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Lightning Strikes Protection by Laser

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Abstract – Lightning strike is a sudden electric discharge between atmosphere and earth bound object. Powerful lightning strikes pose a significant threat to buildings and people. The first systematic and scientific study of lightning was performed by Benjamin Franklin during the second half of the 18th century. Hundreds of devices, including lightning rods and charge transfer systems, are used to mitigate lightning damage and influence the path of a lightning flash.

Keywords: Electric Discharge, Lightning Rod, Laser Technology.

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(1) INTRODUCTION

Lightning strike is a sudden electric discharge between atmosphere and earth bound object. This discharge allows charged regions in the atmosphere to temporarily equalize themselves, when they strike an object on the ground. Lightning is always accompanied by the sound of thunder.

Lightning can take three forms. One is intra-cloud lighting (IC), which takes places between electrically charged regions of a cloud; second is cloud-to-cloud (CC) lighting, where it occurs between one functional thundercloud and another; and third is cloud-to-ground (CG) lightning, which primarily originates in the thundercloud and terminates on an earth surface (but may also occur in the reverse direction). Many factors affect the frequency, distribution, strength and physical properties of lightning flash in a particular region of the earth. These include ground elevation, latitude, prevailing wind currents, relative humidity, proximity to warm and cold bodies of water, etc.

(2) HISTORY:

The first systematic and scientific study of lightning was performed by Benjamin Franklin during the second half of the 18th century. Prior to this, scientists had discerned how electricity could be separated into positive and negative charges and stored. They had also noted a connection between sparks produced in a laboratory and lightning.

C.T.R. Wilson (1869-1959) was the first who used electric field measurements to estimate the structure of thunderstorm charges involved in lightning discharges. Wilson also won the Nobel Prize for the invention of the Cloud Chamber, a particle detector used to discern the presence of ionized radiation.

In addition to ground - based lightning detection, several instruments aboard satellites have been constructed to observe lightning distribution. These include the Optical Transient Detector (OTD), aboard the OrbView-1 satellite launched on April 3rd, 1995 and the subsequent lightning Imaging Sensor (LIS) aboard TRMM, which was launched on November 28th, 1997.

Although a great deal of research on lightning has been conducted, but nowadays lightning stands as a topic of considerable interest for investigation.

(3) LIGHTNING GENERATION MECHANISM:

(a) First Strokes:

lightning strikes originates when wind updraft and downdrafts take place in the atmosphere, creating a charging mechanism that separates electric charges in clouds leaving negative charges (-) at the bottom and positive charges (+) at the top. As the charge at the bottom of the cloud keeps growing, the potential difference between cloud and ground, which is positively charged, grows as well. This process will continue until air breakdown occurs. When a breakdown at the bottom of the cloud creates a pocket of positive charge, an electrostatic discharge channel forms and begins traveling downwards in steps tens of meters in length. In the case of IC or CC lightning, this channel is then drawn to other pockets

of positive charges regions. In the case of CG strikes, the stepped leader is attracted to the positively charged ground.

(b) Subsequent Strokes:

After the negative charge from the cloud base has been transferred to ground, additional charge can be made available on the top of the channel when discharges known as J and K processes take place within the cloud (Uman, 1969). This can lead to some three to five strokes of lightning following the first stroke.

(4) EFFECTS OF LIGHTNING STRIKES:

***(a) Effect on body*:**

Lightning strikes can produce severe injuries, and have a mortality rate of between 10% and 30%, with up to 80% of survivors sustaining long-term injuries. These severe injuries are not usually caused by thermal burns since the current is too brief to greatly heat up tissues; instead, nerves and muscles may be directly damaged by the high voltage producing holes in their cell membranes, a process called electroporation. metallic objects in contact with the skin may "concentrate" the lightning's energy, resulting in more serious injuries, such as burns from molten or evaporating metal.

However, during a flash, the current flowing through the channel and around the body will generate large electromagnetic field and EMPs within the nervous system or pacemaker of the heart, upsetting normal operations. Another effect of lightning on human is hearing problem. The resulting shock wave of thunder can damage the ears. Also, electrical interference to telephones or headphones may result in damaging acoustic noise.

(b) Effect on nature:

(i) Impact on vegetation:

Trees are frequent conductors of lightning to the ground. If the damage is severe, the tree may not be able to recover, and decaysets in, eventually killing the tree.

(ii) Electrical and structural damage:

Telephones, modems, computers and other electronic devices can be damaged by lightning, as harmful over current can reach them through the phone jack, Ethernet cable, or electricity outlet. Close strikes can also generate electromagnetic pulses (EMPs) - especially during "positive" lightning discharges.

Lightning currents have a very fast rise time, on the order of 40 kA per microsecond. Hence, conductors of such currents exhibit marked skin effect, causing most of the currents to flow through the outer surface of the conductor.

In addition to electrical wiring damage, the other types of possible damage to consider include structural, fire, and property damage.

(5) PREVENTION:

The best treatment for lightning strike injuries is prevention. Some preventive measures are:

Remain indoors (or inside a closed car), away from doors and windows, fireplaces and metal objects, to avoid side flashes. When outside and unable to find shelter, maintain distance from tall trees, hilltops, or other exposed areas. A person caught outside in the open without cover crouch on the ground with his or her limbs close together. Do not swim in a lightning storm.

(6) LIGHTNING PROTECTION DEVICES:

(a) lightning rod:

A lightning rod (or lightning protector) is a metal strip or rod connected to earth through conductors and a grounding system, used to provide a preferred pathway to ground lightning terminates on a structure. The class of these products is often called a "finial" or "air terminal". A lightning rod or "Franklin rod" in honor of its famous inventor, Benjamin Franklin. Other names include "lightning conductor", "arrester", "surgitator agitator", and "discharger". These are an early form of a heavy duty surge protection device (SPD). Modern arresters, constructed with metal oxides, are capable a safely shunting abnormally high voltage surges to ground while preventing normal system voltage from being shorted to ground.

(b) Monitoring and warning systems:

The exact location of a lightning strikes and atmospheric flashes is still impossible to predict. However "ground and satellite-based observation devices" and systems have been designed to alert people. The level of detail recorded by these technologies has vastly improved in the past 20 years. lightning detection systems have been developed and may be deployed in locations where lightning strikes present special risks, such as public parks. Such systems are designed to detect the conditions which are believed to favor lightning strikes and provide a warming to those in the vicinity to allow them to take appropriate cover.

(c) Personal safety:

If thunder can be heard at all, then there is a risk of lightning. The safest place is inside a building or a vehicle. Risk remains for up to 30 minutes after the last observed lightning or thunder. The National

lightning Safety Institute recommends using the F-B (flash to boom) method to gauge distance to a lightning strike. The flash of a lightning strike and resulting thunder occur at roughly the same time. But light travels 300,000 kilometers in a second, almost a million times the speed of sound. Sound travels at the slower speed of 344 m/s, so the flash of lightning is seen before thunder is heard. To use the method, count the seconds between the lightning flash and thunder. Divide by three to determine the distance in kilometers, or by five for miles. Immediate precautions against lightning should be taken if the F-B time is 25 seconds or less, that is, if the lightning is closer than 8 km (5.0 mi). The riskiest activities include fishing, boating, camping, and golf. A person injured by lightning does not carry an electrical charge, and can be safely handled to apply first aid before emergency services arrive. lightning can affect the brainstem, which controls breathing.

(7) LASER TECHNOLOGY:

David Aragon (2014) an optical scientists at the University of Arizona and the University of Central Florida have developed a technology capable of sending high-intensity laser beams through the atmosphere much farther than was possible before. The research is still in the laboratory phase. Currently, high-intensity lasers, produced with modern technology essentially disappear over distance greater than a few inches or several feet at best when focused tightly, due to diffraction - the same effect the makes a stick seem to "bend" when dipped into water. This makes them too short- ranged for applications such as diverting lightning. The breakthrough lies in embedding the primary, high-intensity laser beam inside a second beam of lower intensity. As the primary beam travels through the air, the second beam-called dress beam - refuels it with energy and sustains the primary beam over much greater distance than were previously achievable. The development of the new technology was supported by a five-year, $7.5 million U.S. Department of Defense grant - awarded to a group of researchers led by Jerome Moloney, a UA mathematics and optical sciences professor. Moloney is heading up the multidisciplinary, multi-institution research effort to investigate ultra-short laser pulses, focusing on their effects in the atmosphere and ways to improve their propagation over many kilometers.

Laser beams that are more effective in overcoming scattering caused by atmospheric turbulence, water droplets in clouds, mist and rain, according to Moloney (2014). Such beams could be used in detection systems reaching over long distances.

According to Aurlien Houard (France, 2012) Firing a laser would create an ionized channel in the atmosphere, which could conduct the lightning to the ground. Laser lightning rods could be an alternative to lightning rockets. lightning rockets can apparently trigger a lightning strike by bringing a conductive material, like some type of salts, towards the static layer of a thunderhead. But a laser would be easier to control than a rocket.

A team of French researchers set out to test how well lasers can harness and control lightning. They sent a laser beam past a spherical electrode toward an oppositely charged flat electrode. The laser stripped away the outer electrons from the atoms in its way, ionizing the pathway between the electrodes and creating a plasma filament - like lab lightning - that channeled an electrical discharge from the flat electrode to the spherical one.

Then the team added a longer, pointed electrode to their set of electrode shapes and watched what happened. Left to its own devices, lightning follows the path of least resistance, striking the first thing it comes across-in a thunderstorm, that's the tallest thing, and in this experiment, it's the nearest thing. With no laser lightning rod, the discharge predictably hit the tall pointed electrode first. But when the researchers used the laser filament to guide it, the electrical discharge followed the ionized path and hit the spherical electrode instead.

The team found they could pull this off even after the discharge was already on its way, meaning they could divert the path of lightning. Although a great deal of research on lightning has been conducted, but nowadays lightning stands as a topic of considerable interest for investigation.

(8) CONCLUSION:

lightning is a natural phenomenon caused by separation of electrical positive and negative charges by atmospheric processes. When the separated charge gets very large, the air between the positive and negative regions breaks down in a giant spark (an intra-cloud stroke), or a charged region breaks down to ground (a cloud ground stroke). Laser beams and the next generation protective systems (high - intensity lasers) are more effective in overcoming scattering caused by atmospheric turbulence, water droplets in clouds, mist and rain. Although a great deal of research on lightning has been conducted, but nowadays lightning stands as a topic of considerable interest for investigation.

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