# A Long Term Study on the Performance of Early Streamer Emission Air Terminals in a High Keraunic Region

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***Abstract* – The very high keraunic level in Malaysia makes it an ideal location for the field testing of lightning air terminals. The widespread use of the early streamer emission (ESE) air terminals enabled their performance to be studied under real lightning conditions. Lightning strike damage data that would have taken decades to collect in low keraunic regions can be done in a few years only. Using a lightning interception prediction method that was developed by the authors, it was possible to obtain pre-strike and post-strike photographs of the affected buildings. The failure of the ESE air terminals to intercept nearby lightning strikes posed an unacceptable risk to public safety. An earlier version of this study had been submitted to the National Fire Protection Association (USA) in 1999 as part of a review on the efficacy of the ESE air terminals.**

***Keywords*: Air terminals, early streamer emission (ESE), Franklin rods, lightning interception.**

## 1. Introduction

The high keraunic level in Malaysia made it an ideal environment for the study of the actual performance of the ESE air terminals under real lightning conditions. The ESE air terminals are the successors to the radioactive air terminals that had been banned in many countries since the late 1980s. The ESE air terminals are claimed to be able to provide a protective range of up to 100m radius around the structures on which they are installed.

This study was initiated in the late 1980s after it was noted that most buildings equipped with the ESE devices had been struck by lightning. The use of date stamped photography to capture the pre-strike and post-strike images of ESE installed buildings began in the early 1990s after earlier photographs of lightning damaged buildings were doubted by some Malaysian academics and engineering professionals. These photographs provided the direct evidence for the performance of the ESE air terminals under real lightning conditions. The first successful post-strike photograph was taken in August 1993, just nine months after the pre-strike photograph was taken. On average, the duration between the pre-strike and post-strike photographs is about 2 years.

The study was conducted on numerous high-rise and low-rise buildings that had been installed with the conventional and unconventional (ESE) air terminals. Most of the study was done on buildings located in the vicinity of Kuala Lumpur and Shah Alam, two cities where the average annual thunderstorm day is about 250.

The case studies submitted to the NFPA provided indisputable evidence that lightning do strike the buildings after they were installed with the ESE air terminals. They show that the presence of several ESE air terminals, either on the same building or on adjacent buildings, still resulted in lightning strikes on one or more of those buildings.

In the last few years, the number of cases where the lightning damage location (or stricken point) occurred very close to the ESE air terminal has grown significantly. The very close proximity of the stricken points to the air terminals suggests that their effectiveness is below that of the correctly positioned conventional air terminal (i.e. Franklin rod).

Studies conducted on buildings equipped with the Franklin rods also exhibited similar stricken points when these rods are not positioned on the high risk locations. Based on this comparison, we conclude that no advantage can be obtained by using the ESE air terminals in protecting the building against direct lightning strikes.

## 2. Studies on the Efficacy of ESE Air Terminals.

Many studies have been conducted to verify the claims made by the manufacturers of the ESE air terminals.

A high voltage laboratory test study on radioactive and corona rods conducted by Bouquegneau [1] explicitly show that there was absolutely no influence on the strike probability.

In a study conducted by Mackerras et al [2] on the field performance of radioactive rods, several cases of failures were reported with the strike points falling within the claimed zone of protection of the ESE devices.

In another study by the same authors, Mackerras et al [3], on ESE air terminals, simple analysis show that the edges of a building will not be protected by an ESE air terminal. The study was presented to the CIGRE Task Force 33.01.03 "Lightning Interception" for the technical meeting held in Milan, Italy, in May 1995.

In a study by Hartono et al [4],[5] using actual field data collected on the distribution of lightning strike damages on buildings, several buildings equipped with the ESE devices were not spared from direct lightning strikes. Some of these data was also presented to the same CIGRE Task Force as mentioned above.

For a better understanding of this subject, Rakov and Uman [6] provide a comprehensive and critical review of the ESE air terminals.

## 3. Case Studies of Lightning Strikes to Buildings equipped with ESE Air Terminals.

The study was done by taking the pre-strike photographs of the ESE installed buildings from all sides. These buildings were then visually inspected every few months to determine whether any recent lightning strike damage had taken place. Photographs of any new stricken points were taken whenever they were detected and these photographs were then archived for the purpose of this study.

A comparison of the stricken points shows that their shape and size are similar but not identical. They seemed to be dependent on the number of strokes received, the strength of the lightning stroke current, the shape of the structure and the material composition of the stricken part. Damages to parapet walls made of bricks were found to be more severe than that made of reinforced concrete.

The following case studies show some examples of the pre-strike and post-strike photographs of lightning damaged buildings that were taken recently. The case studies highlight the very close proximity of some lightning strikes to the ESE air terminals, showing that they are unable to protect the buildings as claimed by their manufacturers.

### Case Study #1: Royal Selangor Club (RSC) Annexe Building in Kiara Hill, Kuala Lumpur

This building was installed with an Australian made ESE air terminal mounted on a 5m pole in 1998 (Figure 1). The main roof is approximately 40m long with the air terminal installed in the middle according to the Collection Volume Method (CVM) design.

Although the air terminal is claimed to have a protective range exceeding 50m, lightning reportedly struck and damaged the façade which was about 20m away (Figure 2).

Figure 1: A photograph of the RSC building taken in 1998. The building was installed with an Australian made ESE air terminal

Figure 2: A photograph of the RSC building taken in 2001. The building had been struck and damaged by lightning as can be seen on the right.

### Case Study #2: Wisma Tanah Building, Kuala Lumpur

This government administrative building was installed with a French made ESE air terminal mounted on a 5m guyed pole in 1999. The building was also installed with the Franklin rods but they were located about 0.5m away from the corners of the building (Figure 3).

In 2003, the building was observed to have been struck by lightning on the corner of the building that was about 10m away and about 8m below the air terminal (Figure 4).

The air terminal was claimed to comply with the French standard NFC 17-102 that was developed by the ESE manufacturers. The standard had been domestically criticized by a French scientific agency, INERIS [7], which found that the basis of the standard was unsound and that the manufacturers of the ESE air terminals had not tested their product against the standard. The INERIS report also included the NFPA report on the ESE that was published in 1999.

Figure 3: A photograph of the Wisma Tanah building taken in 2000. The building was installed with a French made ESE air terminal.

Figure 4: A photograph of the Wisma Tanah building taken in 2003. The building had been struck by lightning as can be seen on the right.

**Case Study #3: Setapak Ria Apartment Buildings**

These buildings had been installed with the French made ESE air terminals when they were photographed in 1997. The buildings consist of multi-tiered roofs and the air terminals were centrally located on the highest roof per apartment building.

Figure 5: A photograph of one of the Setapak Ria apartment building showing the French made ESE air terminal and the stricken points.

Figure 6: A photograph of the other Setapak Ria apartment building showing a different French made ESE air terminal and the stricken point.

A recent survey shows that the buildings had been struck several times by lightning. A close inspection shows that some of the stricken points had occurred on the same roof where the air terminals were located (Figures 5 and 6).

In these cases, the stricken points had come to within 10m of the air terminals that were installed at the center of the roof.

**Case Study #4: Villa Putri Apartment Buildings, Kuala Lumpur**

These 170m high split-level conjoined buildings were installed with the Australian made ESE air terminals mounted on 5m poles. One air terminal was installed per apartment building and they were centrally located on the roof (Figure 7).

The taller apartment block has a square-shaped concrete upper roof structure with rounded corners while the lower apartment block has a semi-circular middle and lower roof structures. According to the ESE manufacturer, these roof structures have much lower field intensification by virtue of their shapes and hence a lower risk of lightning interception.

Figure 7: Photograph of the Villa Putri apartment showing the two Australian made ESE air terminals installed on the split-level roofs.

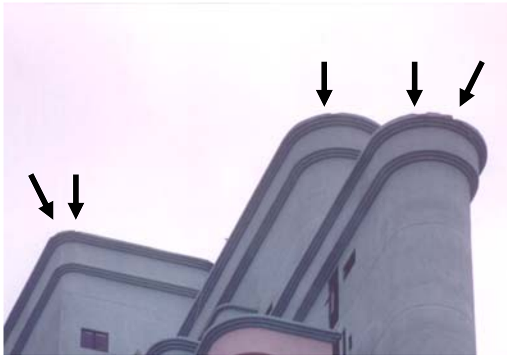

Figure 8: A close-up photograph of the apartment showing some of the multiple stricken points that have accumulated in the five year period since the building was installed with the ESE air terminals.

On the other hand, the air terminal has been designed to provide an enhanced field intensification that could result in a successful capture of lightning strikes.

However, within a five year period, it was observed that seven stricken points had occurred on the rounded edges of the upper, middle and lower roofs. These stricken points clearly show that the enhanced protection claimed by the manufacturer was non-existent (Figure 8).

**4. Case Studies of Lightning Strikes to Buildings equipped with Franklin Rods.**

The studies show that in nearly all cases of lightning damages to buildings installed with the Franklin rods, the rods were found to have been installed some distance away from the stricken points i.e. the high risk locations.

Where the Franklin rods had been located at the predicted interception point and where the down conductors were position and installed correctly, no lightning damage was observed.

The positions of the air terminal play a crucial role in the design of an effective conventional lightning protection system. This had been highlighted by Darveniza [8] and had been proposed in the draft Australian/New Zealand lightning protection standards [9].

**Case Study #5: Damansara Secondary School Buildings, Kuala Lumpur.**

These buildings have been installed with the conventional system but the Franklin air terminals and conductors were not positioned at the known high risk locations i.e. at the ridge ends and edges of the gable roof.

As expected, the stricken points occurred at the predicted locations (Figures 9 and 10). The failure of the Franklin rods to intercept the lightning stroke has more to do with erroneous positions of the rods rather than the rods themselves.


Figure 9: Photograph of a stricken point at the gable roof ridge end. The Franklin rod should have been installed right on top of the ridge end instead of about 1m away from it.

Figure 10: Photograph of a stricken point on the slanting edge of the gable roof. The air terminal conductor should also be installed on the edges of the gable roof.

**Case Study #6: Hicom Apartments, Shah Alam.**

Similar to the school buildings mentioned above, the Franklin rods were not positioned at the known high risk locations. Since these buildings have been built more than a decade ago, many of the apartment blocks had been struck by lightning at almost the exact same location i.e. at the ridge ends of the gable roof. In some cases, adjacent blocks of apartment display similar stricken points (Figures 11 and 12).

These damages could have been prevented if the Franklin rods had been installed right on top of the ridge ends. In this way, the recommendations mentioned in the draft Australian/New Zealand standard represent a significant step towards a more effective application of the conventional air terminal and should be seriously considered.

Figure 11: Photograph of two adjacent blocks of apartment showing similar stricken points. In both cases, the Franklin rods were installed just 0.5m away from the ends.

Figure 12: A close-up photograph of another apartment block showing the stricken point and the Franklin rod beside it. For effective protection, the rod must be positioned right on the ridge ends and similar high risk locations.

## 5. Conclusions.

This study provides the direct evidence required to show that the ESE air terminals do not provide the enhanced protection as claimed by their proprietors.

The study has highlighted the following facts:

(a) That the ESE lightning protection technology is scientifically and technically unsound by virtue that some of the buildings equipped with one or more of the devices had been struck by lightning repeatedly over a period of time.

(b) That the enhanced protection claimed by the manufacturers of the ESE air terminals are unfounded by virtue that some of the lightning damaged locations had been found to be very close to and, in many instances, at a lower height than the position of the ESE air terminal.

This study also shows that for the conventional air terminal to be effective in protecting the building from damage by lightning, they must be positioned correctly on the buildings. Since the vulnerable parts of the building are already known, installing an air terminal at these locations will ensure a successful interception of the lightning stroke.

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