Kursus "Lightning & Surge Protection"

Lightning Protection System

Cawangan Kejuruteraan Elektrik

2021

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3. Physical Damage to Structures/ Buildings & Life Hazard

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1.1 Scope

What is Lightning Protection System?

- IEC 62305-1 - Complete system used to reduce physical damage due to lightning flashes to a building
- It consists of both external and internal LPSs.

1.1 Scope

Lightning Protection System

LPS

External Lightning Protection

- Air termination systems
- Down conductor systems
- Earth termination system
- Components
- Materials & Dimensions

Internal Lightning Protection

- Lightning equipotential bonding
- Electrical insulation / separation of the external LPS
- SPDs

1.2 References

- IEC 62305-1 Part 1: General Principles
- IEC 62305-2 Part 2: Risk Management
- IEC 62305-3 Part 3: Physical Damage to Structure and Life Hazard
- IEC 62305-4 Part 4: Electrical and Electronic Systems within Structures
- IEC 62561 series: Lightning Protection Components

1.2 References

Akta Bekalan Elektrik 1990 (Akta 447):

***Seksyen* 47. Langkah awasan terhadap elektrik atmosfera.**

Mana-mana jabatan Kerajaan Persekutuan atau mana-mana Kerajaan Negeri atau mana-mana pengguna lain yang mengambil atau menggunakan elektrik daripada mana-mana pepasangan hendaklah, jika Suruhanjaya menghendaki sedemikian, memperuntukkan apa-apa kaedah bagi menghindarkan apa-apa risiko kerosakan kepada pepasangan itu melalui elektrik atmosfera sebagaimana yang diarahkan oleh Suruhanjaya atau sebagaimana yang ditetapkan melalui peraturan-peraturan di bawah Akta ini.

1.3 Terms & Definitions

IEC Terminology

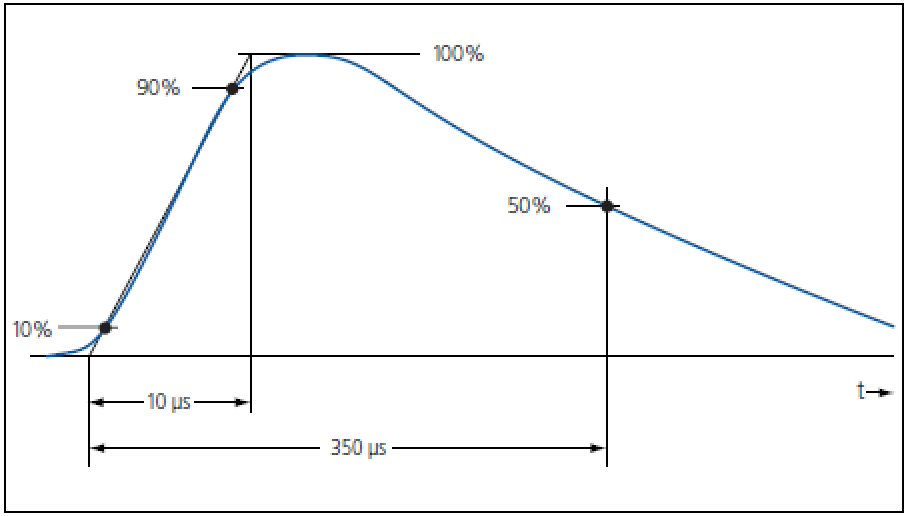
Term	Definition
Lightning stroke	Single electrical discharge in a lightning flash to earth
Lightning flash to earth	Electrical discharge of atmospheric origin between cloud and earth consisting of one or more strokes

Common vs IEC Terminology

Common Terminology	IEC Terminology
Lightning strike	**Lightning flash/stroke**
Discharge current	**Lightning current**

1.4 Lightning Current Parameters

- As shown in figure, lightning current waveshape, the front time (also known as rise time) is 10 μs duration and the time to decay to 50% (also known as tail time) is 350 μs.



Waveshape

1.5 Lightning in Malaysia

- Malaysia is a tropical country which has recorded a high number of lightning strikes and thunderstorm activity throughout the year

1.5 Lightning in Malaysia

Thunderstorm Day & Ground Flash Density in Malaysia

- Lightning ground flash density (N_g) defined as the number of cloud-to-ground flashes per square kilometer and per year (km^{-2} yr^{-1})
- Is an important meteorological data that is used in calculating the risk of lightning strikes to a building
- N_g can be captured or calculated from the Annual Thunderstorm days T_D (keraunic level)

1.5 Lightning in Malaysia

- Malaysian Meteorological Department (MMD) has recorded more than 200 thunderstorm days per year in Malaysia (T_D).

Among the top 3 in the world

Thunderstorm Days Per Year Worldwide	
Bogor, Indonesia (1988)	322
Cerromatoso, Columbia	275-320
Malaysia	180-260
Singapore	160-220
Florida, U.S.	90-110
Colorado, U.S.	65-100
Brazil	40-200
Argentina	30-200
Japan	35-50
Most of Europe	15-40
Australia	10-70
England	5-10

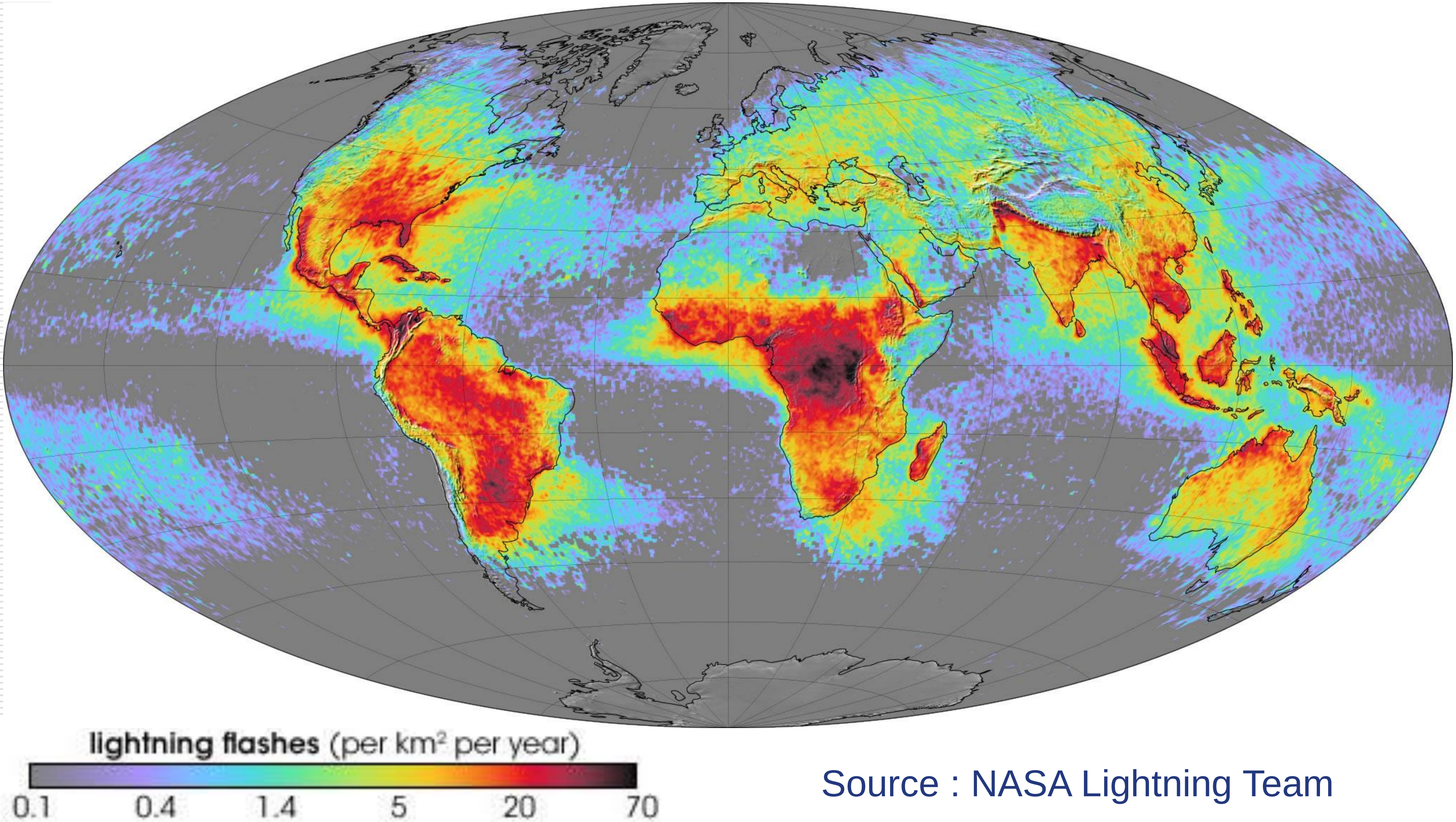
1.5 Lightning in Malaysia

- TNBR has recorded as high as 484.4 kA lightning impulse current in Malaysia using their Lightning Detection Network (LDN)

Top Lightning Flash Density, N_g (ground strikes per km/sq) Sites Worldwide	
Kamembe, Rwanda	82.7
Boende, Dem. Rep. Congo	66.3
Lusambo, Dem. Rep. Congo	52.1
Kananga, Dem. Rep. Congo	50.3
Kuala Lumpur, Malaysia	48.3
Calabar, Nigeria	47.3
Franceville, Gabon	47.1
Posadas, Argentina	42.7
Ocana, Colombia	39.9
Concepcion, Paraguay	37.0

1.5 Lightning in Malaysia

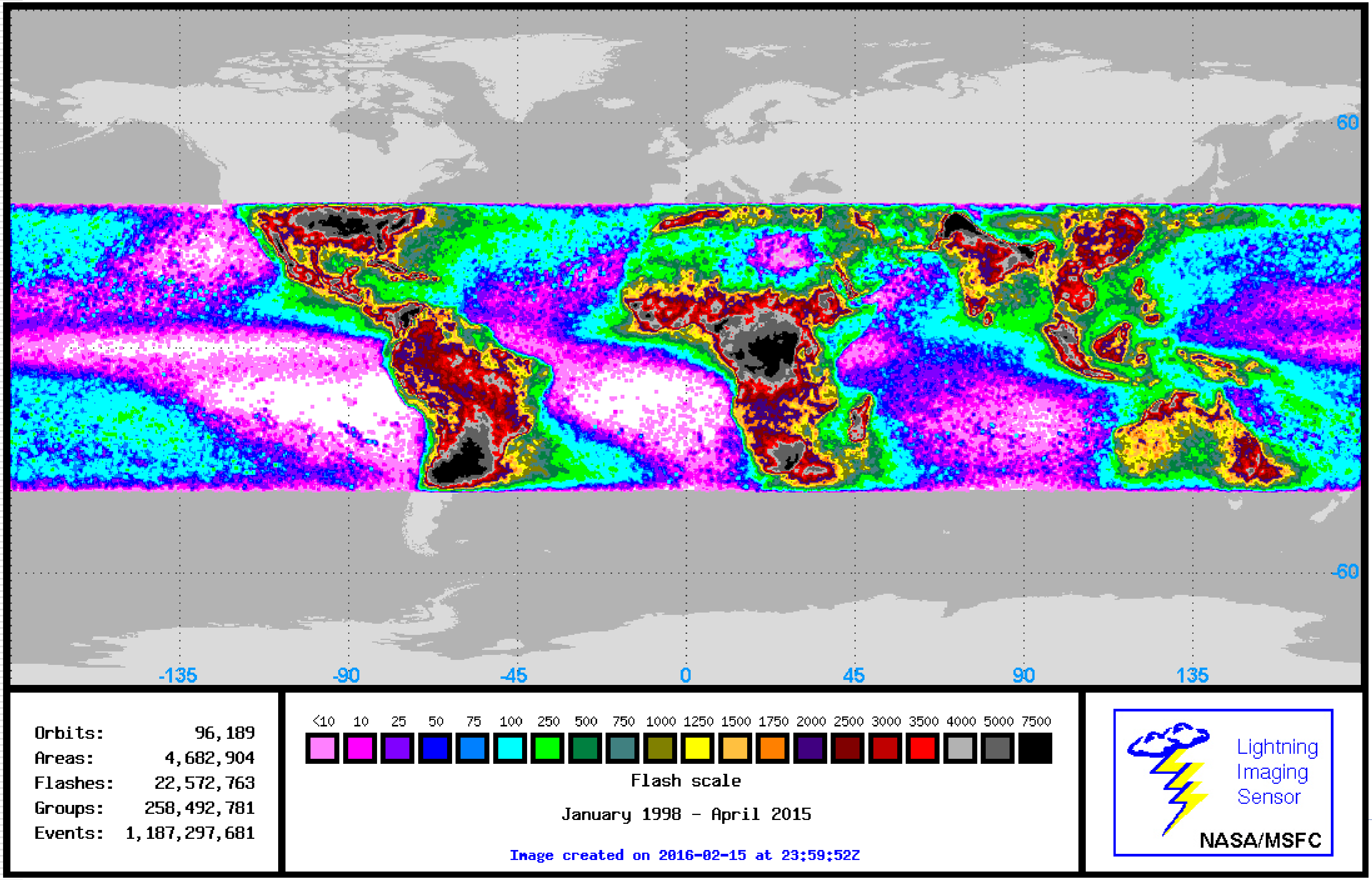
World Lightning Map



Source : NASA Lightning Team

1.5 Lightning in Malaysia

Pattern of Lightning Activity



1.5 Lightning in Malaysia

Pattern of Lightning Activity

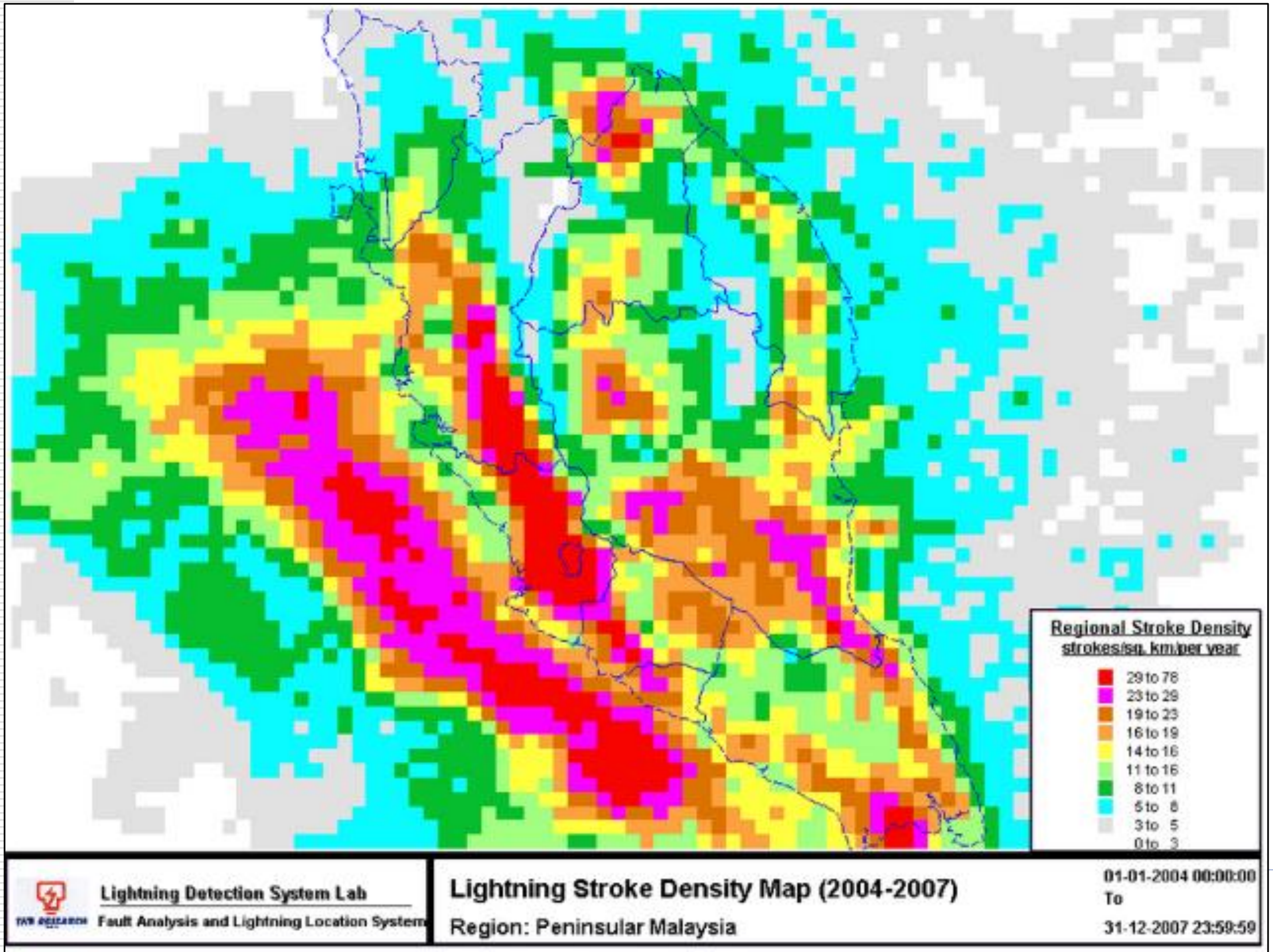
Annual Thunderstorm Day (T_D) Figures for the Year 1993 to 2002 (Hartono 2003)

Major towns/cities	10-year T_D Ave.	Max T_D	Min T_D
Langkawi	101	136	90
Alor Star	165	197	145
Butterworth	172	183	164
Bayan Lepas	202	239	185
Ipoh	165	200	135
Sitiawan	193	235	179
Subang	188	195	180
Malacca	137	165	103
Kluang	191	222	165
Senai	172	206	159
Mersing	171	188	151
Kuantan	154	173	128
Temeloh	112	156	92
Kuala Trengganu	163	184	141
Kota Baru	115	146	94
Kuala Krai	161	177	149
Kuching	184	231	151
Sri Aman	105	132	78
Sibu	103	115	85
Bintulu	133	180	102
Miri	88	101	68
Labuan	147	164	112
Kota Kinabalu	139	158	113
Kudat	79	96	60
Sandakan	155	193	118
Tawau	84	124	45

1.5 Lightning in Malaysia

Pattern of Lightning Activity

Lightning Flash Density (N_g) for Peninsular Malaysia (2004 – 2007) (TNBR)



$$N_g = 0.1T_D$$

1.5 Lightning in Malaysia

- Malaysia encounters more than 70% of power outages due to lightning

1.6 Damage Due to Lightning

Damage to a structure

- **Construction (e.g. wood, brick, concrete etc.)**
- **Occupants (persons and animals)**
- **Connected lines (power lines, telecommunication lines, pipelines)**

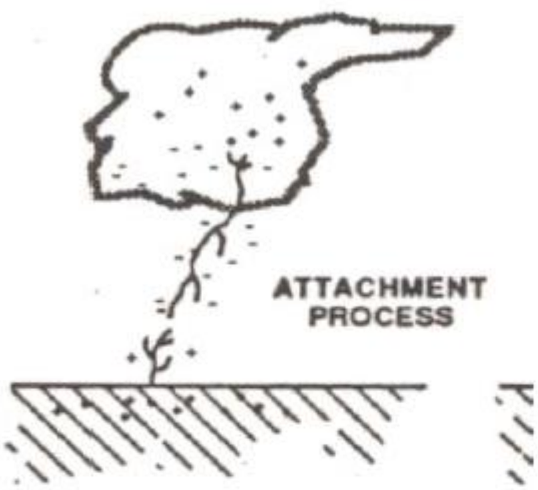
1.6 Damage Due to Lightning

Kes-Kes Panahan Petir di Malaysia

Putrajaya

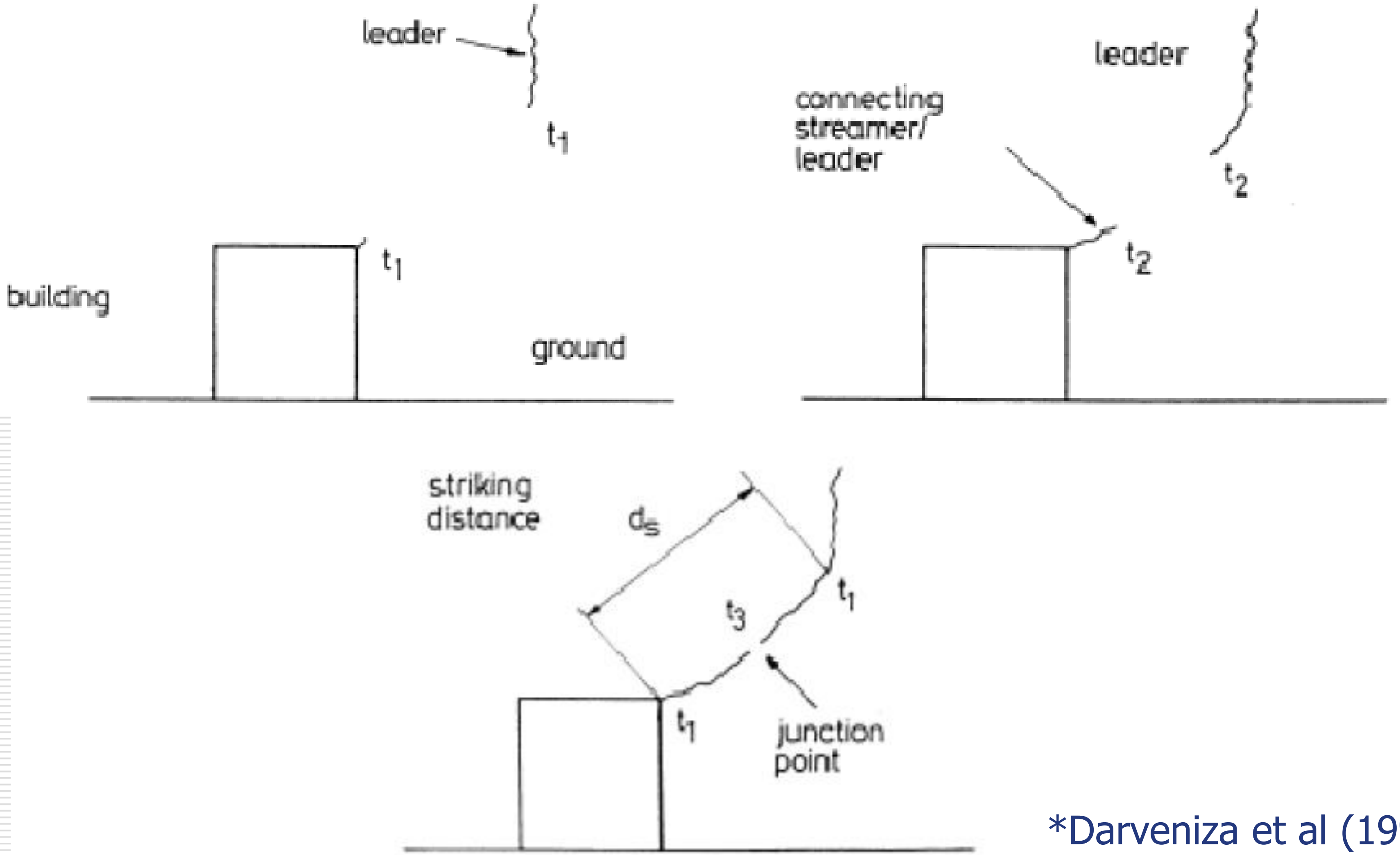
1.7 Theory of Lightning

- Lightning attachment occurs when a discharge from a thundercloud attaches itself to an object on the ground



1.7 Theory of Lightning

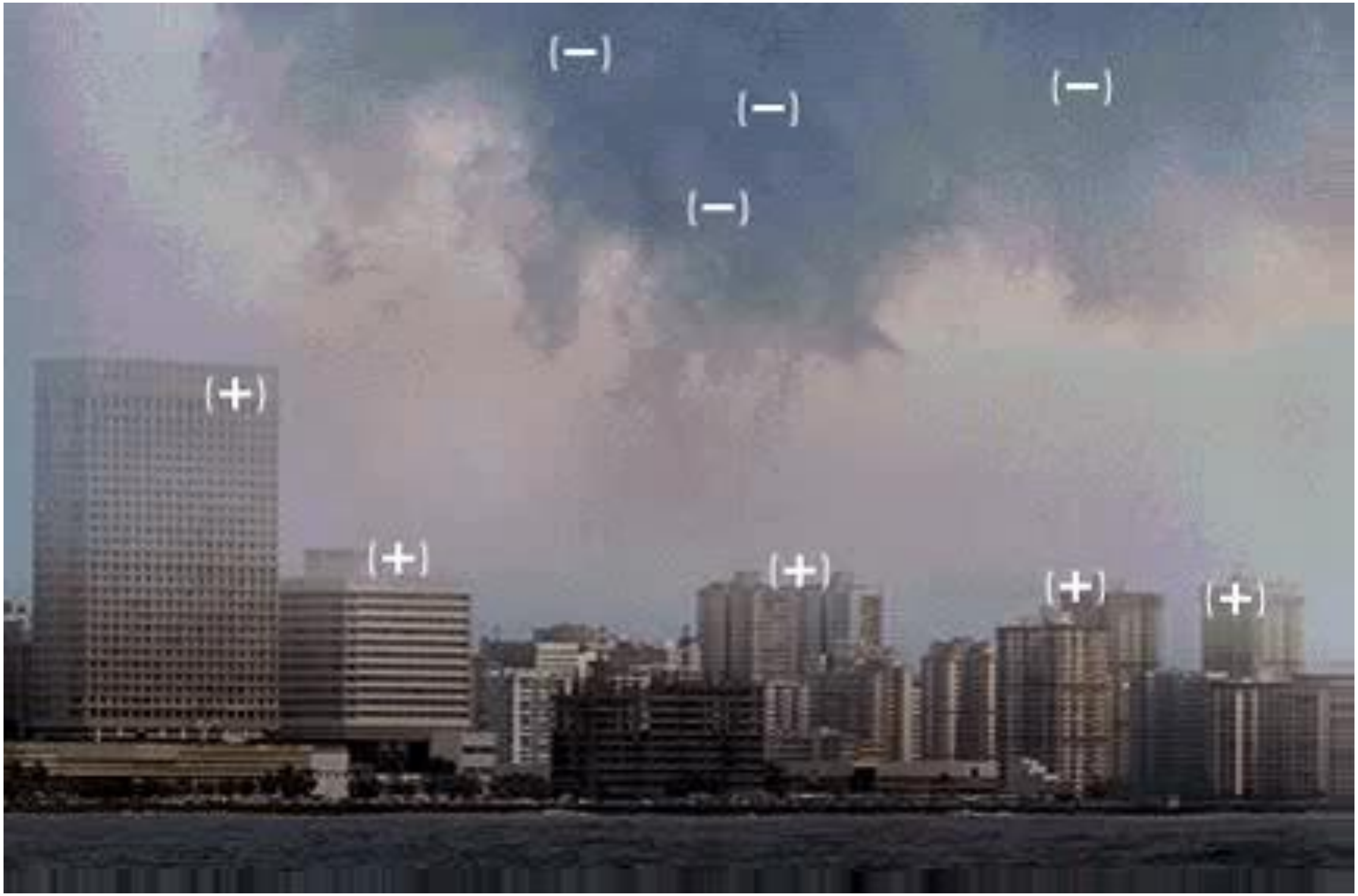
Lightning attachment process



*Darveniza et al (1997)

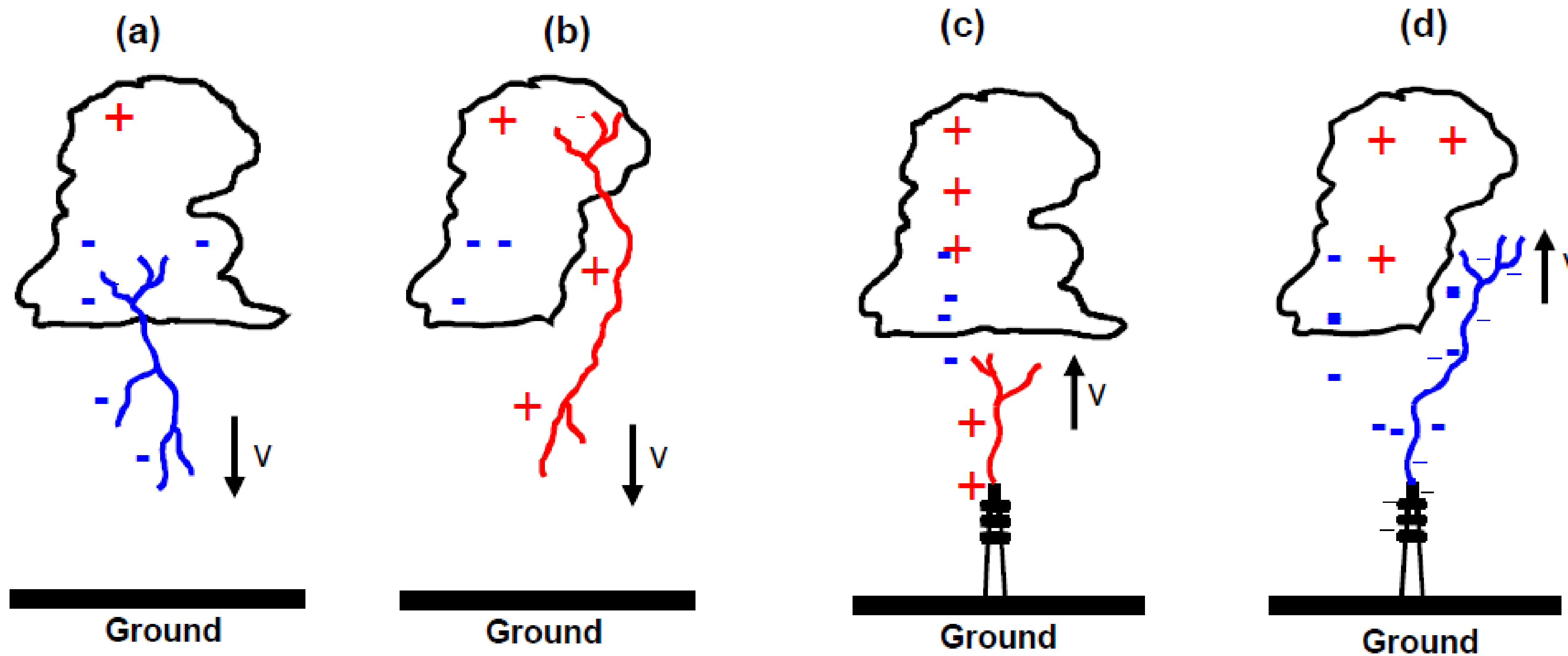
1.7 Theory of Lightning

Lightning attachment process



1.7 Theory of Lightning

Types of Lightning to Ground



(a) negative downward lightning,

(b) positive downward lightning,

(c) positive upward lightning

(d) negative upward lightning

1.7 Theory of Lightning

- Lightning strikes thousands of structures on the ground annually
- In most cases, they attach themselves to the corners and edges
- Sometimes it strikes the highest point of a structure

Lightning attachment to structure
[Photo: The Star Publications]

1.7 Theory of Lightning

- On rare occasions, lightning can also strike the sides of tall structures

[Photo: K. Ambrose]

Lightning attachment to structure

1.7 Theory of Lightning

Lightning attachment to structures

- Studies on high-rise buildings with lightning attachment points in Kuala Lumpur and Singapore revealed a regular pattern of occurrence
- Lightning attachment points seemed to accumulate at corners, exposed points and edges

* CIGRE C4 Colloquium 2010, Kuala Lumpur

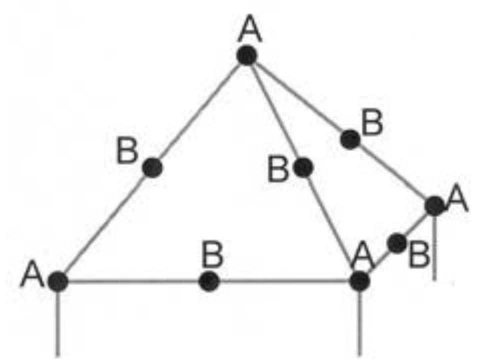
1.7 Theory of Lightning

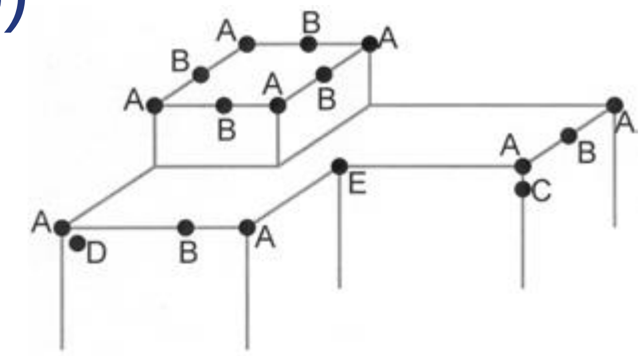
Lightning attachment to structures

- The higher the structure height, the higher the chances of getting struck by the lightning, although that is not always going to be the case

Lightning attachment to structures

- A: Exposed corners and points (>90%)
- B: Straight or curved horizontal edges (<5%)
- C: Vertical edges near A (<2%)
- D: Flat surfaces near A (<1%)
- E: Included corners, etc. (0%)





*(Hartono & Robiah 1995, 2000)

1.7 Theory of Lightning

Exposed corners and points

(Photo: Hartono)

1.7 Theory of Lightning

Exposed edges

(Photo: Hartono)

2. Risk Management

Scope

- IEC 62305-2 is applicable to **risk assessment** for a building due to lightning flashes to earth
- Purpose: evaluation of a risk
- This risk assessment allows the selection of appropriate protection measures (Lightning Class) to be adopted to reduce the risk

2. Risk Management

Terms and definitions

- Urban environment
  - area with a high density of buildings or densely (crowded) populated communities with tall buildings
  - ’Town Centre’ is an example of an urban environment.
- Suburban environment
  - area with a medium density of buildings
  - ‘Town outskirts’ is an example of a suburban environment
- Rural environment
  - area with a low density of buildings
  - ’Countryside’ is an example of a rural environment

2. Risk Management

- To determine if lightning protection is required
- If so, to select the appropriate lightning class (I,II,III,IV)
- To determine values of rolling sphere radius
- To determine the protective angle
- To determine values of mesh size
- To determine no. of down conductors
- To determine the separation distance

2. Risk Management

- Lightning protection can be installed even when the risk assessment process may indicate that it is not required.
- A greater level of protection than that required may also be selected.
- IEC 62305-2 standard is over 100 pages in length and is extremely comprehensive and complex.
- Manual calculation of risk assessment can take 10 hours to complete.
- Therefore, a reduced analysis is conducted, with an electronic tool.
- Third-party software is also available.

2. Risk Management

Four classes of LPS are defined in IEC 62305-2 corresponding to lightning protection level

LPL	Class of LPS
I	I
II	II
III	III
IV	IV

2. Risk Management

Identify the structure to be protected

↓

Identify the types of loss relevant to the structure to be protected
R1 risk of loss of human life
R2 risk of loss of services to the public
(i.e water, power, gas, data/telecommunications)
R3 risk of loss of cultural heritage (*warisan budaya*)
R4 risk of economic loss

↓

Identify the tolerable level of risk
Rt

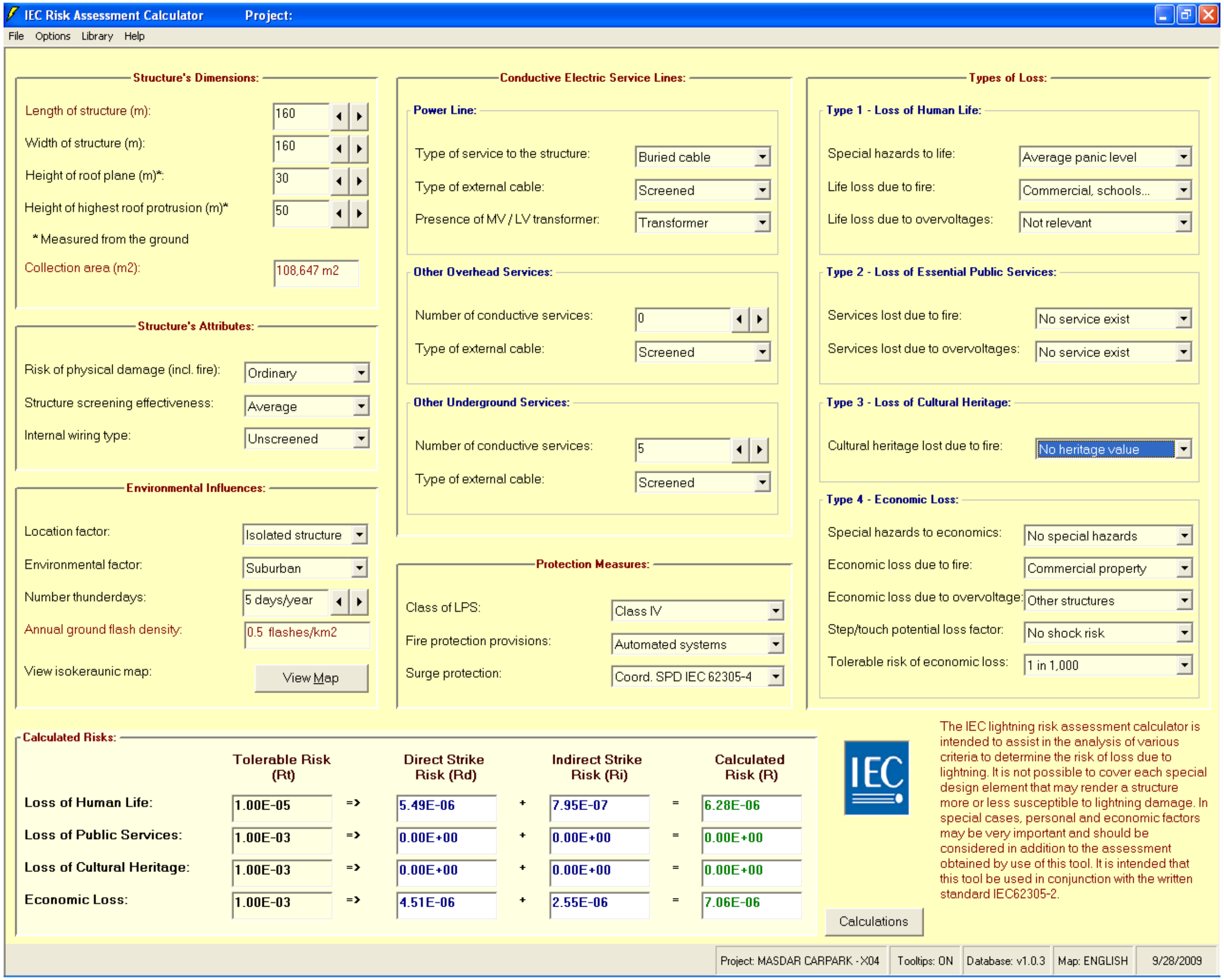
↓

R1,2,3,4 ≤ Rt

YES → Structure is sufficiently protected

NO → Install LPS in order to reduce R1,2,3,4

2. Risk Management



2. Risk Management

Primary risks

Following primary risks (R_n) relate to corresponding types of loss (L)

- R_1 – Risk of loss of human life
- R_2 – Risk of loss of services to the public
- R_3 – Risk of loss of cultural heritage
- R_4 – Risk of loss of economic value

2. Risk Management

R_2 – Risk of loss of services to the public

"services" – water, power, gas, fuel or data/telecommunications

– any type of company who, due to lightning damage, cannot provide their "service" to the public.

(e.g. Supermarket closed due to damage to cash register or a Bank unable to transact business due to phone or website failure)

2. Risk Management

Risk Criteria

Protection against lightning is required if the primary risk R_n (whether that is R_1 *or* R_2 *or* R_3 *or* R_4) is greater than the tolerable level of risk R_T

If $R_n \leq R_T$ No LPS required
If $R_n > R_T$ LPS is required

R_T = max value of the risk which can be tolerated for the building to be protected

2. Risk Management

Identification of Tolerable Risk R_T

Types of Loss	R_T / annum
Loss of human life or permanent injury	1×10^{-5}
Loss of service to the public	1×10^{-3}
Loss of cultural heritage	1×10^{-3}
Loss of economic value	1×10^{-3}

If risk R_n is less than or equal to value of R_T – structure doesn't require protection

If risk R_n is greater than R_T – structure require protection and further calculation will determine exactly what type of protection is required.

3.1 External LPS

- intercept a lightning flash to the structure/building (with an air-termination system)
- conduct the lightning current safely towards earth (using a down-conductor system)
- disperse the lightning current into the earth (using an earth-termination system).

3.2 Internal LPS

- prevents dangerous sparking within the structure/building using either equipotential bonding or a separation distance (electrical insulation) between the external LPS components and other electrically conducting elements internal to the structure.

3.3 LPS Design

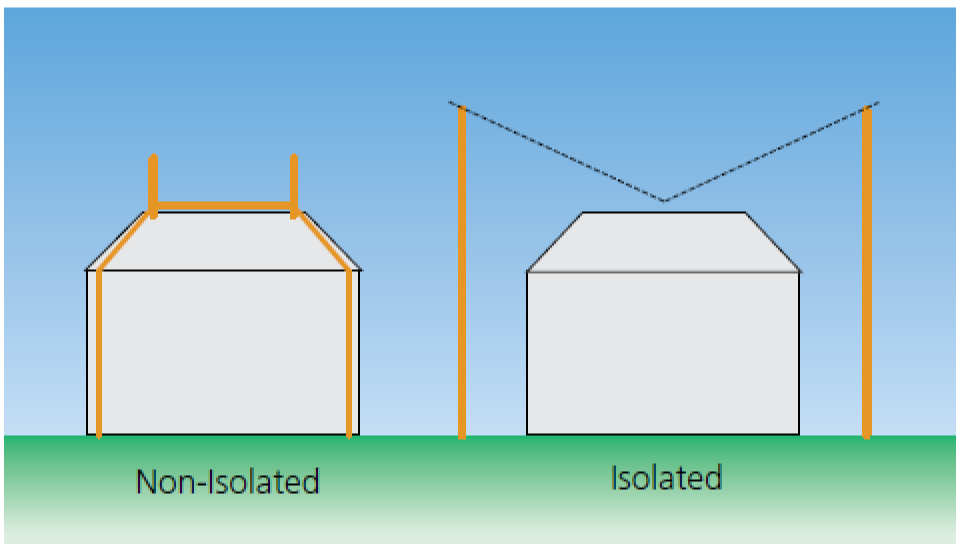
The design of a lightning protection system needs to:

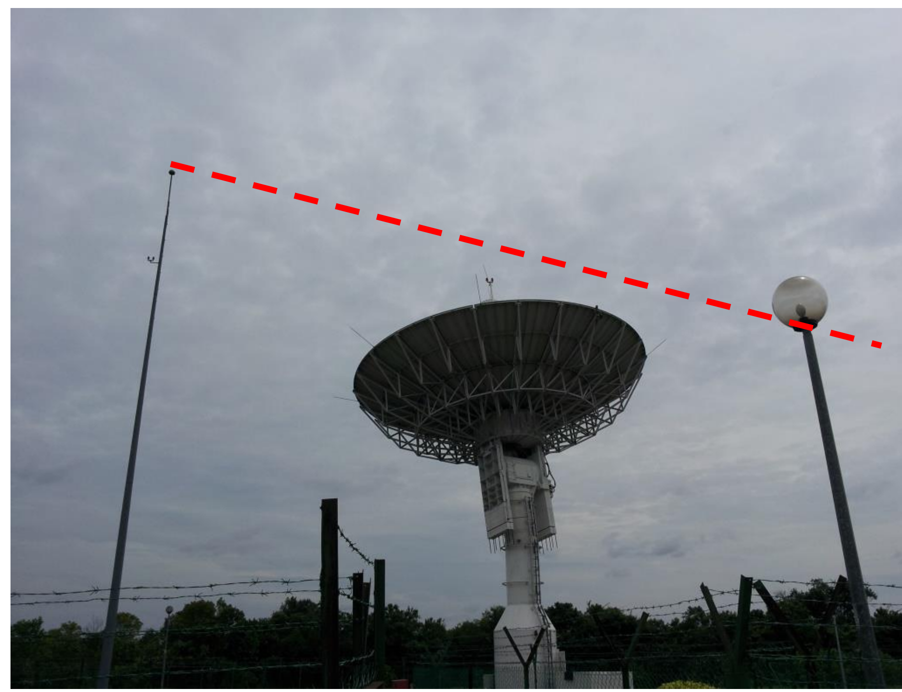
- Intercept lightning flash (i.e. create a preferred point of strike)
- Conduct the lightning current to earth
- Dissipate current into the earth
- Create an equipotential bond to prevent hazardous potential differences between LPS, structure and internal equipment/circuits

3.3 LPS Design

Protection Methods & Risks

- Lightning protection systems typically follow two approaches:



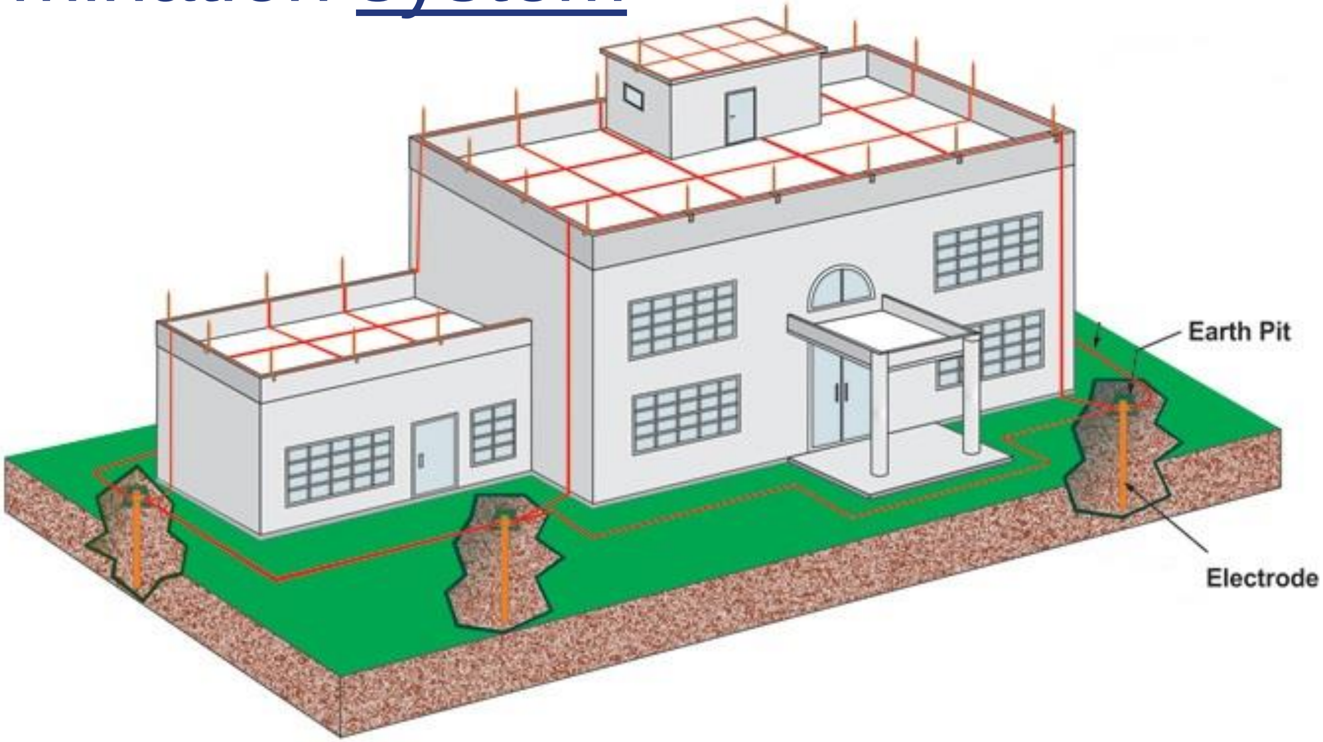


3.3 LPS Design

A. Air termination system

B. Down conductor system

C. Earth termination system



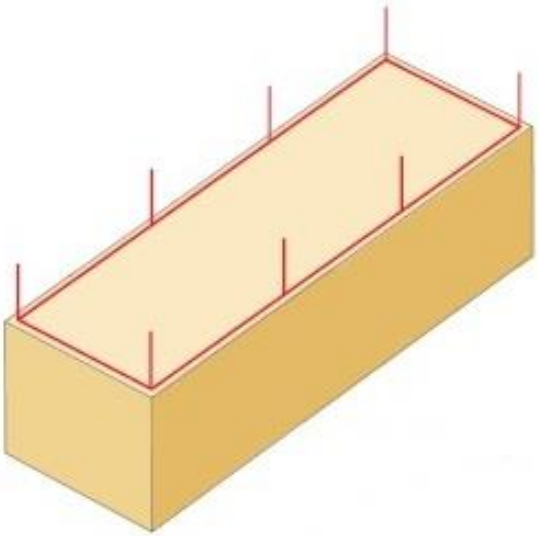
3.3 LPS Design

- A. Air termination system

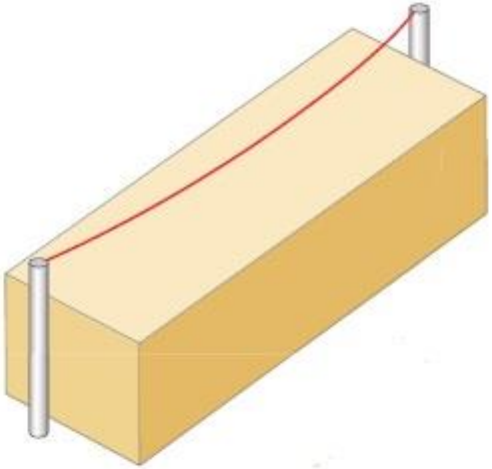
Components

1. Rods
   - the individual rods should be connected together at roof level to ensure current division
2. Catenary wires
3. Mesh conductors
4. Natural air termination components (metal sheets, railings, coverings of parapets, metal pipes, tanks)

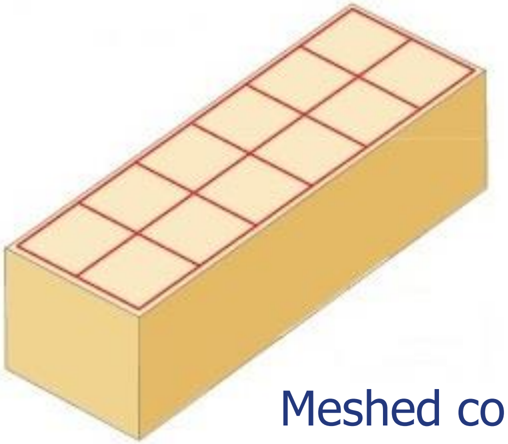
3.3 LPS Design



Air rods (finials)



Catenary (or suspended) wires



Meshed conductors

3.3 LPS Design

Natural air termination components

Material	Minimum thickness (mm)	
	Puncturing, hot spot or ignition *not* permitted	Puncturing, hot spot or ignition permitted
Lead	Not suitable	2
Steel	4	0.5
Titanium	4	0.5
Copper	5	0.5
Aluminum	7	0.65
Zinc	Not suitable	0.7

3.3 LPS Design

Air rod

3.3 LPS Design

- A. Air termination system

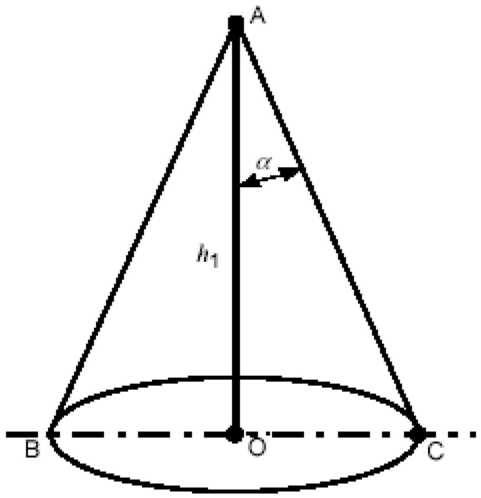
Methods for determining the POSITION of the Air Termination System

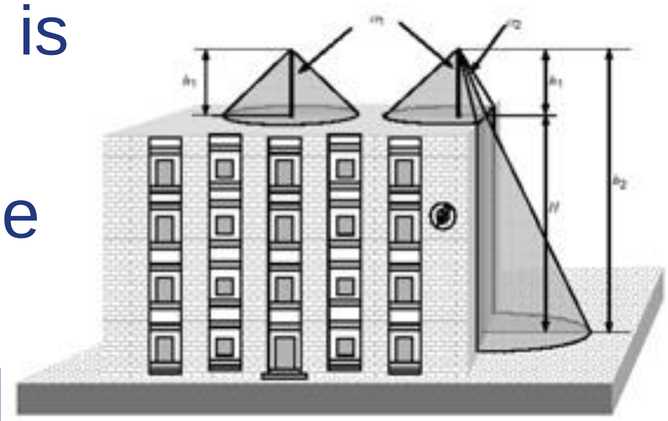
1. Protection angle method
   - subject to limits in Figure below
2. Rolling sphere method
   - suitable in all cases
3. Mesh method
   - suitable for flat surfaces

3.3 LPS Design

1. Protection angle method (PAM)

- Developed by Gay Lussac in 1823
- Air terminal/rod provide a protection zone in the shape of an imaginary cone
- Lightning will attach on the tip of the cone
- Objects within the imaginary cone is protected from lightning strokes
- Method was found to be unsuitable for highrise structures

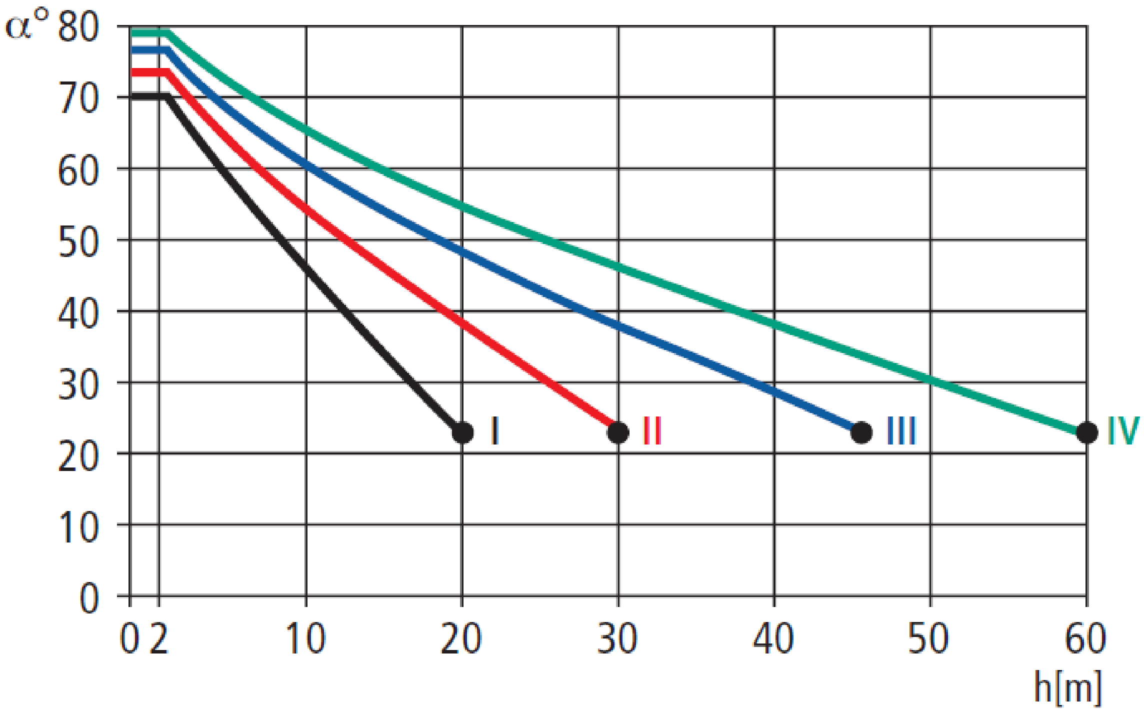




[Note: Diagrams from IEC 62305]

3.3 LPS Design

1. Protection angle method



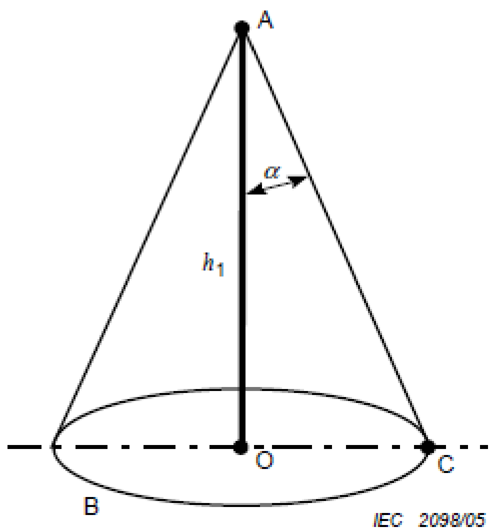
Note 1 : Not applicable beyond the values marked with • Only rolling sphere and mesh methods apply in these cases

Note 2 : h is height or air-termination above the reference plane of the area to be protected.

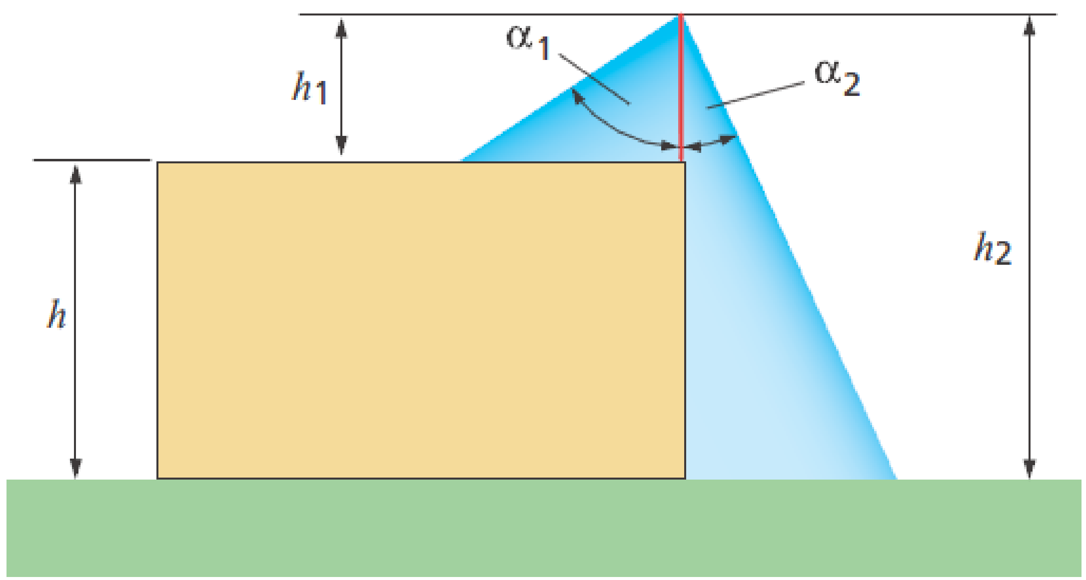
Note 3 : The angle will not change for values of h below 2m

3.3 LPS Design

1. Protection angle method



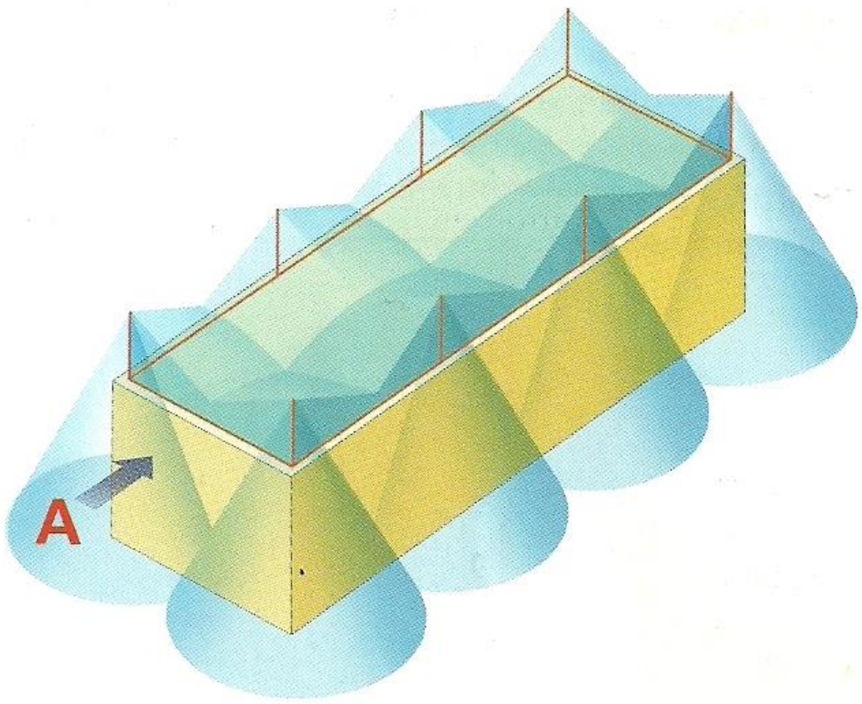
A – tip of air terminal
B – reference plane
OC – radius of protected area
h_1 – height of an air terminal above the reference plane of the area to be protected
a – protective angle according to **Table 1**

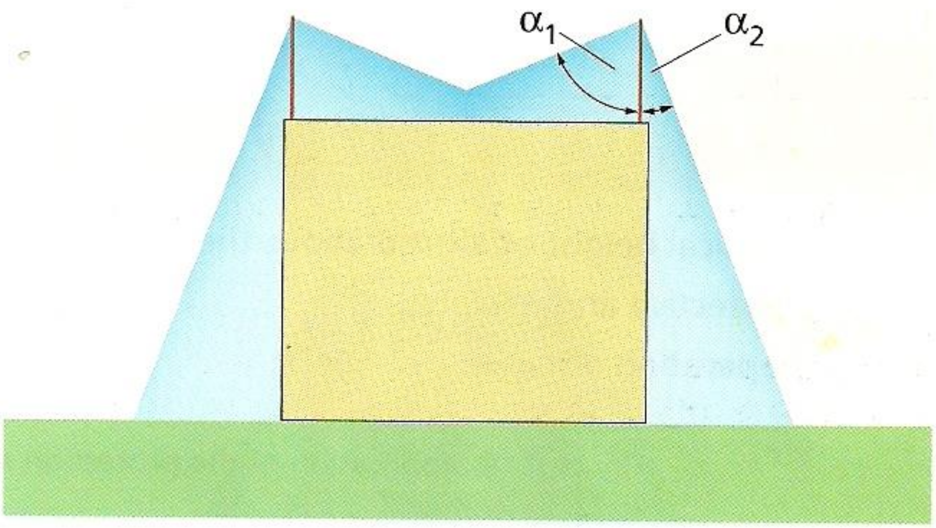


Protective angle according to Table 1 is a change to the simple 45^0 zone of protection in BS 6651

3.3 LPS Design

1. Protection angle method



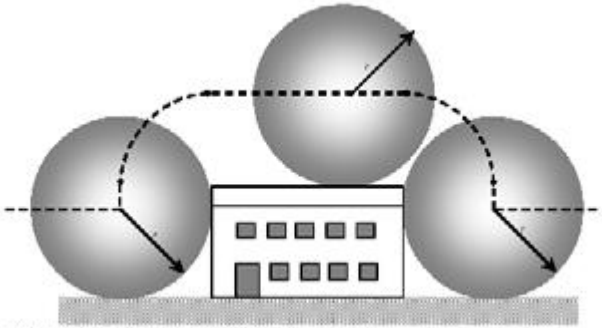


View from **A**

3.3 LPS Design

2. Rolling sphere method (RSM)

- Developed by Dr. Tibor Horvath in 1950s
- An imaginary sphere is rolled over and around the structure to be protected
- Radius of sphere equal to striking distance
- Parts of structure touched by imaginary sphere are at risk of being struck by lightning
- Applied in international standards since 1970s



r Radius of the rolling sphere according to Table 2

Figure E.21a – Side view

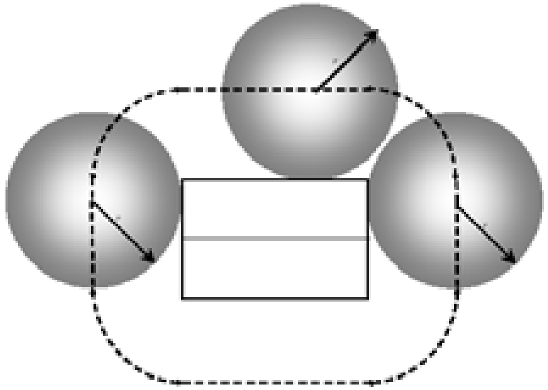
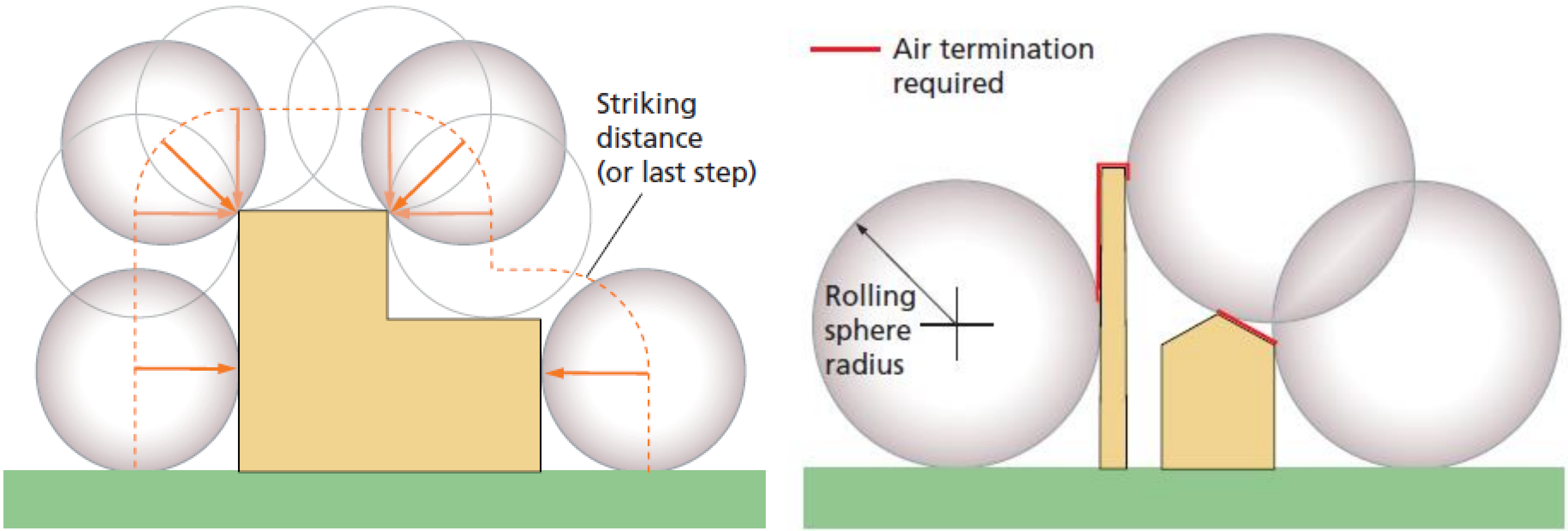


Figure E.21b – Plan view

[Note: Diagrams from IEC 62305]

3.3 LPS Design

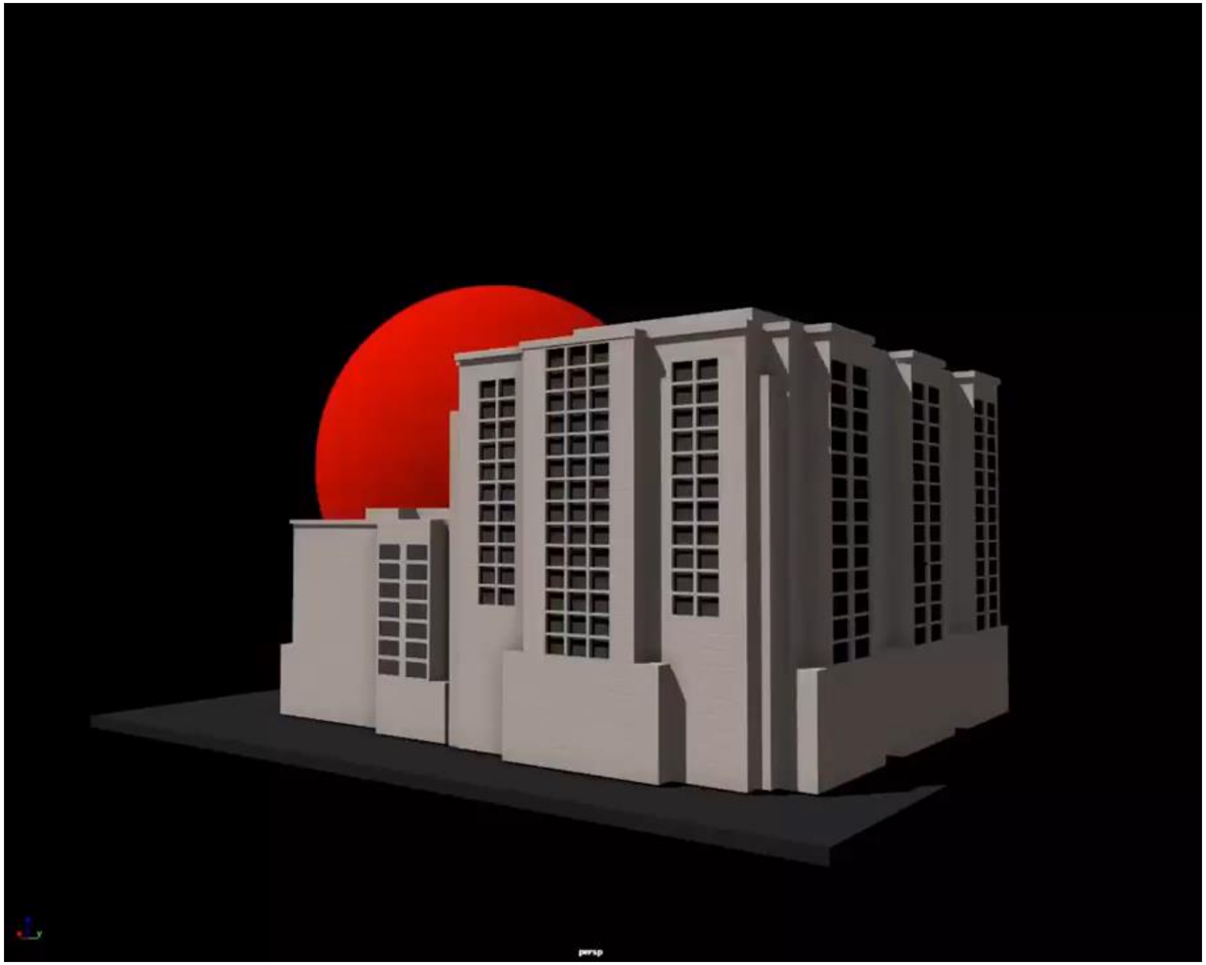
2. Rolling sphere method



Class of LPS	Rolling sphere radius *r* (m)
I	20
II	30
III	45
IV	60

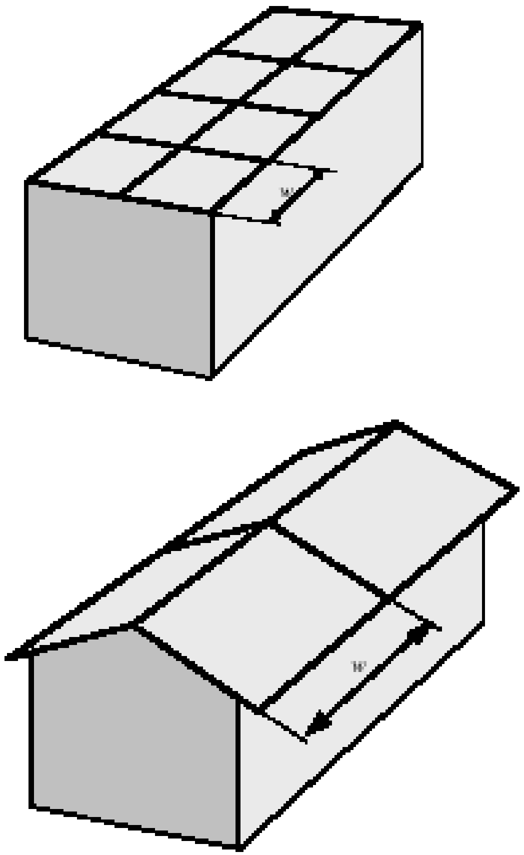
3.3 LPS Design

2. Rolling sphere method (RSM)



3. Mesh method (MM)

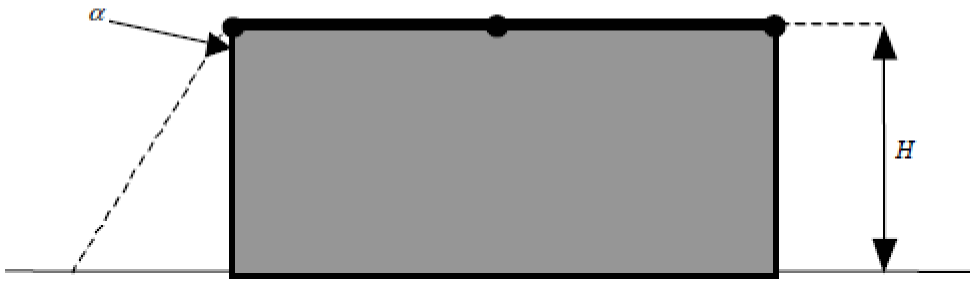
- Developed by J.C. Maxwell in 1876
- Lightning will attach to the grid instead of the structure
- Method was found to be very costly and degrade the aesthetics of the structure

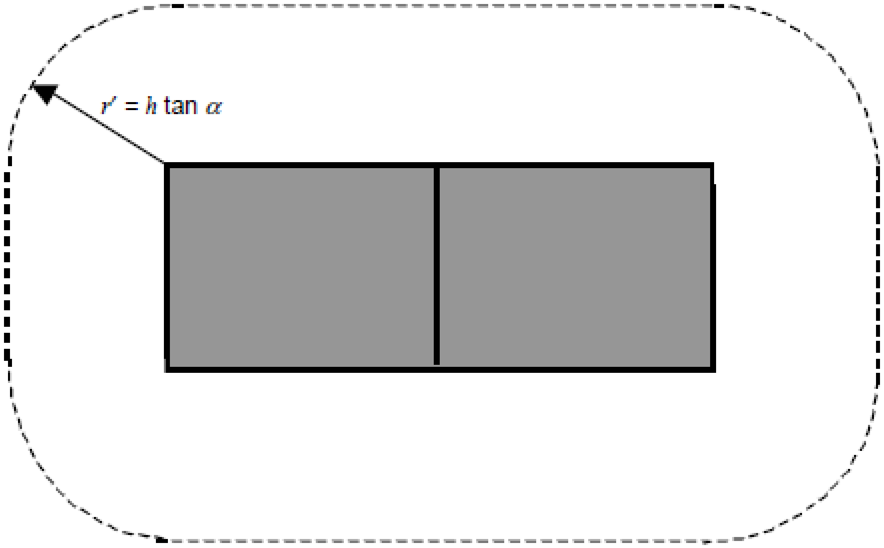


[Note: Diagrams from IEC 62305]

3.3 LPS Design

3. Mesh method





Class of LPS	Mesh size W (m)
I	5 x 5
II	10 x 10
III	15 x 15
IV	20 x 20

3.3 LPS Design

- B. Down conductor system
  - There should always be a min. of 2 down conductors distributed around the perimeter of the structure
  - Down conductors should wherever possible be installed at exposed corner of the structure
  - An equal spacing of the down conductors is preferred around the perimeter
  - It is also good practice for the upper section of the conductor entering into the earth to be insulated. 3 mm thick PVC protecting the first 2-3 m of conductor

3.3 LPS Design

- Typical values of the distance between down-conductors

Class of LPS	Typical Distances (m)
I	10
II	10
III	15
IV	20

3.3 LPS Design

Components

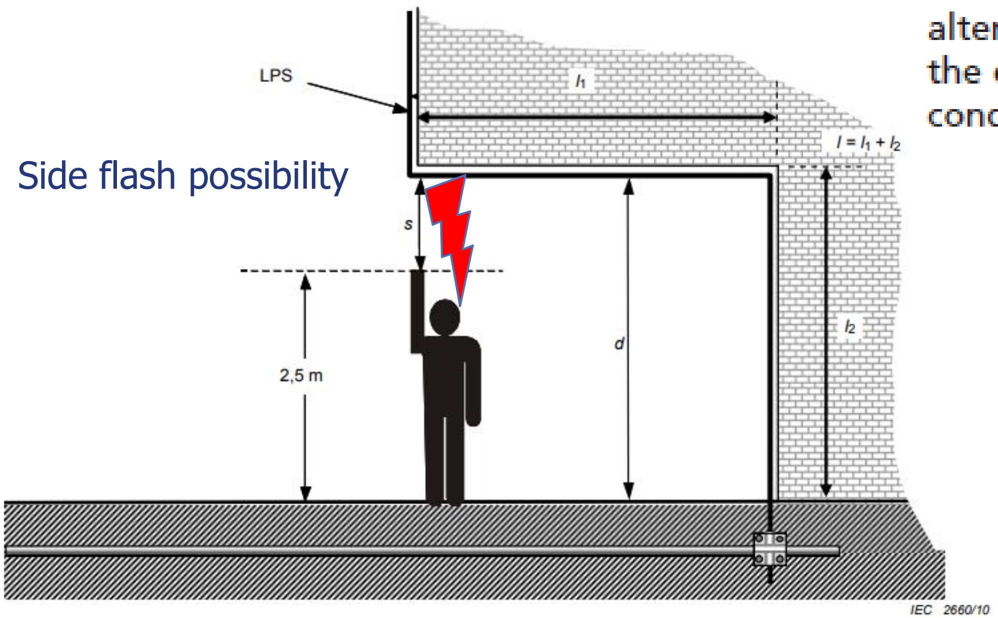
1. Copper tapes, aluminium tapes, galvanized steel wires, stainless steel
2. Natural down conductors (metal of the reinforced concrete, steel framework)
   - » The electrical continuity of the reinforcing bars shall be determined by electrical testing between the uppermost part and ground level
   - » The overall electrical resistance should not be greater than 0.2 Ω
   - » If this value is not achieved, or it is not practical to conduct such testing, the reinforcing steel shall not be used as a natural down-conductor

3.3 LPS Design

- Structure with a cantilevered part

3.3 LPS Design

- Structure with a cantilevered part



To reduce the risk of the person becoming an alternative path for the lightning current to that of the external down conductors, then the following condition should be satisfied:

Class of LPS	k_i
I	0.08
II	0.06
III & IV	0.04

Material	k_m
Air	1
Concrete, bricks, wood	0.5

No. of down-conductors	k_c
1	1
2	0.66
3 and more	0.44

$$d > 2.5 + s$$

$$s = \frac{k_i}{k_m} \times k_c \times l$$

$$l = l_1 + l_2$$

3.3 LPS Design

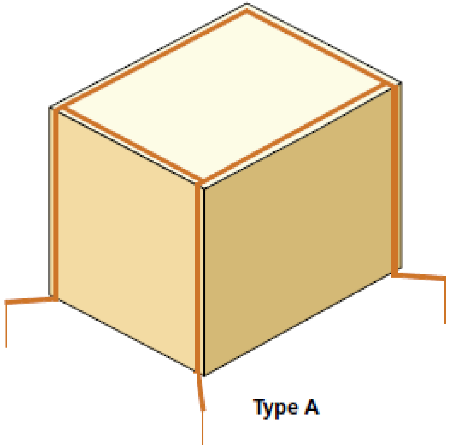
Natural down conductor

3.3 LPS Design

- C. Earth termination system
  - A low earthing resistance is required (with an overall earth termination system of ≤ 10 Ω)
  - 3 basic earth electrode arrangements:
    - Type A arrangement
    - Type B arrangement
    - Foundation earth electrodes

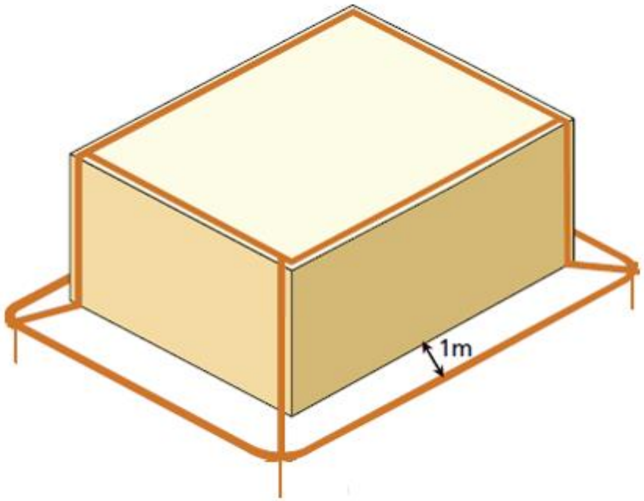
3.3 LPS Design

- Type A arrangement
  - Consist of vertical earth electrodes, connected to each down conductor fixed on the outside of the structure
  - The horizontal copper tapes shall be buried at a depth ≥ 0.5 m
  - If the 10 Ω value cannot be achieved, it will be necessary to use a Type B ring earth electrode



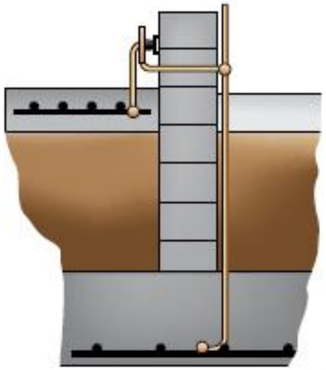
3.3 LPS Design

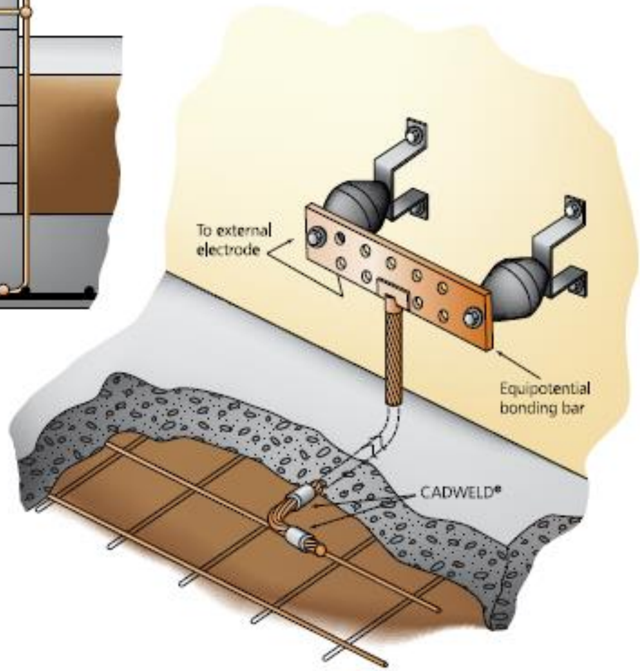
- Type B arrangement
  - Comprise a ring conductor external to the structure
  - The ring copper tapes shall be buried at a depth ≥ 0.5 m
  - Type B arrangement should preferably be buried at a distance of about 1 m around the external walls



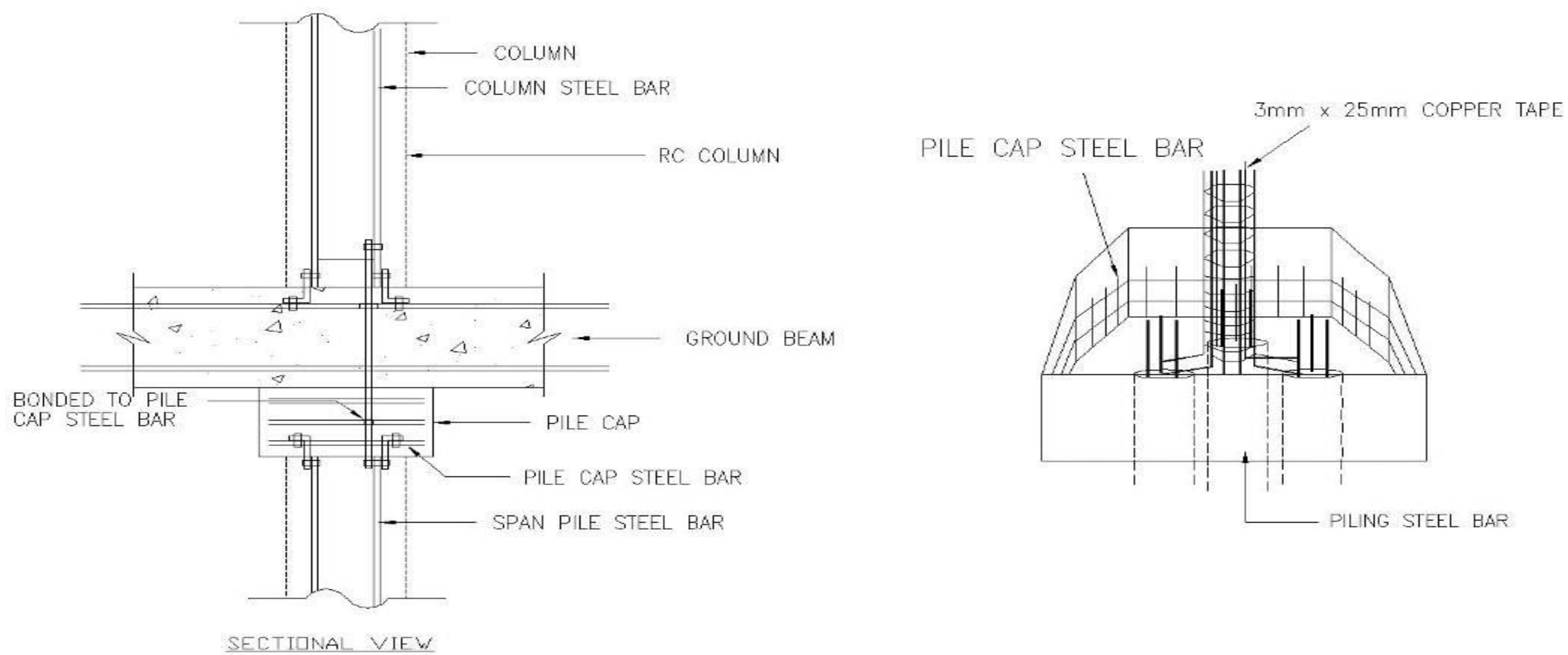
3.3 LPS Design

- Foundation earth electrodes
  - This is essentially a type B earthing arrangement
  - Interconnected reinforcing steel in concrete foundations





3.3 LPS Design

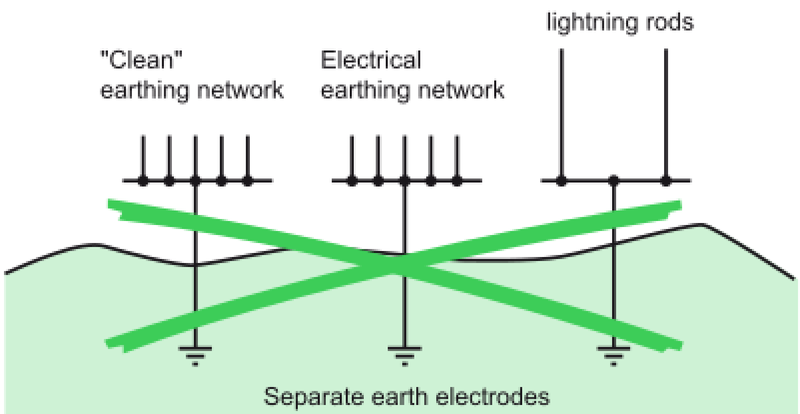


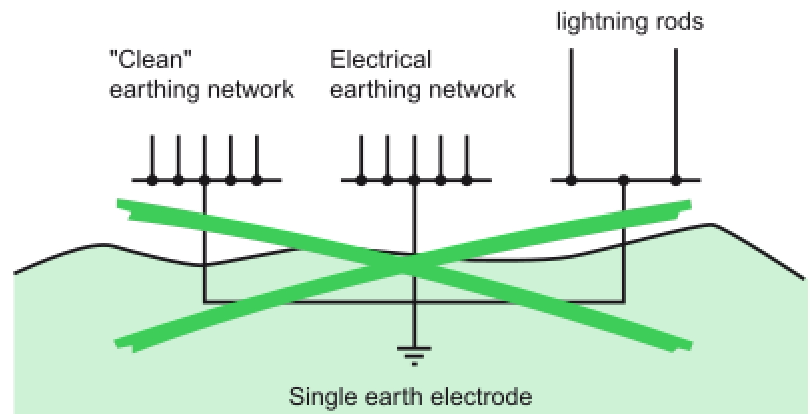
Detail connection at pile electrode

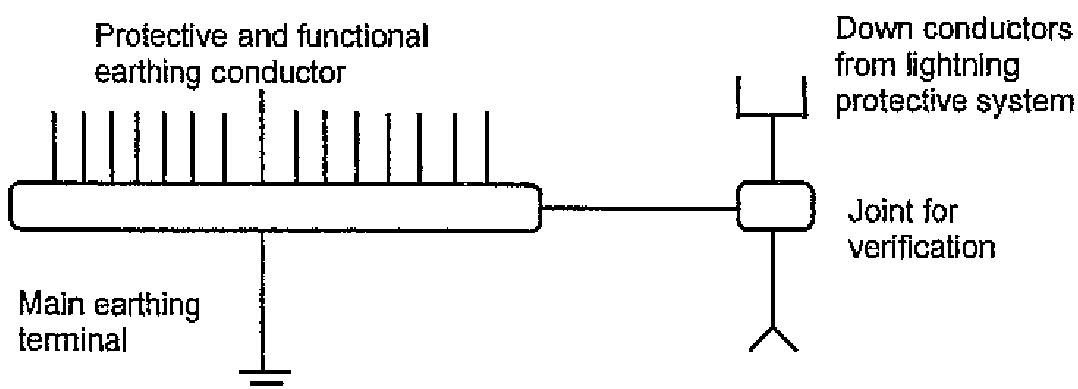
Earth Termination System : Using Steel Piles as an Earth Electrodes

3.3 LPS Design - Interconnection of Earth Electrodes

IEC 60364-4-44:2007 - Protection against voltage disturbances and electromagnetic disturbances





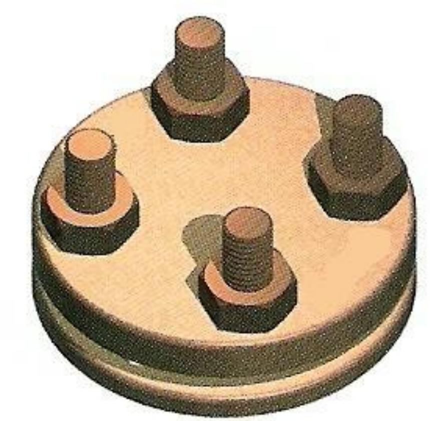


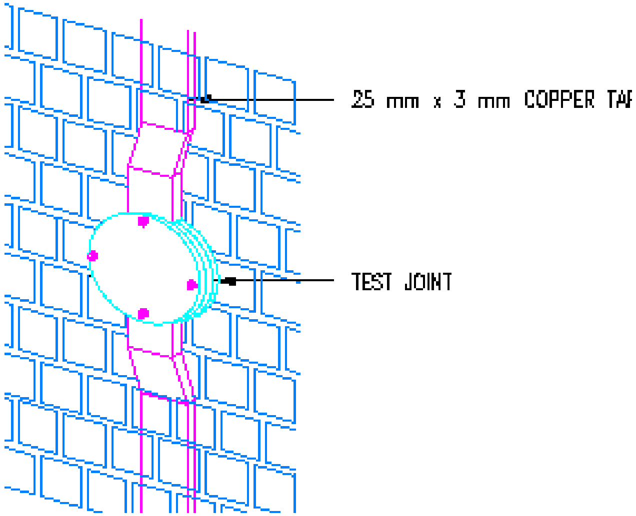
Interconnected earth electrodes

3.4 LPS Components

Selection of components such as rods and clamps shall conform to IEC 62561

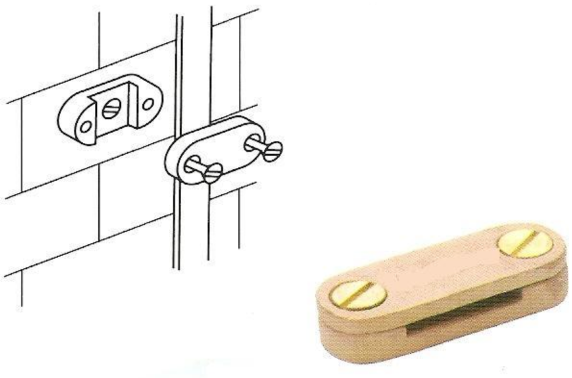
- Testing joints
  a) At each down conductor
  b) Installed at 2500 mm above ground level



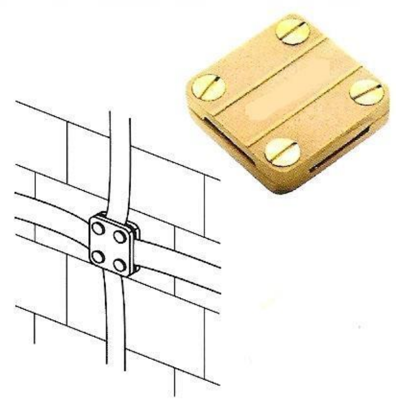


3.4 LPS Components

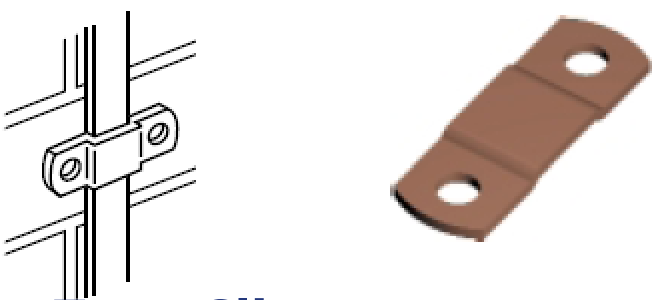
- Made of copper, naval brass or gunmetal



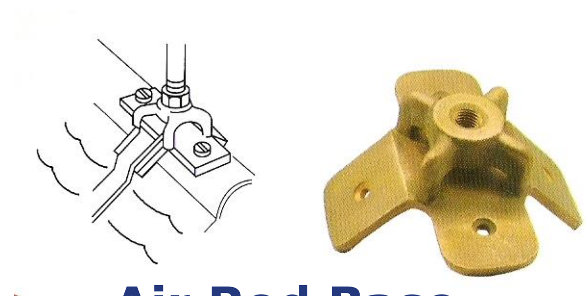
DC Tape Clip



Square Clamp



Tape Clip



Air Rod Base

3.4 LPS Components

Adhesive DC tape clip
Use on metal deck roof

3.5 Materials & Dimensions

Copper versus aluminum

- Aluminium has the advantage of lower cost. Its lighter weight
- However, aluminium is less compatible with many building materials and can not be buried in the ground. Therefore, most lightning protection systems are entirely copper
- As aluminium and copper are not compatible, a bimetallic joint should be used to interconnect these two materials.

3.5 Materials & Dimensions

LPS materials and conditions of use

Material	Use			Corrosion		
	In open air	In earth	In concrete	Resistance	Increased by	May be destroyed by galvanic coupling with
Copper	Solid Stranded	Solid Stranded As coating	Solid Stranded As coating	Good in many environments	Sulphur compounds Organic materials	–
Hot galvanized steel	Solid Stranded	Solid	Solid Stranded	Acceptable in air, in concrete and in benign soil	High chlorides content	Copper
Stainless steel	Solid Stranded	Solid Stranded	Solid Stranded	Good in many environments	High chlorides content	–
Aluminium	Solid Stranded	Unsuitable	Unsuitable	Good in atmospheres containing low concentrations of sulphur and chloride	Alkaline solutions	Copper
Lead	Solid As coating	Solid As Coating	Unsuitable	Good in atmosphere with high concentration of sulphates	Acid soils	Copper Stainless steel

3.5 Materials & Dimensions

Material, configuration and minimum csa of air-termination conductors, air-termination rods and down-conductors

Material	Configuration	Minimum cross-sectional area mm²	Comments [10]
Copper	Solid tape	50 [8]	2 mm min. thickness
	Solid round [7]	50 [8]	8 mm diameter
	Stranded	50 [8]	1,7 mm min. diameter of each strand
	Solid round [3], [4]	200 [8]	16 mm diameter
Tin plated copper [1]	Solid tape	50 [8]	2 mm min. thickness
	Solid round [7]	50 [8]	8 mm diameter
	Stranded	50 [8]	1,7 mm min. diameter of each strand
Aluminium	Solid tape	70	3 mm min. thickness
	Solid round	50 [8]	8 mm diameter
	Stranded	50 [8]	1,7 mm min. diameter of each strand
Aluminium alloy	Solid tape	50 [8]	2,5 mm min. thickness
	Solid round	50	8 mm diameter
	Stranded	50 [8]	1,7 mm min. diameter of each strand
	Solid round [3]	200 [8]	16 mm diameter
Hot dipped galvanized steel [2]	Solid tape	50 [8]	2,5 mm min. thickness
	Solid round [9]	50	8 mm diameter
	Stranded	50 [8]	1,7 mm min. diameter of each strand
	Solid round [3], [4], [9]	200 [8]	16 mm diameter
Stainless steel [5]	Solid tape [6]	50 [8]	2 mm min. thickness
	Solid round [6]	50	8 mm diameter
	Stranded	70 [8]	1,7 mm min. diameter of each strand
	Solid round [3], [4]	200 [8]	16 mm diameter

3.6 Separation Distance

$$s = \frac{k_i}{k_m} \times k_c \times l$$

where

k_i = factor that depends on the selected class of LPS

k_m = factor that depends on the electrical insulation material

k_c = factor that depends on the lightning current flowing on the air-termination and the down- conductor

l = length, along the air-termination and the down-conductor from the point, where the separation distance is to be considered, to the earth termination

3.6 Separation Distance

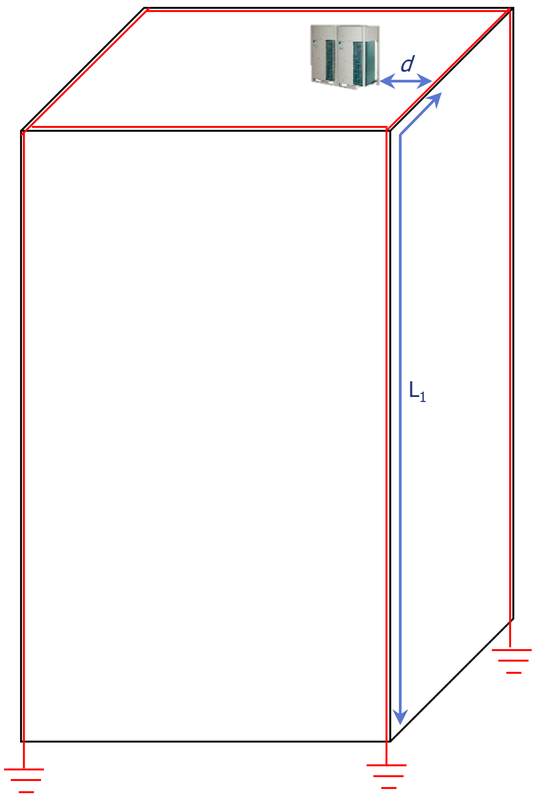
$$s = \frac{k_i}{k_m} \times k_c \times l$$

$$l = d + L_1$$

Class of LPS	k_i
I	0.08
II	0.06
III & IV	0.04

Material	k_m
Air	1
Concrete, bricks, wood	0.5

No. of down-conductors	k_c
1	1
2	0.66
3 and more	0.44



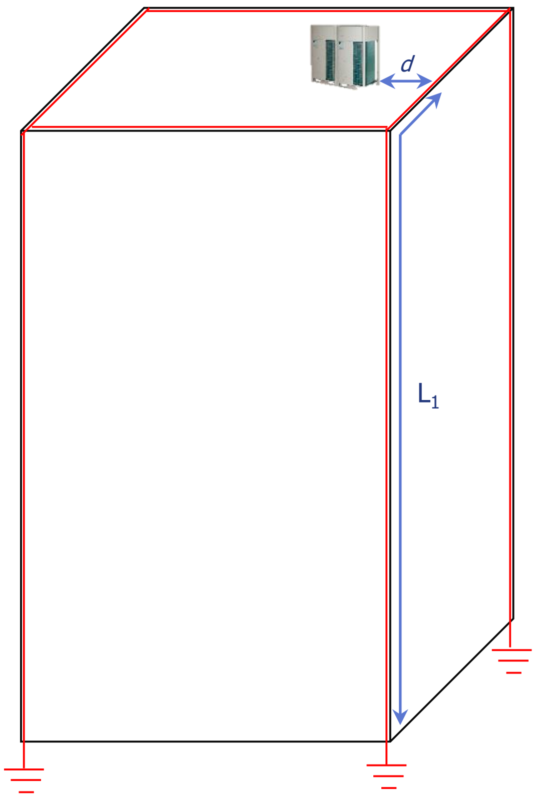
3.6 Separation Distance

$$s = \frac{k_i}{k_m} \times k_c \times l$$

$$l = d + L_1$$

Bond if s > *d*

Copper – 6mm2
Aluminium – 8mm2
Steel – 16mm2



3.6 Separation Distance

$$s = \frac{k_i}{k_m} \times k_c \times l \qquad l = d + L_1$$

Bond if s > *d*

Example

The building with 4 down conductors protects a 20 m high building with lighting protection level I

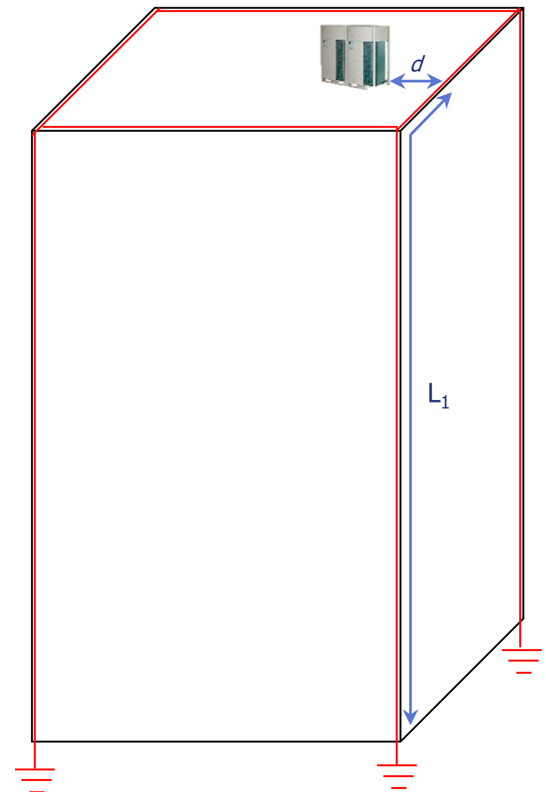
Question:

Should an air conditioning outdoor unit located on the roof be interconnected if 3 m away from the air termination network? Length L_1 = 25 m

Answer:

s = 0.08 x 0.44 x 25 / 1 = 0.88 m

Since the distance (3 m) between the conductor and the air conditioning system is greater than the separation distance (0.88 m), there is no need to interconnect this outdoor unit



3.6 Separation Distance

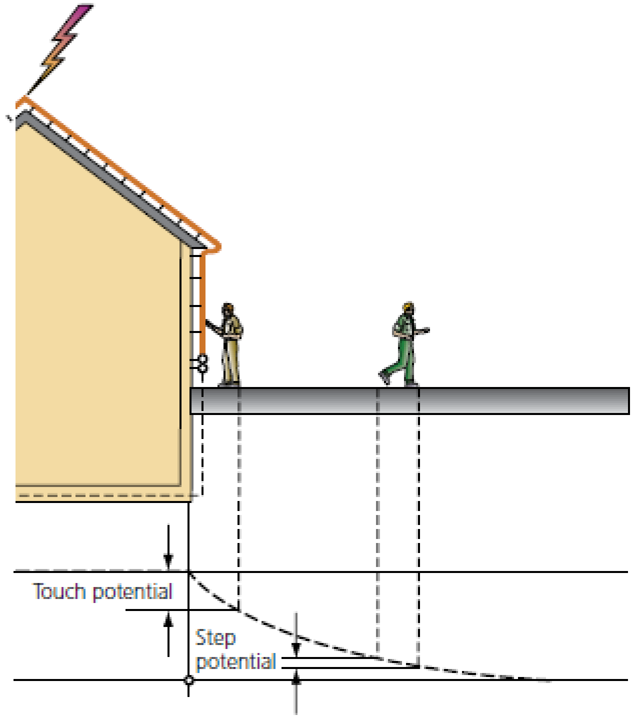
3.7 Protection Against Touch & Step Voltages

Main protection measures against injury to living beings due to touch and step voltages are intended to:

- reduce the dangerous current flowing through bodies by <u>insulating</u> exposed conductive parts, and/or by <u>increasing the surface soil resistivity</u>
- reduce the occurrence of dangerous touch and step voltages by <u>physical restrictions</u> and/or <u>warning notices.</u>

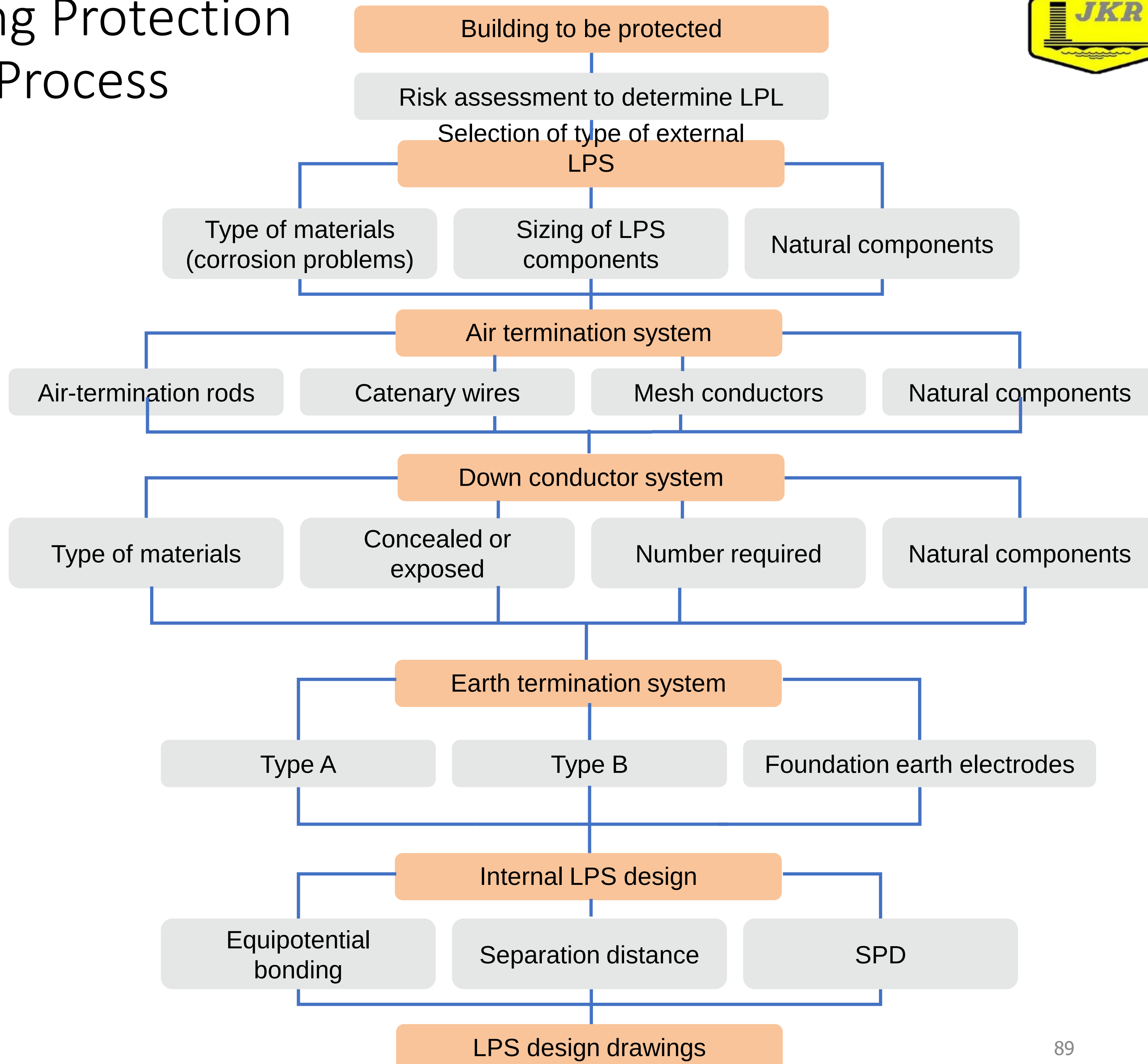
3.7 Protection Against Touch & Step Voltages

- The voltage difference exists between the hand and feet.
- The hazard is considered to be reduced if:
  - The probability of persons approaching, or duration of presence is very low – limiting access to the area can be a solution
  - Natural down-conductors (building façades) are used where extensive metal framework or steel work is interconnected
  - A surface layer with ≥ 5 k ohm.m insulating barrier such as 50 mm of asphalt (bitumen) or 150 mm of gravel (*batu kerikil*) is used
  - The down-conductor is insulated with at least 100 kV 1.2/50 μs impulse insulation (3 mm PVC)



3.7 Protection Against Touch & Step Voltages

3.8 Lightning Protection Design Process



3.9 Site Coordination

Regular consultation between Electrical Engineers, Architects, C&S Engineers, Mechanical Engineers and Contractors is essential in order to achieve the best result

3.9 Site Coordination

Coordination between Test Joint and Rainwater Pipe

3.10 MISCONCEPTIONS ABOUT LIGHTNING

- Most common misconceptions are:
  - "Lightning always strike the highest part of a structure"
  - "Air terminals always attract lightning"
  - Metal rebars in structures attract lightning and cause more damages to structures
  - Air terminals must be positioned away from corners and edges
  - Non-conventional air terminal technologies are new and effective

*CIGRE C4 Colloquium 2010, Kuala Lumpur

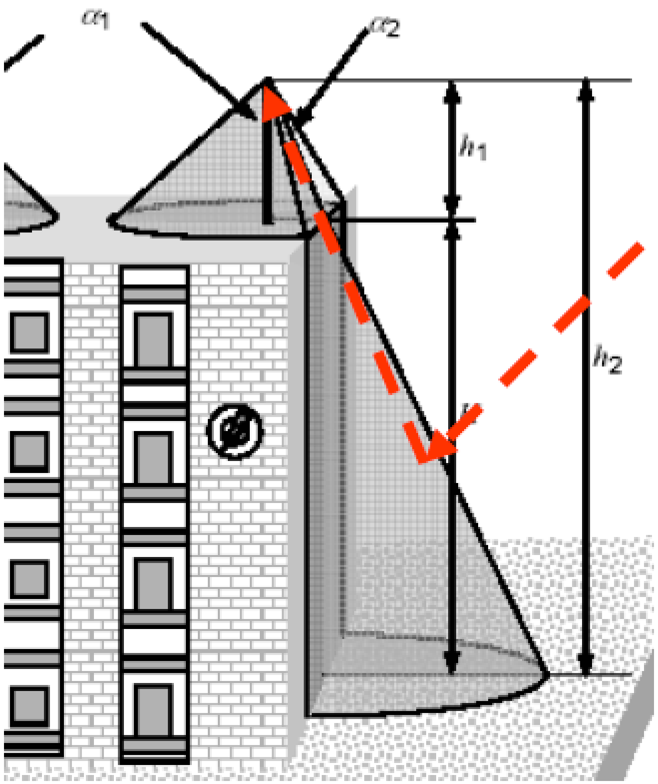
3.10 MISCONCEPTIONS ABOUT LIGHTNING

- Impact:
  - More engineers believed that air terminals can attract lightning
  - More engineers disregard the use of lightning protection standards
  - More engineers look for non-conventional air terminal technologies

*CIGRE C4 Colloquium 2010, Kuala Lumpur

3.10 MISCONCEPTIONS ABOUT LIGHTNING

- Impact:
  - "A stepped leader entering the cone will be attracted to the air terminal"



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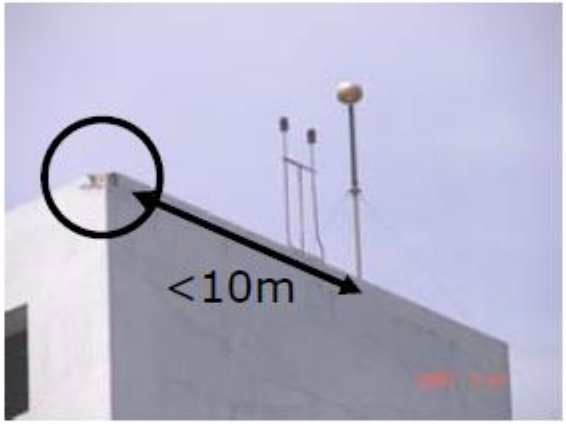
3.10 MISCONCEPTIONS ABOUT LIGHTNING

Misconception: “Air terminals must be positioned away from corners and edges”



Significant number of bypasses occurred within ESE claimed zone of protection

*CIGRE C4 Colloquium 2010, Kuala Lumpur

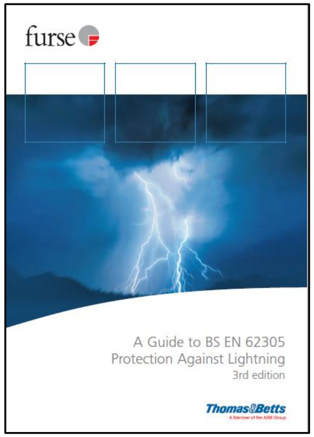
3.11 Non-conventional LPS

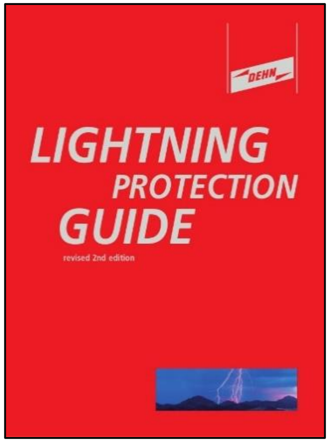
What is not lightning protection?

- Early Streamer Emission – ESE
  - Radioactive
  - Pulse Voltage
  - Sparking – Controlled Leader Trigger (CLT)
- Lightning Elimination
  - Dissipation Array System (DAS)
  - Charge Transfer System (CTS)
- Not allowed by
  - ST
  - NFPA
  - IEEE
  - IEC
  - US Military
  - Underwriter Laboratory (UL)

Further Reading

- “A Guide to BS EN 62305:2006, Protection Against Lightning”, U.K: Thomas & Betts
- “Lightning Protection Guide”, 2nd Updated Edition, Germany: Dehn and Sohne, 2007
- “Panduan Sistem Perlindungan Kilat di Bangunan”: Suruhanjaya Tenaga





Terima Kasih