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Post-Show Report

ELROMA 2021

"Smart Efficient Rotating Machines and Control Solutions for a Greener World"

Digi lec Bharat
2nd Edition
20th - 26th October, 2021


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COVID-19
Stay Safe

Lightning and Protection

for Humans (& Animals) from Lightning

Introduction and Relevance

Lightning is certainly a very frequent and spectacular event of nature. Everyone would have seen it many many times. The actual number in any area seen by a person depends on the age (!) and region of the country. Globally speaking, it is estimated that there will be about 1400 million lightning flashes per year. Even if it is seen from a large distance, say a few km, the abruptness, brilliance, branched & zigzag nature, ear-splitting thunder and also multiple strokes in quick succession make it both fearsome and awe-inspiring. See Fig.1. If it occurs close by, it will be totally mind-blogging and awfully fearsome. Other than these, lightning has been causing many painful, life-long debilitating injuries as well as deaths.

It is estimated that in India, the number of deaths due to lightning –about 2000 to 3000 per year – is more than due to any other natural calamity. In view of this, in the present article, an effort is made to briefly explain the physics of the phenomena finally leading to lightning, how it causes lifelong debilitating injuries, often resulting in death. More importantly, approaches to avoid such tragic events are also presented.

However, before going on to these aspects, it will set a relevant background to briefly go through some relevant information on global lightning stroke data and the types of injuries including their extremely painful, life-long nature.

It has been estimated that globally (based on field data), about 35 to 45 lightning strokes occur every second, of course, distributed over the entire world. The actual number significantly varies from country to country, region to region within a country and has seasonal variations. Only well developed countries have been active in collecting reliable data.

For example:

In USA, every year, over the past few years, about 25 million cloud to ground lightning strokes occurred, injuring about 300 and causing 25 to 30 fatalities.

In Britain, on the average, 30 to 60 people are injured by lightning of which about 3 persons die and

In Japan, average death-rate is about 14 per year. It was 20 deaths in 2004.

It may appear that the above numbers are small but it should be noted that persons in these countries have been educated about how to effectively avoid injuries and deaths due to lightning. Before practice of such precautionary measures, the number of injuries and deaths were much higher. Probably the numbers were 10 times higher.

In India, data on the number of lightning strokes per year is not available. However, it is reported that, since 2005, about 2000 to 3000 people die every year. The number of injuries are not known. It should be now clear how essential it is to adopt precautionary measures to significantly reduce this huge number of deaths/injuries.

Some specific information of interest (from Newspapers, and TV broad casts) are given below:

April 16, 2016 – 41000 lightning strokes across India

June 2016 – 93 persons killed and 20 injured in Bihar, Jharkhand, UP & MP

April 26, 2018 – In Andhra Pradesh, in a 13-hour period, 35,479 lightning strokes reported.

2018 – Estimated more than 3000 people died across India

Since May 15, 2020 lightning strikes have killed 315 in Uttar Pradesh and Bihar

Fig. 1 Photographs of typical Lightning Strokes (source: Internet)

Types of Injuries Caused by Lightning

From the data given above for developed countries injury cases are approximately 10 times the number of fatalities. Information on injuries due to lightning is not available for India. If we apply same ratio of 10, the average number of lightning-injuries in India should be around 20,000 to 30,000 per year. In the absence of real-life field-data, it is difficult to accept this alarmingly large number. Also, in India, the types and nature of injuries and fatalities do not seem to have been recorded. However, the types of injuries and consequences may be safely assumed to be similar to those in the developed countries.

The types of injuries in USA have been made available by National Weather Service of USA. The injuries are spread over a wide range. As mentioned earlier, these injuries are most often permanent -- lifelong or frequently recurring. Also, they make life highly painful and miserable. It is therefore essential to appreciate how to protect oneself from such injuries and possible fatality. Presently, the types of injuries are listed and in a later section it will be discussed in some detail as to how to avoid injuries caused by lightning.

Types of Injuries

Burns – horrible looking, both internal and external – accompanied by one or more of the following:

Excruciating, mostly constant or frequently recurring pains; Headaches, fatigue, numbness, depression, brain-fag, memory loss (temporary or frequently recurring), dizziness, constant (24 x 7) ringing or buzzing in the ears, hearing loss, anger-issues, loss of concentration, coma, temporary loss of speech, taste-buds changing after some time,

Joint and muscle pains, fractured vertebrae, pain in hips and back. Legs & feet tingle and numb, swellings in upper back, chest and neck, frontal lobe-damages; Neuropathy, fibromyalgia (constant pain in fibrous and muscular tissues of the body in one or several regions, mainly in the back), initial paralysis (may improve after some time), Insomnia; Apraxia due to brain damage (involves inability to carry out certain specific skilled activities such as use of fingers, use of lips, etc), Petit-mal seizures (occasional, unpredictable brief loss of consciousness), which can obviously be very dangerous. (these are also known as 'Absence Seizures'). Rarely, Psychic Abilities (ability to foresee).

This has been compiled from an article (published in internet) by National Weather Service of USA. See Fig.2 for some typical injuries.

As stated earlier, it is simply horrendous to suffer such life-long injuries. It is therefore extremely important to know possible methods of avoidance. These will be presented after a brief look at the phenomena of lightning which will enable us to appreciate the methods of avoidance.

Fig. 2 Photographs of more severe type of injuries due to Lightning (Source: Internet)

Basic Phenomena of Lightning

Benjamin Franklin and His Kite Experiment

Any article about lightning should recall Benjamin Franklin and his invaluable contributions based on his 'Kite Experiment', and the conclusions and applications thereof. On June 15, 1752, he conducted his famous kite experiment in which he flew a kite while positioning himself under a roof and standing on an electrically insulating object. It was raining under thunderstorm weather with distinct possibility of occurrence of lightning. The roof prevented him from getting wet while the twine (of the kite) got wet. Under the influence of thunder clouds overhead, there were intermittent discharges (sparks) along the wet twine. When he connected the twine to a Leyden Jar (probably the earliest form of the electric battery), it got charged. This absolutely and unambiguously demonstrated the electric nature of lightning.

By further astute thinking, Benjamin Franklin conceptualized that a tall metallic pole erected on mother earth can attract lightning to itself thereby protecting the immediate surroundings from the disastrous effects of direct stroke of lightning. The pole also forms a convenient and easy path to earth for the huge

lightning currents. Such metallic poles (rods) are very aptly and commonly referred to as 'Franklin Rods' or Lightning Rods.

Franklin used such rods for protection of his own house and later (in 1752 itself) the Academy of Pennsylvania (later University of Pennsylvania) and Pennsylvania State House. Another remarkable example of utility of Franklin Rods is the case of Campanile of St. Mark, Venice: This was damaged/destroyed by lightning in the years 1388, 1417, 1489, 1548, 1565, 1653, 1745, 1761 and 1762. In the year 1762, Franklin Rods were installed and no further lightning –damages!

There are many more examples of averting serious to very serious damages by lightning using such Franklin Rods. Over the last several decades, based on vast field experience and analysis thereof, very useful methodologies and rules have been developed for economical and effective protection of small, large and tall buildings (commercial, residential etc;) heritage structures etc., from lightning. The main backbone is the 'Franklin Rod' or 'Lightning Rod'. (Ref. International standard, IEC 62305-Protection against lightning Part 1- General Principles, Part 2-Risk management, Part 3-Physical damage to structures and life hazard and Part 4-Electrical and electronic systems within structures and Indian counterpart standard IS 62305).

Electrification of Clouds – Root Cause of Lightning

It is now established beyond doubt that lightning is an electric phenomena and involves flow of very huge electric charges i.e., huge electric currents, luckily for a very short time. We will now briefly see how this electrification of clouds takes place.

Solar energy (sunlight) falling on the surface of earth heats it up causing (a) heating the air (and moisture inherent in it) in contact with the surface of earth and (b) vapourisation of the moisture content of earth surface. This relatively hot mixture of air, moisture and the invariably present fine dust content (aerosol particles) move up forming what is known as the 'updraft'. As this updraft reaches a height of about 2km -3km (above earth), temperature falls to around 4 oC – 0 oC and the moisture starts condensing on the aerosol particles forming superfine droplets. The whole mixture moves up and up. The temperatures gradually fall to about -40 oC to -50 oC at heights of about 14km (above earth). During this period, moisture and the superfine water droplets form large water drops, medium to large size ice crystals i.e., hailstones which start falling down under the gravitational attraction of earth.

The air itself will be having turbulent motion superposed on the updraft. These conditions, having the appropriate contents of moisture, aerosols and air having mainly an updraft and turbulence are highly conducive to electrification i.e., formation of positive and negative electrical charges. Further, these charges tend to get separated with most of the positive charges drifting upwards and most of the negative charges moving downwards (towards earth). Several theories have been formulated to explain this generation and separation of charges –positive charges drifting upwards and negative charges moving downwards. Of course, there will be some amount of charge recombination also. Obviously, the positive and negative charge distributions are not uniform and there will be regions of concentration. See Fig.3.

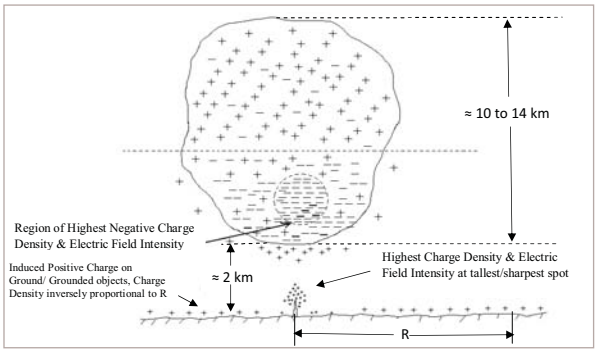

Fig. 3 Typical charge distribution in a Thundercloud and induced charge on earth and earthed objects. Not to scale

Further, the volumes of charge distributions are quite large and may spread over several kilometers. The negative charges at the bottom of the cloud induce equal positive charges on the surface of the earth and the objects below. Now, the picture of electrification of the cloud and the positive charges on the earth below is complete for our purposes and we can visualise the occurrence of lightning. Three types of Lightning are possible; they are described below.

Intra-Cloud Lightning

As the positive and negative charges separate inside the cloud, an electric field gradually builds-up. When the electric field reaches a sufficient value, a discharge (breakdown) occurs inside the cloud between the positively and negatively charged regions. This is the Intra-cloud lightning. See Fig.4. This produces momentary beautiful illumination of the cloud volume and, of course, a thunder which can be heard over fairly long distances and must be taken as a forewarning to persons on the ground of impending lightning to ground and possible undesirable effects. They should quickly move indoors, within this 'safe period' of 20 to 30 minutes.

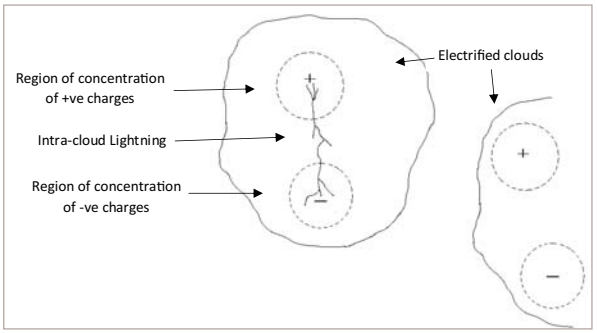

Fig.4 Intra-cloud Lightning Discharge-between the +ve and –ve charge regions of a thunder cloud

Cloud to Cloud Lightning

If the positive charge centre of one cloud is in sufficiently close proximity to the negative charge centre of an adjacent cloud, a lightning discharge can occur between them when the electric field builds up to a sufficient value. This is known as the cloud – cloud lightning or inter cloud lightning. The brilliant, multiple-branched rather horizontal zig-zag discharge path is very spectacular and accompanied by a thunder. See Fig. 5.

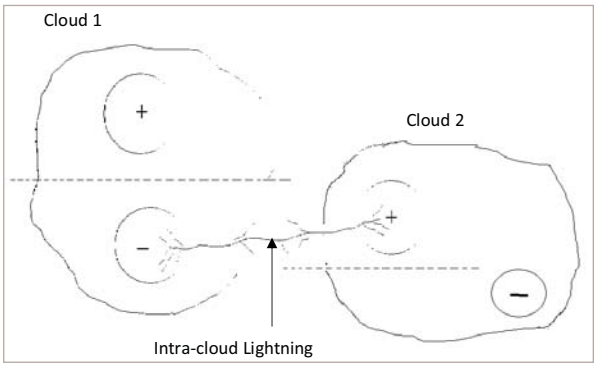

Fig.5 Inter-cloud Lightning Discharge – between negatively charged region of one cloud to positively charged region of another cloud

Cloud to Ground Lightning

This is of utmost importance to humans on the ground (and animals) and electricals/electronics inside buildings. As cloud to ground lightning has caused all the injuries and deaths to persons(animals) and other damages to properties every year, we will deal with it in some detail.

As already stated, the cloud bottom develops a large concentration of negative charges which induces an equal amount of positive charges spread out on a wide surface of earth including tall earthed objects (on earth). The tall objects include:

- Tall trees – this has been main cause of injuries/ deaths to humans & animals
- Tall towers – microwave towers, electrical transmission towers/poles, flag-poles especially if they are on tall buildings – etc.
- Tall buildings, primarily corners & edges, and projecting structures on top of the buildings if any.
- Humans, especially if they are present in large open spaces (i.e., in the absence of nearby taller objects, including tall trees).
- Overhead water tanks; etc; etc;

As the negative charge concentration increases in the cloud-bottom, the electric field increases. When it reaches a critical level, breakdown channel/s start developing from cloud bottom towards earth particularly towards tall objects underneath. This will be in steps. Therefore, this is known as the 'Stepped Leader' of the 'Forward Stroke', shown in Fig.6(a) in dotted line as it is not visible to the naked eye.

The charge density on the top of tall objects on earth and electrical field increases with approaching forward stroke (leaders). Also, as the electric field exceeds the electrical strength of surrounding air, local upward electrical discharges develop on top of the tall objects. These are known as 'Streamers'.

When the downward leader develops down further and meets the upward streamers, the 'Forward stroke' is complete. This acts as an imperfect short circuit between the negative charge of the cloud and the positive charge on the earth. This enables flow of extremely huge currents (through the channel created by the forward stroke) and is the bright 'Lightning Strokes' and the accompanying thunder. This is known as the 'Return Stroke' and is the 'Cloud to Ground Lightning'. See Fig.6 (b).

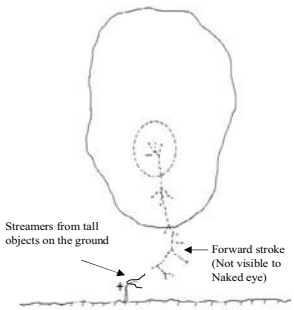

Fig.6(a) Cloud to ground lightning showing development of Forward Stroke – Not visible to naked eye

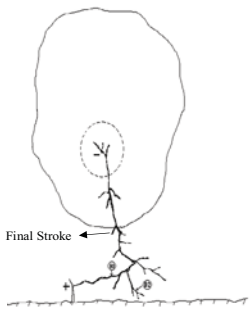

Fig. 6(b) Cloud to Ground Lightning with very high current and blinding brightness, zig-zag path terminates on the tallest object in the vicinity

Dangers of a Cloud to Ground Lightning

Ground Current: The high current in the stroke distributes from the point of stroke attachment to the earth all around – both on the surface layer and inside. This current flow extends over very large distances. Because of the very high currents, though of relatively short duration, injuries and fatalities to humans & animals (see section 1.2) and damages to properties have occurred over large areas. The flow of current

in the soil produces very large voltages (potential gradients) on the ground reducing from very high values at the point of current entry into earth and reducing with distance, R. See Fig.3.

If any person (or animal) is standing in this area of current flow, part of the current enters by one foot (or 2 feet in case of animals) and exits through the other (or other pair of feet of animals). The magnitudes of these current is high at the point of stroke current entry into earth. Obviously:

As the area of current flow in the earth is very large and all around the stroke attachment point, it can affect many persons (animals) simultaneously.

As persons tend to take shelter under trees, if a tree is hit, the person/s under that tree are in very great danger. See Fig.8

Any contact with the tree hit by lightning, such as one hand touching the trunk, and the legs on the ground, will be almost always fatal. If not fatal, there can be serious to very serious injuries.

Even if a person is not under the tree but only a small distance away, say 5m, there is still a high probability of injury and possibly fatality.

The same dangers – (a) to (d) above hold good for persons in the proximity of other tall objects listed above, (section 2.2.3).

An important and obvious inference from the above is that persons (animals??) should definitely avoid proximity of tall objects and stay as far away as possible –probably 20m or more may be considered somewhat safe. However, this also depends on the stroke current magnitude.

Unfortunately, for obvious reasons, animals like cattle or sheep that graze in large open fields are subject to these hazards. See Fig.7(a) shows a very large number of animals (more than 300) having died due to a single Lightning stroke and Fig.(b) illustrates an example of lightning hitting a tree and how it creates ground current injuries. There is also a recorded instance of 412 sheep having died due to a single Lightning stroke. Probably, the only way of avoiding such unfortunate incidents is to educate the responsible persons/farmers not to allow the animals into open spaces or gather them back at the first indication/warning of thunderstorms. As the ground currents due to a lightning stroke current spread over a large area, it is understandable that this is the main cause of injuries and fatalities.

From the above it is clearly understandable that lightning injuries/fatalities occur to persons (animals) who are involved in outdoor activities during thunderstorm weather. Therefore, it is essential to educate and strongly impress people not to engage in outdoor activities during thunderstorm weather. They must stay indoors.

From the field data it is seen that, injuries/fatality due to such ground current is highest – 50%.

Fig. 7(a) Lightning Kills More Than 300 Reindeer in Rare Mass Death (from internet)

Fig.7(b) Illustrates an example of lightning hitting a tree and how it creates ground current injuries[7]

Side –flash

If a tree is struck by lightning, the current distributes among the many branches and finally goes to ground along and through the trunk of the tree. Of course, the whole tree is intensely illuminated for a short time and possibly some branches or whole tree can get damaged. See Fig.8(a), (b), (c) & (d). If a person is standing fairly close to the tree and if the clearance to the overhead branches or to the trunk (or both) is sufficiently small, a flash can occur from the overhead branch or from the nearby part of the trunk to the person – either to the head or to the body – possibly arm/s or shoulder. This is known as a 'side-flash' and can be very dangerous causing injuries or even fatality.

To avoid such side-flashes, it is obviously necessary to avoid staying under or close to tall trees under thunderstorm conditions.

From field data, the probability of injuries/fatality is second highest – is about 20%.

Observations in an actual case: Death of a lady sitting on a large root projecting above soil. Unfortunately, photo not available but photo personally examined by first author: (i) Extensive burns at the back of head which was apparently in contact with the trunk (ii) Blouse burnt at the shoulder blades; Lissajous(like branched

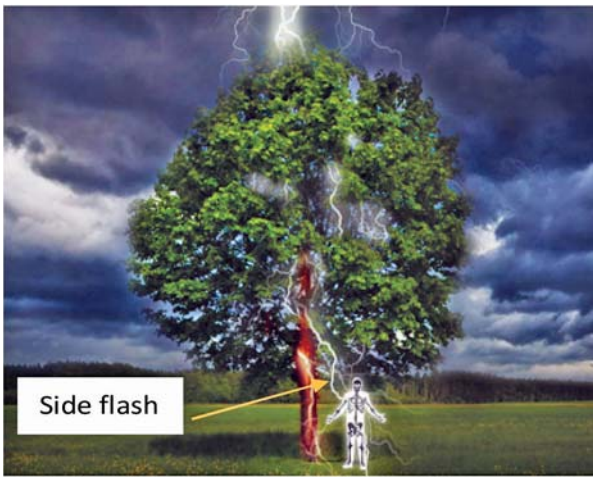

Fig.8(a) Side flash for a person standing near a tree during lightning (from internet[7])

Fig.8(b) Lightning strike to a tree showing branched lightning current (from internet)

Before Lightning Stroke

After Lightning Stroke

Fig. 8(c) & (d) 4 persons injured in lightning strike at Gurgaon condo, March 2021
(Source: The Indian Express)

tree) figures had formed on the skin (iii) Extensive burns of the clothing at the hips (on which the person was resting) and (iv) current had exited from the feet--fingers and sole; the silver ring usually worn on the leg--fingers had got blown out. An example of lightning hitting at tree and how it creates contact injuries is illustrated in Fig.8(e).

Fig.8(e) Illustrates lightning hitting at tree and how it creates contact injuries[7]

Dangers of 'Conduction Current' due to Lightning

During lightning stroke, as stated earlier, current enters ground and flows outwards, part of it can flow through long metallic objects, if any, on the ground like, for example, a metallic fence (garden fence). This is known as a conduction current. If a person touches such a metallic object, part of this current flows through him/her causing mild/severe injuries. Such incidents can obviously be avoided by not touching metallic objects during thunderstorm weather.

Similar dangerous shocks/injuries can occur due to contact with metallic objects indoors--such as corded telephones, TV wiring (except remote control units), water pipes, electrical-wire carrying conduits, etc. Therefore, persons indoors also should avoid such contacts, including boundary walls.

From field data, the probability of injuries/fatality is about < 10%.

Dangers/Injuries from Streamers

In section (2.2.3) above, it has been mentioned that tall objects (towers, trees etc;) develop streamers at the top under the influence of approaching leader/s from the cloud. If person/s happen to be the 'tallest object' as may happen if person/s is/are in very large open spaces (where really tall objects are far away), the streamers can start from the top of the person/s and cause relatively minor injuries to the person/s. Therefore, under thunderstorm weather, person/s should get away very quickly and take shelter indoor, but as stated above, **certainly not under trees.**

Usually, there will be an interval of 20 minutes to 30 minutes from the first thunder to the cloud to ground stroke. Person/s should take advantage of this fairly large time interval and move quickly indoor. If not possible at least person/s should move away from tall objects like tall trees, towers etc. **It is worth repeating and emphasizing here that taking shelter under trees is 'extremely dangerous' and must be avoided.** Even proximity of less than about 10m should be avoided.

From field data, the probability of injuries/fatality due to streamers is about 3-5%.

The injuries are due to streamers developing on the top of person/s in large open areas. Holding of tall objects projecting above heads, like umbrellas, golf-clubs, metallic poles etc., aggravate the situation.

Direct strokes

In the previous section, possibility of streamers developing from the top of person/s in very large open spaces has been mentioned. If these streamers develop to the extent of meeting the approaching leader (or vice versa), the person will suffer a direct stroke. This will cause unimaginably high level of injuries and almost certainly fatality.

This is a relatively rare event but, obviously, it is not at all worth taking a chance. The person/s must very quickly move indoors taking advantage of the 20/30-minute available time-gap between occurrence of the first thunder and the first lightning to ground. From field data, the probability of injuries/fatality is about 3%.

Possible Remedial actions for broad areas

Creating awareness of all above avoidance methods by proper broad level communication via popular local language TV channels and newspapers in local languages is an attractive and simple way. Such broadcasts may be conveniently repeated before and during lightning season.

Holding seminars and/or video-shows using simple local languages in all schools/colleges, especially in rural areas.

In large agricultural areas, coastal areas and areas of having high intensity of lightning, appropriately large lightning protected shelters to be built.

Summary of Modalities of Lightning Injuries and Methods of Avoidance

From the above, it is evident that cloud to ground lightnings cause a large number of injuries and fatalities. The modalities of injuries/fatalities have been divided broadly into five categories. These categories and the methods of avoidance are again listed below.

Streamers

The injuries are due to streamers developing on the top of person/s in large open areas. Holding of tall objects projecting above heads, like umbrellas, golf-clubs, metallic poles etc., aggravate the situation.

Occurrence - relatively small fraction of the total injuries. (probability about 3-5%)

Avoidance - Avoid large open areas like large open foot-ball fields, paddy fields & similar agricultural fields, trekking etc; during thunderstorm weather do not carry objects like, umbrella, metallic poles, etc., projecting above the heads.

Direct strokes

Direct strokes are usually consequences of streamers (as in 3.1 above).

Occurrence - Probably lowest probability but injuries can be extremely serious, most often Fatality. (probability about 3%)

Avoidance - As under (3.1) above, avoid large open spaces.

Note: Long ago the 'lightning crouch' was recommended to possibly avoid dangers due to streamers and possible direct strokes. In the lightning-crouch, one was recommended to sit on the toes(of legs) with heels raised and head bent to be between the knees. The National Weather Service (USA) has stopped recommending this lightning crouch in 2008 – "The crouch simply does not provide a significant level of protection. Whether you are standing or in the crouch position, if a lightning channel approaches from directly above (or very nearly so) you are very likely to be struck and either killed or injured by the lightning stroke". Further, in the opinion of the present authors: The lightning crouch is very uncomfortable and cannot be held for probably even one/a few minutes. Can anybody anticipate the stroke to that extent?! Thus, the lightning crouch is obviously of no use at all.

Ground Currents

As the ground currents extend over a very large area, this is the main cause of injuries/fatalities due to lightning.

Occurrence: Below and Proximities of tall trees and other tall objects like microwave/electric-transmission towers, flag-poles etc; probability 50% or higher.

Avoidance: As soon as hearing the first thunder (which usually signifies an intra-cloud lightning) move indoors very quickly. Totally avoid proximity of tall trees, tall metallic towers and other tall objects. Stay away at least 20m while moving towards indoor shelters.

Side-flashes

This is second most common cause of injuries/fatalities caused by lightning.

Occurrence: Typically, these occur due to close proximity to tree branches/trunk and other tall metallic objects (see 3.3 above) (Probability is about 20%)

Avoidance: Totally avoid taking shelter under tall trees and also close proximity under tall tree and other tall objects. Small unprotected structures like isolated bus passenger shelters in open areas must also be avoided.

Conduction Currents

Occurrence: Part of Lightning currents flow in long metallic objects existing in the open such as – metallic fences, metallic cloth lines etc; (probability about 5%)

Avoidance: During thunderstorm weather do not touch metallic objects in the open like fences, cloth lines, water pipes, electric conduits etc; Also, even when indoor do not touch objects like corded telephones, electrical-wire carrying conduits, cloth-lines (metallic), water pipes, etc; also avoid contact with boundary walls.

Very Important inferences for INDIA

From the above, particularly from 2.2.4 (i) and (ii), it must be easy to infer why there are so many lightning-caused deaths in India:

- India is predominantly an agricultural country. More commonly, in the pre-monsoon and post-monsoon seasons, agricultural activities – obviously, outdoor activities – could be responsible for a large number of deaths.
- It is therefore essential to painstakingly educate the farmers as to the necessity of avoiding the outdoor work and remain indoors as soon as thunderstorms become active (They should not wait for an actual cloud to ground lightning).
- In India, both in urban and rural areas, use of two wheelers - bicycles and motor bikes is very common. It is more than probable that bicycles are in very common use in rural areas. The riders of such two wheelers have a strong tendency to take shelter under trees on the onset of rains under thunderstorm conditions. This is, as explained, extremely dangerous. Also, it is common practice to take shelter in small bus-passenger shelters – obviously, not protected from lightning – in a crowded manner which can be very dangerous. Again, people need to be educated about the serious danger of taking shelter under trees and small shelters obviously not protected against lightning. However, field data is not available in this regard.
- Use of 3 wheelers – cycle rickshaws – is also dangerous.

Some Basics of Protection of Tall Buildings/Structures etc.

As an inference from section 2.1, the Franklin Rod (Lightning Rod) is the main backbone of lightning – protection as was exemplified by the 'instantaneous', amazing success in the case of Campanile of St. Mark of Venice.

Based on the extensive field-experience-based analysis, any lightning protection has three basic, equally important, components:

- The Air terminal, such as the Franklin Rods erected on top of the buildings.
- The Down-conductor System, such as the length of the Franklin Rod from the top the point of entry into the ground, and
- The Earthing System, such as the length of the rod/s or mesh from the bottom of the Franklin conductor-entry into ground and the entire length underneath the ground level.

Each component is equally important. The roles are very clear from their very names. The components are all to be metallic & continuous.

A simple Franklin Rod or lightning rod (or tube) has limited applications. If it is of height about 20m or less and alone on ground, the Protected Zone is expected to be a cone of inverted semi-conical angle of 30o (α), with the tip of the cone as the top tip. See Fig.9 (it must be noted that if the height is more than about 20m, the 30o semi conical angle(α) is not valid any more). Close proximity to the point of entry of the down conductors

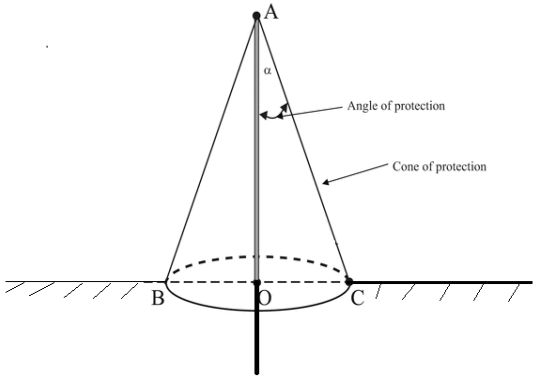

Fig. 9 Lightning Protected Zone is inside the semi-conical volume

to the earth point has the danger of 'Ground Current' described above. This is a simplistic presentation and it is strongly recommended that for actual design the international standard IEC 62305 or Indian standard IS 62305 should be consulted.

Therefore, in case of large structures (buildings), the lightning protection system comprises of (a) set of lightning rods as an Aerial terminal system, (b) a set of down conductors and (c) a set of earth conductors. A metallic strip horizontally along the top edge of the building is sometimes used. This strip bonds the several lightning rods that are mounted positively at the corners and possibly at other locations. At the ground end, the down conductors are also bonded by a metallic strip, preferably running about 1m below earth surface. The down conductors are taken down about 3m into the soil.

IEC/IS 62305 gives elaborate description and instructions to design a proper and effective lightning protection system.

As stated earlier, the above is an extremely elementary and necessarily incomplete description of lightning protection schemes for large buildings (and structures).

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IEC standard: IEC 62305, Parts I to IV. Also, Indian counterpart IS62305,

7 https://www.canada.ca/en/environment-climate-change/services/lightning/safety/dangers.html ■

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