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# The ESE and CVM Lightning Air Terminals: A 25 Year Photographic Record of Chronic Failures

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## Abstract

The Early Streamer Emission (ESE) and Collection Volume Method (CVM) lightning air terminals have been used in Malaysia for over 25 years. Initially, the ESE/CVM air terminals were mainly used for the protection of high-rise and large buildings against direct lightning strikes but later they were also applied on small and low-rise buildings as well as open spaces.

Bypasses were initially observed on the outer perimeter of high-rise and large buildings but later they were observed to have occurred much closer to the air terminals. They were also observed to have occurred on low-rise buildings and open spaces as more of these places were installed with the ESE/CVM air terminals.

**Keywords:** Lightning, bypasses, early streamer emission, collection volume method, air terminals, structures.

## 1. Introduction

The ESE/CVM air terminals were introduced in Malaysia as a replacement for the radioactive lightning rods which were banned worldwide in the late 1980s [1]. The Dynasphere, a CVM air terminal, was initially marketed as an ESE air terminal throughout the 1990s but it was later marketed as a CVM air terminal after the ESE technology was rejected by the National Fire Protection Association (NFPA) in 2000.

These air terminals were mainly installed on high-rise and large buildings for protection against direct lightning strikes but bypasses (i.e. lightning caused damages) were observed to have occurred on some of these buildings from 1991. The frequent occurrences of these bypasses suggest that the claimed protection zones of the ESE/CVM air terminals are much smaller than those claimed by their inventors and manufacturers.

Although these bypasses have been highlighted since 1995 [2], they were repeatedly ignored by the Malaysian authorities due to deceptive information provided by proponents of the ESE/CVM air terminals in industry and by an academic from a local public university [3]. Hence, the use of the ESE/CVM air terminals continued unopposed even though they did not comply with the national and international lightning protection standards.

In 1999, the same academic and his colleagues also attempted to include the non-conventional air terminal technologies in the revised Malaysian lightning protection standard, MS939. However, it failed after SIRIM, the national standards body, was informed about the rejection of the ESE/CVM technology by the NFPA in 2000. The proposed revised standard was instead replaced by the IEC 61024 standard in 2001.

In order to further mislead the authorities, some academics form the same university later claimed to have confirmed the effectiveness of the ESE air terminals [4] and they subsequently invented a ESE air terminal [5]. This resulted in the ESE/CVM air terminal being accepted by the government and led to an increase in their use on low-rise buildings such as schools, bungalows, shops, places of worship etc. This subsequently led to bypasses being observed on the low rise buildings, albeit on a smaller scale.

The ESE/CVM air terminals were also installed on tall masts in order to protect terraced houses and large open spaces such as stadiums, school fields, golf courses, public parks and photo-voltaic farms. Consequently, bypasses and casualties due to lightning have also been reported at some of these places.

This paper highlights some examples of the more pertinent bypass events that have occurred over the past 25 years which clearly demonstrates the chronic failure of the ESE/CVM air terminals to protect all forms of high-rise and low-rise structures and open spaces.

## 2. Common Shapes and Positions of Bypasses

Bypasses that occurred as a result of lightning strikes to masonry and concrete surfaces come in various shapes and sizes depending on the strength of the lightning current and the material strength of the affected surface.

Since the majority of cloud-to-ground lightning flashes are low current events, the bypasses that resulted on the above mentioned surfaces are usually small in size i.e. about 0.5 x 0.5 x0.5 m. The larger bypasses are believed to have been caused either by the larger lightning currents or by weak building materials such as unreinforced brick facades and firewalls. In most cases, the presence of steel reinforcement bars within the affected building materials help to limit the damages caused by lightning strikes. Figures 2.1 to 2.8 illustrate the common shapes of bypasses in Malaysia.

The method of identifying the locations of these bypasses on buildings before they occur was first published in 1995 [2]. Known as the Collection Surface Method, it has been applied for the placement of air terminals in the AS1768:2003 and IEC62305:2006 standards. Since then, the method has been applied in various lightning interception studies [6] [7] [8].


Fig. 2.1. A small bypass located at the corner of the roof of a public building. This is the most common shape of bypasses seen in Malaysia.

Fig. 2.2. A small bypass on top of a facade with the lightning impact point at the wall end.


Fig. 2.3. A small bypass on top of a firewall with the lightning impact point located away from the wall end.

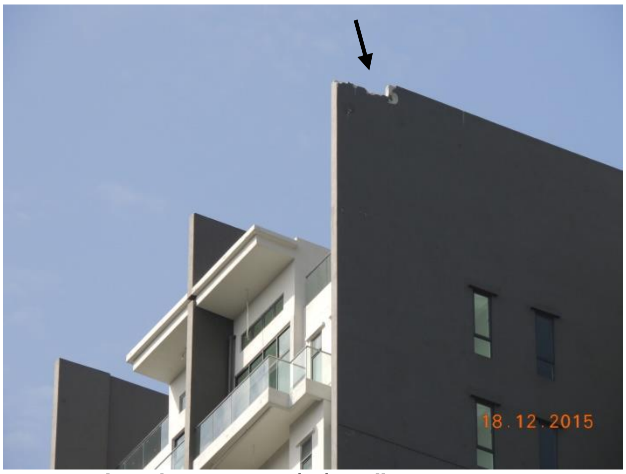


Fig. 2.4. A larger bypass on top of a firewall.


Fig. 2.5. A much larger bypass on top of a firewall. The same bypass shown in fig. 2.4 had been repaired earlier.

Fig. 2.6. A very large bypass on the parapet wall, photographed in 1991. The building had just been installed with a CVM air terminal.

Fig. 2.7. A bypass on top of a pointed facade.


Fig. 2.8. A bypass on top of a curved facade.

## 3. Bypasses to High-Rise and Large Buildings

While bypasses have been observed on most high-rise (>25m) and large buildings installed with the ESE/CVM air terminals, they mainly occurred at the corners of the roof which is located some distance away from the air terminals. However, since hundreds of these buildings have now been installed with the ESE/CVM air terminals, a growing number of these bypasses have been found to occur at a distance of less than 10m from the air terminals, as shown by the following pictures.

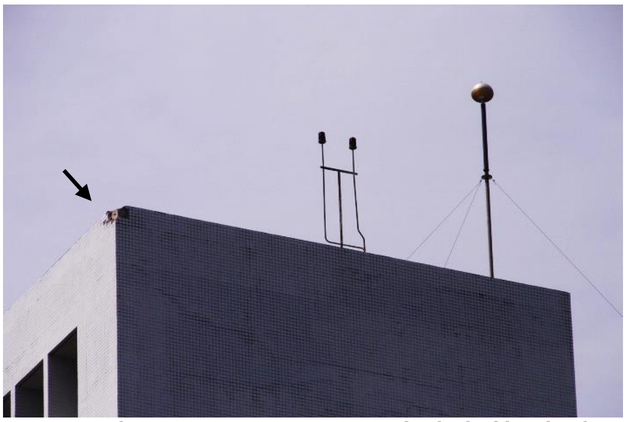

Fig. 3.1. A bypass near a CVM air terminal. The building has been struck about six times before this bypass occurrence.

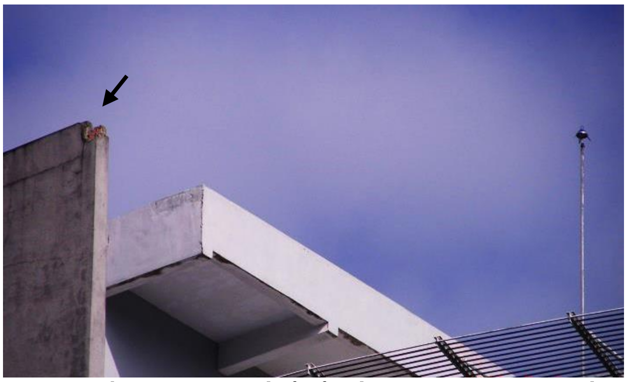

Fig. 3.2. A bypass on one end of a façade near an ESE air terminal. A similar bypass also occurred at the opposite end of the same building.

Fig. 3.3. A bypass on one corner of the roof of the elevator motor room near an ESE air terminal. Another bypass had occurred earlier at one of the distant corners of the same building.

Most high-rise and large buildings installed with the ESE/CVM air terminal seem to have been struck by lightning at least once within four years of being constructed. Some buildings were found to have been struck more than once per year. For example, the Univ360 apartment in Kuala Lumpur was struck at least six times over a period of two years resulting in three major bypasses.

Fig. 3.4. The Univ360 apartment was struck at least six times within a period of two years. The arrows indicate the locations of the major bypasses. See also figs 2.3, 2.4 and 2.5.

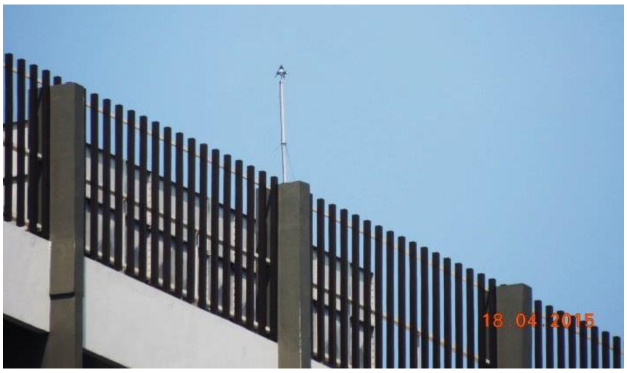


Fig. 3.5. The ESE air terminal installed on the Univ360 apartment and located at the center of the roof (circle in fig. 3.4).

## 4. Bypasses to Buildings installed with more than one ESE/CVM Air Terminals

Due to the high rate of failures of the ESE/CVM air terminals, a significant number of high-rise and large buildings around the country have been installed with two or more air terminals. However, these buildings were later found to have been struck and damaged by lightning, some repeatedly. This is clear evidence that the use of multiple ESE/CVM air terminals is incapable of protecting such buildings from direct lightning strikes.

Fig. 4.1. A 100m high apartment building with multi-level roofs installed with two CVM air terminals (arrowed).


Fig. 4.2. Although located between two CVM air terminals, several bypasses was observed on this section of the upper level roof.

Fig. 4.3. Multiple bypasses were observed on the lower level parapet walls located near the CVM air terminal.

Bypasses have also been observed on low-rise buildings installed with more than one ESE/CVM air terminals. Although the occurrences of bypasses on these buildings are less frequent than those on the high-rise buildings, they also provide clear evidence of the ineffectiveness of these air terminals.


Fig. 4.4. Two second generation CVM air terminals (arrowed) installed on a low-rise public building.

Fig. 4.5. A bypass was observed on the corner of the roof (arrowed). See fig. 2.1 for a close-up picture of the bypass.


Fig. 4.6. A low-rise college building installed with one ESE and one CVM air terminals.


Fig. 4.7. The same building installed with two ESE/CVM air terminals (arrowed) and photographed without a bypass in 2010.


Fig. 4.8. The same building observed with a bypass (arrowed) in 2015.

## 5. Bypasses at Open Spaces

Mast mounted ESE/CVM air terminals have also been used to provide protection for open spaces such as playing fields, botanical parks, golf courses and photo-voltaic farms. Bypasses to ground-mounted solar panels and lightning related injuries/deaths at stadiums and playing fields have been reported at some these locations and these incidences demonstrated that the air terminals are incapable of providing protection at ground level.

For example, in a reported lightning incident at a solar farm, several solar panels mounted about 1.5m above ground were struck by lightning although they were located within the claimed protection zone of one of several ESE air terminals that were installed throughout the farm.

Fig. 5.1. One of several mast-mounted ESE air terminals installed at a photo-voltaic farm where a bypass had occurred.

Fig. 5.2. Two of the bypasses on the center portion of a solar panel that was struck by lightning.

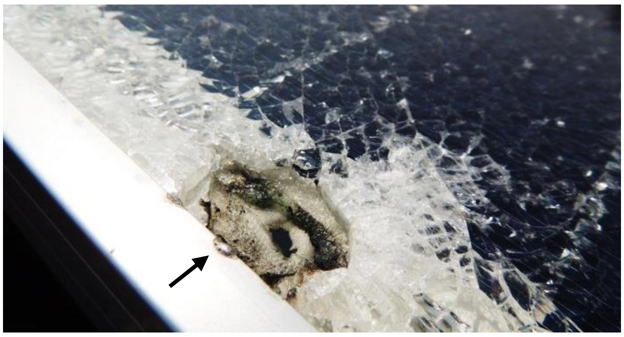

Fig. 5.3. One of the bypasses located at the edge of the solar panel. The blob of melted metal (arrowed) on the aluminum frame suggests that it was caused by a very high temperature event, such as a lightning stroke.

In 2012, a university student was struck and killed by lightning on a football field in front of a stadium grandstand. The metallic roof of the grandstand needed no protection against lightning but it had been installed with a pole-mounted ESE air terminal whose claimed protection zone covered the entire football field adjacent to the grandstand.

The unfortunate death of the student, Mohd Ridwan Jamal, clearly suggests that playing fields and similar open spaces that have been installed with the ESE/CVM air terminals are unsafe during thunderstorms.

The above incidences strongly suggest that mast mounted ESE/CVM air terminals do not provide the large protection zones claimed by their inventors and that their application in such a manner constitute a public safety hazard.

Fig. 5.4. The Malacca university stadium grandstand and field where the student was struck and killed by lightning.


Fig. 5.5. The ESE air terminal mounted on one of the grandstand's metallic pillars.

## 6. Frequency of Bypasses

From observations made to a large number of high-rise and large buildings, it is estimated that most of these buildings have been struck at least once within four years of being installed with the ESE/CVM air terminals. Therefore, it is possible to make a statistical model of this occurrence based on the assumption that an average of 25% of the above buildings are struck for the first time by lightning annually (see Table 1) where:

A: the number of new high-rise and large buildings installed with the ESE/CVM air terminals per year

B: the cumulative number of these buildings installed with the ESE/CVM air terminals

C: the number of buildings displaying the initial bypasses occurring at the rate of 25% per year

D: the cumulative number of buildings displaying at least one bypass

E: the overall percentage of buildings displaying at least one bypass

TABLE I

Percentage of buildings with initial bypasses by year of usage

| YEAR | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| A | 100 | 100 | 100 | 100 | 100 |
| B | 100 | 200 | 300 | 400 | 500 |
| C | 25 | 50 | 75 | 100 | 100 |
| D | 25 | 75 | 150 | 250 | 350 |
| E | 25% | 38% | 50% | 63% | 70% |
| YEAR | 6 | 7 | 8 | 9 | 10 |
| A | 100 | 100 | 100 | 100 | 100 |
| B | 600 | 700 | 800 | 900 | 1000 |
| C | 100 | 100 | 100 | 100 | 100 |
| D | 450 | 550 | 650 | 750 | 850 |
| E | 75% | 79% | 81% | 83% | 85% |

The above statistical model suggests that at least 80% of all the high-rise and large buildings installed with the ESE/CVM air terminals have been struck at least once by lightning by the year 2000 i.e. a decade after the study began. This figure explains the high rate of buildings that have been observed with bypasses in 2004 [1].

Interestingly, a statistical study of bypasses to new buildings in Malaysia that were installed with the CVM air terminals was recently conducted in Canada by Haller and Woyczynski in 2016 [9]. These buildings had reportedly been inspected independently by a German firm, TUV Hessen, between 2010 and 2012. The study concluded that only 12.5% of the buildings inspected during the two year observation period were struck and damaged by lightning. They remarked that this value is in contradiction with the figure of 80% reported above.

However, the Canadian study did not provide any physical data of the buildings inspected by TUV Hessen. There was no specific information regarding the height of the buildings and the type of material used for the construction of the roofs. Hence it is not possible to evaluate the data in order to make a proper comparison between the Canadian study with that of the Malaysian study which was based mainly on high-rise buildings.

An earlier statistical study on the effectiveness of the CVM air terminal was also conducted in Malaysia in 2002 [10]. However, the raw data of this study, which was submitted earlier to Standards Australia, had been independently reviewed and was shown to be dubious in nature since some of the buildings in the study had metal cladded roof while other buildings were included because they had abnormally high lightning counter readings [11]. This led Standards Australia to reject the CVM from the revised Australian standard, AS1769:2003.

A follow-up statistical study using some of the original Malaysian raw data was again conducted in 2006. This study included more buildings that have been installed with the CVM air terminals [12]. Again, no raw data was provided concerning the new buildings nor their associated lightning counter readings. However, an analysis of the available data suggests that a significant number of new buildings with abnormally high counter readings had been selected for this study in order to support the claimed efficiency of the CVM system [13].

## 7. Discussion

From the above long term study of bypasses to ESE/CVM air terminals, more physical evidence have been discovered which strongly suggests that these air terminals are incapable of providing protection against lightning to high-rise structures as well as to objects at ground level.

Attempts by the vendors to use multiple ESE/CVM air terminals also failed to protect these structures from being struck by lightning. Therefore, the ESE/CVM air terminals are considered a total failure in protecting structures and open spaces from being struck by lightning.

Furthermore, the study by Haller and Woyczynski can be considered as invalid since the primary data of the buildings obtained by TUV Hessen have neither been revealed for scrutiny nor independently verified for relevance in the study.

## 8. Summary and conclusion

This paper presents a brief summary of the chronic failures of the ESE/CVM air terminals encountered in Malaysia during the past quarter century of observation. The failures documented vary from bypasses that occurred on photo-voltaic panels installed just 1.5m above ground level to multiple bypasses that occurred at the corners of high-rise structures.

The observed growing number of bypasses occurring very close to the ESE/CVM air terminals provides clear evidence that they do not provide any enhanced zone of protection as claimed by their inventors and vendors. Hence the use of the ESE/CVM air terminals should be considered a public safety hazard and should be discontinued.

For enhanced safety of buildings, the ESE/CVM air terminals should be replaced with conventional air terminals positioned and installed in full compliance with the IEC62305 standard. Such practice will enable the lightning flash to be intercepted by the conventional air terminals with an estimated efficiency of 98% [7] [8].

## References

[1] Z. A. Hartono and I. Robiah, "Conventional and Un-conventional Lightning Air Terminals: An Overview", ACEM Forum on Lightning Protection, Kuala Lumpur, January 2004

[2] Z. A. Hartono and I. Robiah, "A Method of Identifying the Lightning Strike Location on a Structure", Int. Conference on Electromagnetic Compatibility, Kuala Lumpur, April 1995

[3] H. Ahmad, "*Kilat dan Perlindungan* (Lightning and Protection)" Universiti Teknologi Malaysia, 1998, pp. 46–48.

[4] E. E. Ngu and A. Darus, "A study on the early streamer emission lightning protection system", Masters of Engineering thesis, Universiti Teknologi Malaysia, 2004

[5] H. Ahmad, "Study on the early streamer emission mechanisms aided by laser radiation ionization process", Research Vote No. 74276, 2007.

[6] M. Becerra, V. Cooray and Z. A. Hartono, "Identification of Lightning Vulnerable Points on Complex Grounded Structures", Journal of Electrostatics, August 2007

[7] J. Dudas and M. Dudas., "Software for Lightning Protection System Diagnosis according to IEC 62305", 29th ICLP, Uppsala, Sweden, June 2008

[8] A. Kern, C. Schelthoff and M. Mathieu, "Probability of lightning strikes to air-terminations of structures using the electro-geometrical model theory and the statistics of lightning current parameteters" 30th ICLP, Cagliari, Italy, September 2010

[9] H. S. Haller and W. A. Woyczynski, "Interception effciency of CVM-based lightning protection systems for buildings and the fractional Poisson model", Open Access Library, Cornell University, 2016

[10] N. I. Petrov and F. D'Alessandro, "Assessment of protection system positioning and models using observations of lightning strikes to structures", Proc. of the Royal Soc. A, February 2002.

[11] Z. A. Hartono and I. Robiah, "An analysis of the data contained in the paper "Field validation of an air terminal placement method"", Report submitted to the Australian lightning protection study group, EL024, January 2002.

[12] F. D'Alessandro and N. I. Petrov, "Field study on the interception efficiency of lightning protection systems and comparison with models", Proc. of the Royal Soc. A, January 2006.

[13] Z. A. Hartono and I. Robiah, "Case studies on the performance of commercial-grade lightning event counters", Proceedings of Asia Pacific EMC Symposium; Singapore; May 2008.