A" promote the use of salt-leaching rods which it manufactures. Such a rod consists of two 3" (76 mm) hollow copper tubes, one is 3 ft (0.9 m)long and the other is 6 ft (1.8 m)long, forming a T-shape and filled with a chemical which leaches in the ground to reduce soil resistivity in the surrounding area. According to a testimony letter from Lafayette Utilities System dated 22 April 1991, those chemical rods were installed at each of the substations where the charge dissipaters of Manufacturer "A" were installed. In addition to the grounding, some charge dissipater manufacturers, especially Manufacturer "A", also require that surge arresters be added.

## 2. CAN LIGHTNING BE ELIMINATED?

### 2.1 Field Observations

In every one of the few cases where instrumentation was provided, indisputable proof was obtained that lightning did strike the towers which were equipped with the so-called lightning elimination devices. Evidence to that effect was also obtained from some un-instrumented cases as eye witnesses happened to be on-site at the instant of the lightning strike, or the occurrence of the strike was proven by the damage it left behind. Consider the following:

1. The 1974/1975 tests at Kennedy Space Center (Durrett [11]): These tests were unique in that they were conducted by persons who were hoping that the dissipation arrays will work. The reason is that the

decision to install such devices was prompted by the 21 June 1971 incident in which the Launcher Umbilical Tower of the Apollo 15 mission sustained several damaging lightning strikes. Charge dissipaters were hence installed on four structures, but one of these (the Unified S-Band Station) had no history of lightning strikes neither before nor after the installation of dissipation arrays. Hence the results for only the three other structures are given hereafter:

a) The 150 meter weather tower: Galvanized steel charge dissipation panels were installed on 21 June 1974 and a temporary ground was attached between the panels and the tower ground network. The tower was struck by lightning next day, 22 June 1974. The installation was completed by Manufacturer "A" on 30 June 1974. On 18 July 1974, the tower was struck twice within a 12 minute period, and the documentation of the strikes included video pictures. The manufacturer then advised NASA that the subject dissipation arrays should be considered defective because the galvanizing used in manufacturing them was so thick that it blunted the dissipation points. Replacement stainless steel panels were installed on 30 July 1974. These were struck by lightning on 20 July 1975 and 3 October 1975.

b) Mobile Service Structure LC-39: Four charge dissipation panels were installed on 24 July 1974. Lightning struck the structure on 25 July 1974, 21 August 1974, and 9 May 1975. The latter two incidents were captured on video pictures.

c) Mobile Service Tower LC-41: Ten stainless steel dissipation arrays built byMmanufacturer "A" were installed on 26 February 1975. These are believed to have been struck by lightning on 7 June 1975 and 16 June 1975 (video pictures were not taken).

By comparing the records of lightning strikes to the subject facilities before and after installation of the charge dissipaters, Durrett [11] concluded that charge dissipaters have had no significant effect on the frequency of lightning strikes to tall structures at Kennedy Space Center.

2. Bent et al. [4] report on lightning strikes to a 1200 ft (366 m) tall tower situated on an 800 ft hill (244 m) at Eglin Air Force Base in Florida while equipped with charge dissipaters supplied by Manufacturer "A". The dissipaters were installed on 1 September 1972 and suffered two damaging direct lightning hits on 30 September 1972. Further lightning damage was discovered on 2 January 1973, 4 June 1973, 18 June 1973, 29 June 1973, 2 July 1973, and February 1974. That latter event burned the charge dissipater and hence the manufacturer replaced it on 22 April 1974. On 21 May 1974, a further lightning strike occurred and damage was discovered in the ground wire of the dissipater within the subsequent few weeks. Mr. W.B. Evans, who manned the 1200 ft tower for many years, was on hand when the dissipater experienced its first lightning hit following installation. This involved two lightning strikes within about one minute. The first strike burnt a recorder and the second blew the array series resistor and capacitor to pieces. Being near the explosion, Mr. Evans' hand suffered slight burns. Nevertheless, Manufacturer "A" stuck to its claim that lightning did not hit the charge dissipater! The site was subsequently instrumented to record lightning strikes by video cameras and also by magnetic links. Three magnetic link stroke readings of 19 kA, 19 kA and 37 kA were recorded at the base of the tower during June and July 1975 while the tower was equipped with charge dissipaters. Photographic evidence of direct lightning strikes to the arrays was obtained on 1 May 1975 and 8 June 1975. On 16 May 1976, a photo was also obtained of an upward leader which was induced from the

array by a nearby lightning strike to ground. The combination of magnetic links and video records gave a total of 10 direct lightning strikes during a brief recording period. This indicated that the frequency of lightning strikes remained at about 40 events/year, same as it was when Franklin rods were earlier used.

3. Bent et al [4] reported that lightning struck a charge dissipater at Site C74 of Eglin Air Force Base, Florida. The event occurred during the Spring of 1975 and it was witnessed by two students from the University of Minnesota who were doing research on corona currents in co-operation with the US Air Force.

4. During 1973, Manufacturer "A" supplied and installed an extensive system of charge dissipaters at NASA's satellite tracking station at Rosman, North Carolina. These included panel arrays, umbrella arrays, and a conical array. Bent et al. [4] report that **lightning damage subsequently occurred during the months of March, April and July 1974.**

5. Field tests were conducted in 1988 and 1989 by the Federal Aviation Adminstration (FAA) to study the performance of dissipation arrays and compare them with Franklin rods [2]. The tests involved the traffic control towers of three airports in Florida, which were located in a high keraunic level zone: Orlando, Sarasota and Tampa. Umbrella dissipaters from Manufacturer "A" were deployed at the Tampa Airport, doughnut dissipaters from Manufacturer "B" were deployed at Orlando, and standard Franklin rods were retained at Sarasota. All three towers were instrumented to detect lightning strikes and this included automatically-activated video cameras. **On 27 August 1989, the umbrella dissipater at Tampa received a lightning strike** which caused outages to several systems. World renown **lightning experts Professors M.A. Uman and E.P. Krider** were commissioned to examine the test data and **they confirmed that the charge dissipater of manufacturer "A" was struck by lightning.** It should be mentioned here that no damage occurred when a lightning strike to the Franklin rod system of Sarasota airport occurred on 25 June 1988. This confirmed that equipment outages will not result when the standard Franklin air terminals together with grounding and surge protection are properly installed. The above indicated the fallacy of the claim that charge dissipaters can prevent lightning and hence a decision was made on 11 January 1990 to terminate this test project.

It should be noted here that the 1988-89 tests by NASA generated a controversy (Bishop, [7,2]), which deserves to be summarized here: The facilities of Federal Express Company in Memphis, Tennessey, had no lightning protection whatsoever, and they ended experiencing some lightning damage. Instead of applying a traditional properly designed Franklin rod/shield wire system which would have solved their problem, they choose to buy charge dissipaters from Manufacturer "A". These were installed in 1981/1982 and that solved the problem. At that time, Mr. Mcartor was Vice President, Operations. In 1987, Mr. Mcartor became an FAA officer and he recommended charge dissipaters to FAA regional managers. This recommendation was opposed by the staff of FAA who have been aware of the 1975 tests of charge dissipaters at Kennedy Space Center and other facilities. Nevertheless, Mr. Mcartor's decision was carried out. With the expectation that lightning will strike the charge dissipaters, NASA played it safe by adopting a test setup in which the existing Franklin rods were replaced by charge dissipaters while retaining the existing down conductors and grounding system. (The grounding system was even enforced at one site.) The manufacturers of traditional lightning protection systems objected as any positive results from the charge

dissipaters will be partly or mostly due to the contribution from the existing components of the traditional system. To protect their interest, they formed the **Coalition Against Noneffective Lightning Protection Technologies (CAN'T)** under the direction of Joseph P. Foley. CAN'T enlisted the support of Congressman Martin Sabo (Democrat, Minnesota) whose district includes the headquarters of a Franklin rod system manufacturer. The pressure applied to NASA failed to get NASA to change the test setup. However, they acknowledged that the test program was not a scientific one and that its scope was limited. Any way, the traffic controllers at Tampa saw a flash of light during a storm, heard thunder and observed a shower of sparks drop past the tower window. A later visit to the rooftop revealed that a part of the charge dissipater array of Manufacturer "A" had disappeared. This led to cancellation of further testing and re-installation of the earlier Franklin rods. Manufacturer "A" then claimed that its array was not struck by lightning! To put the matter to rest, Professors Uman and Krider were commissioned to review the incident as was mentioned above, and they confirmed that the subject charge dissipater was struck by lightning. Because of the above controversy, FAA decided not to make their report available to others unless the request is made under the Freedom of Information Act.

6. Rourk [22] reviewed lightning-related events at nuclear power plants for the period 1980 to 1991. One nuclear plant experienced three direct lightning strikes on August 1988, July 1989, and November 1989. **Charge dissipaters were then installed in the hope of preventing further lightning strikes. These did not help and the nuclear power plant was struck again by lightning during August 1991, November 1991, and June 1992.**

## 2.2 Theoretical and Other Considerations

1. Golde [13] reports after J. Zeleny that the leaves of trees in forests constitute a huge natural charge dissipater which is known to glow in the dark (St. Elmo's fire) during thunderstorms. If charge dissipaters were indeed capable of preventing lightning, then forests would not be struck by lightning and the related fire and damage would not occur. This is contrary to observations and it shows that dissipation arrays cannot prevent lightning.

2. Golde [13] reveals the following errors in the calculations of Manufacturer "A" regarding the magnitude of the total charge dissipated by its arrays: a) They ignore that the field to which the arrays are exposed reverses polarity. b) They ignore that the high pulses of point discharge currents last only over very short periods. c) In one of its reports to a US Government agency, it exaggerates the magnitude of point discharge current by a factor of 50. d) They are based on a corona inception field magnitude which is incorrect. e) They ignore that only a fraction of the dissipated charge reaches the base of the cloud and that the rest is blown away by the wind or gets neutralized by attachment shortly after leaving the source. f) They ignore that replacing a single rod which is installed at the peak of a tall structure by an array might not increase the total dissipated charge according to Chalmers' measurements. g) They ignore that the total charge measured over a whole year from Berger's masts did not exceed that of about 5 lightning flashes of average intensity.

3. Professor Moore [18] points out that Franklin initially thought that his proposed rod would prevent lightning, but hastily changed his mind based on experience and took the now established position that the rod only provides a sacrificial point for the termination of lightning

strikes. As such, the promoters of charge dissipaters are still at the level of Franklin's first speculations. With lightning being unpreventable, Professor Moore then points out that a blunt rod is expected to be more efficient in collecting lightning flashes, as a rod with a sharp point(s) tends to protect itself.

4. Risler [21] also points out that the charging rate in storm clouds is orders of magnitude greater than the 150 mA nominal discharge current of a dissipation array, considering that the clouds overhead regenerate electric fields back to their original value within one to four minutes after a flash. Within that four minute period, the charge dissipated by the array would total 0.036 coulomb. On the other hand, the median charge of a negative lightning flash is 7.5 coulomb (Berger et al., [6]), which is **larger by a factor of about 200.** For a positive flash, the median charge is 80 coulomb [6], which is larger by a factor of about 2200! Even if we assume that all the charge produced by a dissipation array reaches the base of the cloud, it is obvious that lightning cannot be prevented by discharging the clouds.

5. Since charge dissipaters cannot neutralize the charge in the clouds, their effect is basically the creation of a charge within the gap across which the lightning discharge takes place. The laboratory tests by Allibone et al. [1] show that the effect of irradiating an air gap on its flashover voltage is rather small (in the range 0.5-10%). It follows that the effect of charge dissipaters on the incidence of natural lightning, if any, will also be small.

## 3. EXPERIENCE WITH OTHER INSTALLATIONS

The field tests reported in Section 2.1, in which charge dissipaters failed to prevent lightning, were conducted on tall towers. Experience with commercial applications to other installations, mostly telecommunication towers, has not been as negative. Actually many such applications produced satisfied customers. Results of applications to other towers are reviewed herein based on both published data and on lists of "satisfied customers" submitted by Manufacturers "A" and "B" [23]. The latter source of information was in the form of letters from users to the manufacturers, and those letters were presumably solicited by the manufacturers. No attempt was made herein to verify the claimed positive experience on communication towers, and the reported observation period was usually too short to draw definitive conclusions. It is possible that some of the towers which were reported in the users' letters to be strike-free have since been struck by lightning. It is also possible that some of the statements in those letters were false for one reason or another. Nevertheless, they are adequate for our purpose herein as they show a trend which is consistent with the theory which is presented later in this paper.

1. Block [8] was an eye witness at WDBO broadcast station when its two-tower directional array in Eatonville, Florida, was equipped with two 10 ftx10 ft (3 mx 3m) **panel** dissipaters. Block reports that the two towers subsequently suffered many lightning strikes, but they were successful in minimizing further damage by careful adjustment of the arc-over balls at the tower bases.

2. The report about the performance of the dissipation arrays which were installed on the 725 ft (221 m) gas stack of the Philadelphia Electric Peachbottom atomic power plant in Pennsylvania's Susquehanna Valley states (Eskow, [12]): "We previously had standard lightning rods protecting the area, but we kept losing electronic sensing equipment when lightning struck it (the gas stack). Since the cone-

shaped array was erected above the gas stack, the plant hasn't had any strikes. **We've had a few ground surges [a build-up of the positive particles(?)], but they haven't done any damage.**"

3. Cajun Electric Power Cooperative uses a dissipation array on the microwave tower of their control center. Their report states (Lowrey, [16]): "We probably averaged six lightning hits a year before. In the last eight years, **since the dissipation array system was put in, we've only taken a direct hit that affected anything maybe twice.**"

4. Dixie Electric Membership Corporation has a dissipation array on a 300 ft (91.4 m) combined VHF radio and point-to-point microwave tower. Their report states (Lowrey, [16]): "The tower was only in service about a year before we had about $100,000 in damage caused by lightning. We put in the dissipation array system and **although we've had some lightning problems in the building since then, they didn't involve the tower."** (?)

5. A letter from the Guy Gannette Broadcast Co. reports on two towers in Florida (heights: 320 and 490 meters) equipped with doughnut dissipaters states that "they experienced no damage in 1.5 years but are not sure whether the towers have been struck by lightning" [23].

6. A letter from WPSD TV in Paducah, Kentucky, reports that no damage has been experienced in about 2 years of operating a 91 m tower located on a high point in Illinois while equipped with a doughnut dissipater [23].

7. A letter from WESC AM/FM of Greenville, South Carolina, reports that no service interruptions were experienced in 4.5 years of operating a 391 m tower equipped with a doughnut dissipater and located on Ceasar's Head Mountain [23].

8. A letter from Florida Power Corp. reports that no damage was experienced on a microwave tower located in Winter Park, Florida during 3 years of operation while equipped with a doughnut dissipater [23].

## 4. A PROPOSED THEORY

Based on the field data and the arguments presented in Sections 2 and 3 above, it is fair to conclude the following:

1. There is indisputable proof that the so-called "lightning elimination devices" cannot eliminate lightning.

2. There are definitely cases where "lightning elimination devices" drastically reduced the frequency and extent of the damage which lightning inflicted on the subject facilities before those devices were installed.

The theory presented hereafter reconciles the above apparent contradictions.

When a cloud-to-cloud or a cloud-to-ground lightning discharge occurs, upward streamers are induced at the peaks of vertical objects in its vicinity. Such upward streamers are insignificant from the lightning protection point of view as their current is within a few hundred amperes. However, when conditions are conducive for their development, these upward streamers reach the base of the clouds and draw subsequent negative strokes, thus developing into full fledged upward flashes which has the potential of causing lightning damage. When upward flashes were first observed on the Empire State Building in New York [17], it was thought that they can only occur on very tall structures. However, Berger [5] noted their occurrence on very short objects in mountainous terrain. As a result of this and other

observations, several researchers including A.J. Eriksson, Muller-Hillebrand and Szpor discussed the incidence of lightning flashes to tall structures in terms of an "effective height" which is different from the actual height. However, the assignment of an effective height in a given case has been rather arbitrary and little or no justification was given. In 1986, the writer [19] examined the field observations regarding the incidence of upward flashes to 11 tall structures and concluded that this phenomenon was governed by the **altitude (height above mean sea level) of the peak of the structure**. Hence this **was proposed as the definition of the effective height.** Additional justification for this proposal was presented by examining several other relevant parameters including variation of conductivity of the air with altitude, variation of velocity of the return stroke along the lightning channel, variation of the breakdown gradient of the air with altitude, and variation of the resistance of the first 1 km portion of the column of air which an upward discharge has to penetrate with altitude of the peak of the structure. The writer [19] also then observed that **upward flashes do not occur when the effective height is below about 300 m.**

Below the critical effective height of 300 m, only modest increases in the frequency of lightning strikes occur with increase in height of the structure. Beyond the 300 m effective height, on the other hand, the frequency of lightning strikes to a structure drastically increases with increase in height. The reason is that the structure starts to act as a "repeater" for all the lightning strikes, both cloud-to-cloud and cloud-to-ground which occur within an increasing radius from it. The case of a 30 m high structure having footings occupying a 1 m$^2$ area and located in a zone where the keraunic level is 40 was numerically discussed in [19] and the results were found to be approximately as follows:

Prior to the installation of the structure, the area occupied by its footings receives $4 \times 10^{-6}$ flashes/year. When the 30 m structure is installed in an area of low altitude so that the effective height is below 300 m, the number of flashes funnelled through the 1 m$^2$ area occupied by its footings increases to about $4.5 \times 10^{-2}$ flashes/year. While this represents a significant increase over the value which existed before the tower was installed, the absolute value is still very low (**once every 22 years**). On the other hand, if the same tower was located on a high mountain so that its effective height allows it to act as a repeater for all the lightning flashes occurring within a 1 km area, and if we assume the ratio of cloud flashes to ground flashes to be 4:1, then the number of flashes collected by the structure would increase to about 63 per year, i.e. **more than once per week.**

Where the effective height exceeds the 300 m critical value, a tall structure is not doomed to produce many upward flashes, because its "repeater" action can be weakened or even eliminated by changing its needle shape to a geometry which is resistant to the generation of upward flashes. Some of the designs of the charge dissipaters inadvertently accomplish this objective by virtue of their shape and not because of the charge they are emitting. For example, installing an umbrella which is 6 m in diameter on a 30.5 m (100 ft) high tower drastically changes its previous needle-like geometrical shape which was making it susceptible to the generation of upward flashes. The guy wires associated with the conic array (Fig. 1D) accomplish the same geometry modification objective in an even better way. They further have the added advantage of intercepting the downward flashes which strike the sides of tall structures which were earlier discussed by Mousa and Srivastava [20]. On the other hand, devices like ball arrays and panel arrays which only dissipate ions without significantly modifying

the geometry of the structure will have a negligible effect, if any.

Any operator of a telecommunication tower which is encountering 63 flashes per year as in the case discussed above will be crying for help. If some device could suppress the repeater action of his tower which is responsible for producing the induced upward flashes, then this would eliminate 90% or more of his problem. It would then appear to him that the subject device has eliminated lightning. Needless to say, the natural downward flashes will still continue to happen in the above case. But if their frequency was only about once every 22 years, then they will hardly be noticeable. If one of such flashes occurs within the first few months or years of operation, then about another 22 years of "peace" will follow regardless of whether a corrective measure is taken or not. This allows the manufacturer the luxury of claiming that "the device does prevent lightning but it needed some fine tuning which he has now provided, and that it will work trouble-free thereafter!". If both low resistance grounding and surge suppressers were provided at the time of installing the charge dissipaters, then even the occasional natural downward flash would not cause damage and hence it would go un-noticed unless the tower was instrumented to detect lightning strikes.

The so-called lightning elimination devices fail miserably and the fallacy of the underlying concept gets exposed when their configuration does not change the geometry of the tower to one which is significantly less susceptible to the generation of upward flashes. They also fail when applied to a tall structure which is located in a low-altitude area so that its effective height is below the critical value of 300 m. This is what happened in the Florida installations which were tested during the famous 1975 and 1989 programs [2, 4, 11, 18, 21]. Consider the following:

1. According to [2], the average altitude of the site at Tampa airport is only about 20 ft (6.1 m), and the height of the tower is 230 ft (70.1 m). Hence the effective height of the tower is only about 76.2 m. This being less than 300 m, upward flashes do not occur and hence a charge dissipater, regardless of its configuration, will have little or no effect on the incidence of lightning strikes to the tower.

2. According to [11], the shape of all the dissipation arrays used on three structures at Kennedy Space Center which are discussed in Section 2.1(1) was that of flat panel arrays (fakir's bed of nails). Fig. 2 shows two of those structures as examples. Such dissipaters do not change the effective configuration of the structure and hence cannot have an impact on the occurrence of upward flashes. Further, the overall heights of the structures shown in Fig. 2 are 427 ft (130.2 m) and 250 ft (76.2 m), respectively. With the altitude of the subject ocean-side installation being only a few meters, the effective heights of both structures were less than half the 300 m critical value. Hence upward flashes did not occur in the first place. **The combination of the above factors made the above sites the perfect place to demonstrate the fallacy of the underlying theory, and that is exactly what happened!**

In the above cases, the relatively high frequency of lightning strikes was attributable to the excessive ground flash density rather than to the occurrence of upward flashes. In the medium range of effective heights, say 300 to 500 m, both upward and downward flashes occur in significant numbers. Hence the geometrical shape modification caused by installing an umbrella or conic dissipater would produce a noticeable **reduction** rather than **"elimination"** of lightning strike incidents. The Cajun Electric Power Cooperative case in item 3 of Section 3 appears to be an example of such a case. The case of the gas
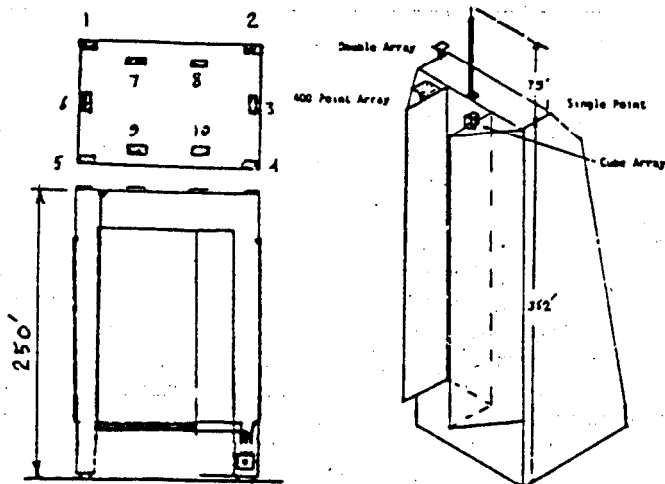
Fig. 2. Configurations of the dissipation arrays used on the Mobile Service Structures at Kennedy Space Center [11].

stack of the Peachbottom atomic power plant which is mentioned in item 2 of Section 3 also appears to fall in that category even though the reporting person appears not to understand what is really happening.

Based on the words used by some of the "satisfied customers" themselves, and noting that none of the subject installations was instrumented to ascertain the incidence of direct lightning strikes and that the observation periods were short in most cases, it is more appropriate to state that lightning elimination devices significantly reduced or even eliminated **lightning damage** in those cases rather than state that they eliminated lightning itself. Hence those observations are also in agreement with the above theory.

Note that a typical Franklin rod system together with low-resistance grounding and surge suppressors will prevent damage but the tall structure will continue to experience the annoying frequent transients associated with the occurrence of upward flashes. That is one reason why the operators of some tall towers felt an improvement when their Franklin rod systems were replaced by charge dissipaters. In other cases, the improvement mainly resulted from the grounding and surge suppression improvements associated with the new installation. Needless to say, such improvements would have materialized if the Franklin rods were retained and only the grounding and the surge protection were improved.

An article by radio consultant Chuck Condron, which was originally published in Radio Guide magazine and excerpts of which were included in literature distributed by Manufacturer "A", gives a classical example of the effects of grounding and surge suppression improvements. The article talks of the frequent outages experienced by the transmitter of KMGR-FM, which was located in a rocky area at Lake Mountain when only two loosely-installed ground rods were used at the base of the tower, and how things significantly improved (from about one outage per week to only about twice per year) when manufacturer "A" replaced these by seven chemical leaching rods arranged in a circle and interconnected with 3/4" (19 mm) copper wires. The same article states that Kool-FM in Phoenix, Arizona, drastically reduced its surge problems by installing surge suppressers built by manufacturer "A".

## 5. CASE OF POWER SYSTEMS

Neither transmission line towers nor substation structures has the needle-like shape which causes the generation of upward flashes on tall communication towers. Hence they do not experience upward flashes and only downward flashes occur. This being the case, and since none of the charge dissipaters is capable of "eliminating" the natural downward flashes, such devices are useless where power lines and substations are concerned. The only exception is any "tall" communication tower which may be part of the facilities of a substation. In the few cases where the introduction of charge dissipaters improved the lightning performance of a power system component, such an improvement could have been obtained by applying traditional shield wires. For example, most utilities build distribution lines with neither shield wires nor low resistance grounding. Where the line is not shielded by adjacent buildings and trees and is located in a high keraunic level area, outages will be frequent. It is preposterous then to install twin barbed shield wires together with low resistance grounding at each tower then suggest that the improvement was caused by the ion dissipation of the barbed wires. Such a case could have been adequately handled at a fraction of the cost by installing just a single traditional shield wire plus low resistance grounding.

## 6. CONCLUSIONS

1. Natural downward lightning flashes cannot be prevented.

2. The induced upward flashes which occur on structures having effective heights (altitude of the peak) of 300 m or more can be prevented by modifying the needle-like shape of the structure. Some charge dissipater designs inadvertently accomplish this and hence appear to "eliminate" lightning. Such an effect has little or nothing to do with the existence of multiple points on those devices.

3. Charge dissipaters will have no effect, whether intended or inadvertent, on the frequency of lightning strikes to tall towers where the altitude of the site is such that the effective height of the tower is less than about 300 m.

4. Charge dissipaters like ball arrays and panel arrays will have little or no effect, whether intended or inadvertent, on the frequency of lightning strikes to tall towers because their shape and dimensions do not significantly reduce the susceptibility of the tower to the generation of upward flashes.

**5. Charge dissipaters will have no effect whatsoever on the frequency of lightning strikes to substations and transmission towers since such systems do not experience upward flashes.**

Finally, it is hoped that the publication of this paper will induce an organization which owns suitable tall structures and has adequate R&D funds to test the above theory by comparing the lightning incidence to two tall towers; one of which is equipped with an umbrella array made of barbed wire while the other is equipped with an umbrella made of plain wire. The author would be pleased to assist in designing the details of such tests.

ASK DR. MOUSA if this claim would be applicable to A subbote mast

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[23] Copies of the letters referred to herein are available from the author upon request.

Abdul M. Mousa (M'79, SM'82, F'95) received the B.Sc. and M.Sc. in Electrical Engineering from Cairo university, Cairo, Egypt, in 1965 and 1971, respectively, and received the Ph.D. in 1986 from the University of British Columbia, Vancouver, Canada. He is Specialist Engineer with the Transmission design Department, British Columbia Hydro and Power Authority, Burnaby, B.C., Canada. Prior to joining B.C. Hydro in May 1978, he was Senior Engineer with the Department of Power Systems Planning and Research, Teshmont Consultants Inc., Winnipeg, Canada. He has published many papers and discussions on lightning, the safety aspects of power lines, and several other power line design topics. Dr. Mousa is a member of the IEEE Power Engineering Society and is a registered Professional Engineer in the Provinces of Ontario and British Columbia, Canada.