BÁNKI KÖZLEMÉNYEK
3. ÉVFOLYAM 1. SZÁM

Can we avoid a lightning strike if we are in an open space?

Elkerülhetjük-e a villámcsapást, ha nyitott térben tartózkodunk?

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Abstract: **The humanity has been in constant struggle with natural forces since ancient times. In this struggle, lightning protection has played a prominent role and nowadays, one of its main areas is the protection of human lives. We wouldn't even think of the dangers of storms during our various leisure activities. This article draws attention to the various sources of danger and proposes to eliminate these hazards.**

Keywords: leisure activities, lightning strike, danger, security measure, protection of human life

Összefoglalás: **Az emberiség fejlődése során ősidők óta folyamatos küzdelemben áll a természeti erőkkel. Ebben a küzdelemben kiemelt szerepet kap a villámvédelem melynek fő feladata az emberi élet védelme. Nem is gondolnánk, hogy különböző szabadidős tevékenységünk során milyen veszélyben lehetünk zivatartok kialakulása idején. Jelen cikk a különböző veszélyforrásokra hívja fel a figyelmet és javaslatot tesz ezen veszélyek elhárítására.**

***Kulcsszavak*:** szabadidős tevékenység, villámcsapás, veszély, veszélyeztetettség, biztonsági intézkedések, emberi élet védelme

1 INTRODUCTION

Persons, organizations and objects are threatened by various kinds of natural and artificial hazards. Natural dangers and events causing severe damage are called natural disasters. Artificial hazards are on the other hand can be external human actions (e.g. forced entry), on the other hand the impact of internal voluntary or inadvertent human actions (e.g. unexpected fire, explosions, mechanical damage, losses, etc.) and in extreme situations, industrial disasters.

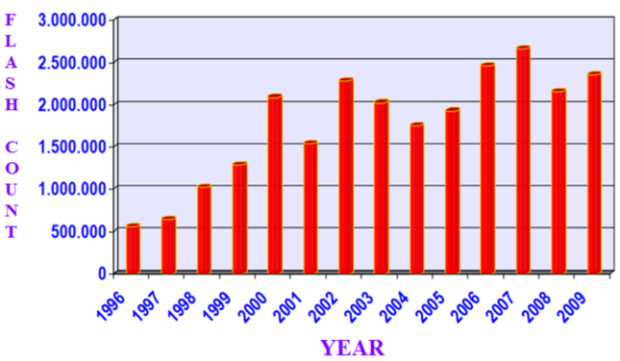

Figure 1: Increase of lightning strike numbers in Germany [2]

Nowadays, based on the natural phenomena, we can conclude that global warming caused by infrastructural activities of man increased the number of lightning strikes. As much as 1% of temperature rise will increase the number of lightning strikes by 6% per annum [1].

Parameters of strikes are also increasing (e.g. lightning density, peak value). This demands higher attention to these natural contingencies. Should we spend time in open spaces outside either due to work or during recreational activities, there is a risk of lightning strike. Employees are reminded of this danger upon their work safety training, but do we think about the fact that we are at risk of lightning strike during recreational activities? Many of us remember those kinds of accidents when people working on the fields or even returning home (bringing their metallic tools on their shoulders) were struck by lightning. In the present article I would like to draw attention to the danger of lightning strike during some outdoor works and recreational activities and to the preventive actions to it.

2 THREATS IN NATURE

While spending time in nature, one is exposed to two hazards as well. One is the direct lightning hit, the other is the potential funnel formed. The direct hit is deadly, due to its lightning current can reach up to 200 kA. The only solution against it is to avoid this current route. The other case is when the lightning strike creates a potential funnel around the point of impact, which causes high touch and step voltages. Between the limbs of the person in the open space, a life-threatening difference in potential may build up that in the worst case can cause death when current damages essential organs.

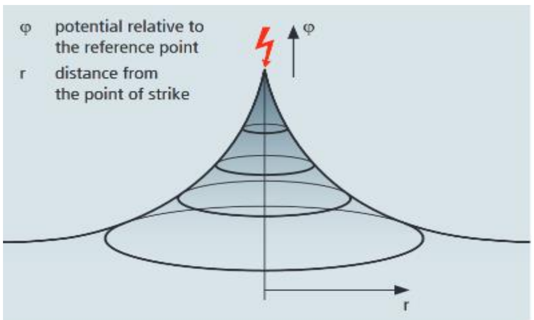

Figure 2: Potential funnel in ground [3]

In the news we can often hear about events when animals died however they were not hit by direct lightning. Step voltage is behind this kind of damage.

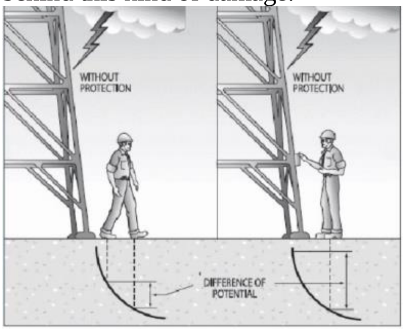

Figure 3: Formation step and touch voltages [4]

2.1 Lightning formation

In case of high air pressure difference, clouds start moving. Due to the friction between clouds and air flowing below, water molecules are teared away, creating positive and negative charged ions. Ions with negative charge are heavier, so these will take place on the bottom part of the cloud. So, the lower part of the cloud will have negative, the upper part will have positive charge, therefore an electric condenser is formed.

The ground surface is also ionized, its surface will have positive charge as well. When the voltage difference between the two "conductive plates" exceeds a certain level, discharge occurs. This is how lightning is formed between cloud-cloud and cloud-ground. The charged ions' speed is higher than sonic speed so in each case we hear a sonic boom or thunderclap.

As air is compressed in the way of lightning, its speed is decreased and it is forced to change direction. This is why lightning travels a crisscross path. The reason we hear several thunders during lightning strikes is that this above-mentioned speed changing (acceleration – deceleration – new acceleration) is repeated several times. Accelerating ions emit light, therefore making their path visible. Acceleration may reach a level that leads to higher energy gamma radiation.

2.2 When are we in danger?

To define the distance of lightning, we only need to know the time gap between the lightning's light and the thunderclap. Light almost immediately covers the sought distance since it travels at a closely 300 000 km/s (!) speed. This is why it is enough to calculate only with the speed of sound, which is more or less has a value of 340 m/s. By rounding ($v = 333$ m/s) we can get a calculation method easy to remember, that is, sound travels one kilometer in three seconds. Therefore, dividing the time gap by three, we will get the distance in kilometres.

If the time gap is gradually decreasing, we can say that lighting is trending towards us, so it is worthwhile to prepare for a lightning hit in our environment. It is a very bad signal if our hair stands on end (image 1) or if we hear the sputtering or ringing of metallic tools (e.g. pickaxe) we have with us. At this time, we still have a few seconds to quickly give up our tools and move to an adequate place, because in a few moments there will be a lightning hit at very close quarters. During this short time, we should get a low positioned squatting.

Image 1: Hair indicating lightning strike [5]

A few general rules

Pillars, trees, overhead wires, different projecting objects pose a high risk in terms of lightning strike. During thunderstorms we should avoid standing close to these. To minimize the risk of lightning hit, the most important is to go to a protected area. There are some general rules that in every case must be observed. These are:

- Avoid lying on the ground.
- If we are on a plain area, crouch and hug knees to the chest with closed legs.
- Lie tools on the ground.
- Diverge from the vicinity of projecting objects for at least 3 metres.
- Take a place into a protected area

Image 2: Lightning strike to tree [6]

3 SOME CASES OF STAYING IN OPEN SPACE

2.3 On plain areas

On plain areas lightning aims at projecting points, but does not always hit the highest objects. If we do not have the possibility to go to a safe area, avoid waterfronts, wet areas, and water streams and try to take the lowest possible position. With the heels together, crouch and hug knees to the chest. If there are more of us, keep a distance of at least 5 meters from each other.

2.4 The „tree" case

Protection from the rain offered by the foliage of trees is very tempting, but one might raise the question if it is permissible to stand below a tree in these situations. Keeping some rules in mind, yes. We shall stand as far from the trunk – as conductor – in this case (see Image 2) as possible (min. with our body height), so the optimal position is the edge of the foliage.

2.5 Being on sport courts and on sport events

Most sports events are organized on outdoor locations where spectators sit on spectators' terraces.

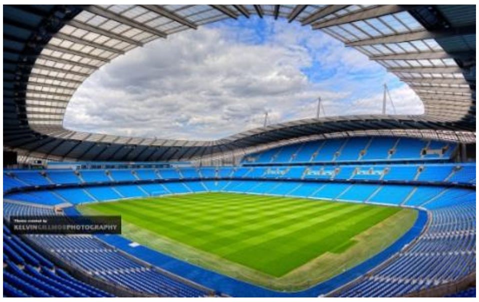

Image 3: The Etihad Stadium in Manchester [7]

In case of thunderstorms the vicinity of projecting objects (flagpoles, result advertising posts, etc.) should be avoided. Staying on the spectators' terrace is safe only if the building is covered and has lightning protection.

It is important to remark that in case of open terraces, lightning with the highest lightning current (I = 200 kA) may reach and hit the surface of the play field even if the building around the terraces has lightning protection on it (see Image 3). A possible countermeasure would be to by-pass the open part cross-ways with cables in a way that the distance between the cables is no more than 20 meters. In this case the cable, by acting as a lightning conductor, creates the protected space above the field and protects players and people standing there.

2.6 Fishing, camping and swimming

In the summer good weather offers opportunities for several outdoor activities. We rarely think about that the tools used by us and presumed harmless might rush us into danger. Staying close to tent poles, fishing rods and pool equipment puts us at risk, since these metal appliances attract lightning strikes. If we are in the water, we should immediately come out, leave the waterfront and go to a safe area. A countermeasure may be the usage of isolation mats or staying in an automobile or trailer, as the metal body protects those inside by acting as a Faraday cage.

2.7 Mountaineering

When standing on hill ridges or mountaintops, or during rock-climbing we are acutely exposed to the risk of lightning hit. Ladders, chains, metal tools attract lightning, therefore in case of the formulation/approaching of thunderstorms it is worth getting rid of these tools. If we do not have time to descend to a valley, then move to a cave if we can stand at least 1.5 meters away from the entrance and the walls.

2.8 Outdoor cultural events, festivals

When visiting festivals, the above-mentioned rules apply, with a difference. We should only move to metal containers, different small booths or large tents only if they are applied with lightning protection. My own experience is that most of these buildings are without lightning protection, therefore it is safer to sit in an automobile or bus as its metal frame protects us.

2.9 In town, in populated areas

On populated areas we are mostly safe, since we are in protected space. Due to lightning conductors on buildings, the height of buildings will give protection against lightning strikes. When leaving the protected space (squares, open areas) we can be safe by observing the rules above.

2.10 On ship & boat

Ships are exposed to the risk of lightning strikes on open water, in harbors and on land as well, therefore the protection of the lives of passengers and crew is very important. The number of lightning strikes is higher on land as on open water, therefore for different calculations regarding harbors, values for land should be applied. Water is an excellent conductor, so fishing rods and mast act as arrestors. In case of inadequate protection, lightning will find its way towards the ship's body, and as a result a hole might be burnt into the body. On open water this is mostly detectable, but in case of vessels left in harbor for the winter, this could result in the unnoticed sinking. In case of the lightning protection of ships, we should protect against the secondary effects [8] of lightning as well which saves the sensitive equipment (e.g. navigation, communication equipment, etc.) on board. In case of staying on open water, far away from land, the protection of navigation and communication equipment is highly important. Not only avoiding this equipment going out of service is important, but also the safety of stored data should be ensured [9].

If the ship body is made of metal, which is directly connected to the metal structure, there are no further actions needed for the spreading of the lightning current. If lightning hits the mast, then most part of the lightning current and partial lightning currents will travel toward the water through the mast, the poles, the hull and the keel.

If the ship body is made of non-metallic material (wood, plastic, composite), then lightning protection measures are required. If the mast is non-conductive, then a lightning arrestor of at least 12 mm diameter should span at least by 300 mm beyond the mast and the cross section of the lightning conductor should be at least 70 mm^2. All connections of the lightning current should be solely bolted, riveted or welded. It is worthwhile to apply arrestors on the bends of the ship body (see Figure 4) and ground them towards the water. If this is not possible, portable grounding may be used (see Figure 5). In harbors, during stationing, ship bodies are in most cases connected to ground potential with portable grounding.

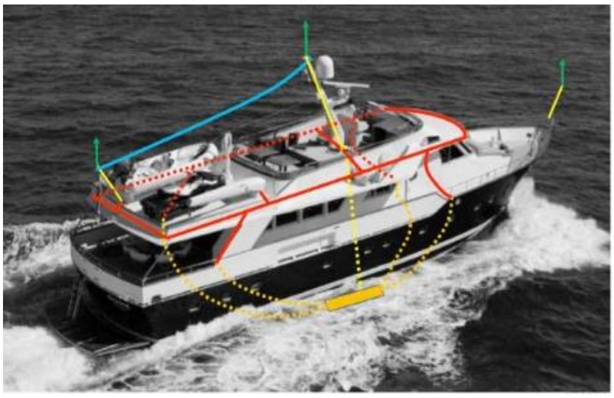

Figure 4: Conductors in use [10]

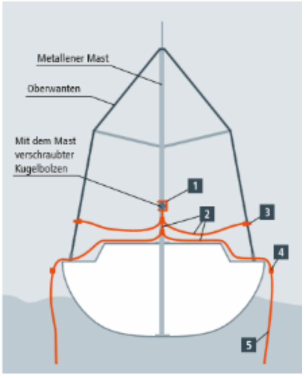

Figure 5: Mobile grounding in use [11]

2.11 In car

In case of lightning hit to an automobile, lightning current will pass through the bodywork, partly through the suspension and finally discharge to the ground through the brake disc (rims) (see Figure 6). The metal bodywork protects the passengers (see Figure 7) as referred to in section 3.4. It is important that the person staying in the automobile should not touch the steering wheel or the door. In the future electric drive vehicles are expected to become more and more widespread. In order to increase effective range, manufacturers are planning to produce the car bodies out of non-metallic materials (plastics, composite materials). These materials are not conductive, but have insulating properties. Due to their short effective range, electric drive automobiles (cars, buses) are mostly used in populated areas, cities at that. This gives protection against lightning strikes. Buildings, due to their height and arrestors placed on them grant safety against lightning hits.

Some questions may rise up what happens in case an electric vehicle exits this protected area:

- What happens in case of a lightning strike?
- Are passengers in danger?
- Is there any lightning protection?

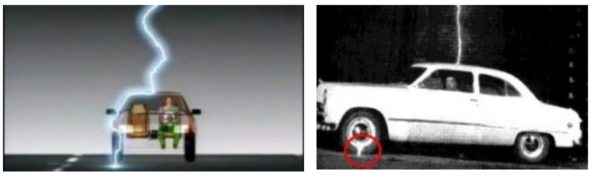

Figure 6: Lightning current route in schematic diagram and in reality [12][13]

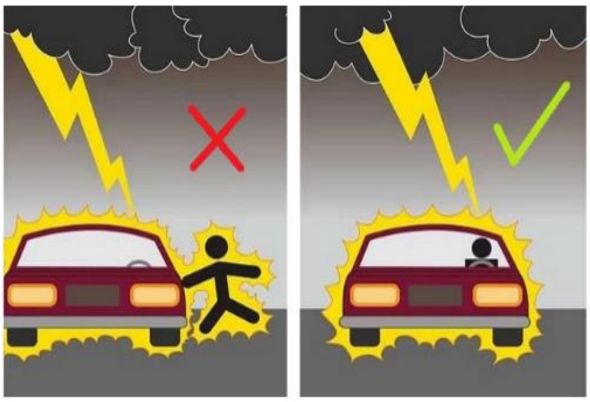

Figure 7: Action in case of thunderstorm [14]

Technically, the aim is to capture the lightning and conduct it towards the ground.

Figure 8: Rolling sphere design for a commercially available car (own editing)

To find the fixing points, we should use the rolling sphere method. This is a procedure to design the lightning arrestors, according to which the protection is appropriate, if a rolling sphere of given radius cannot come in contact from the outside with the protected surface without touching the lightning arrestor. In practice, this means that we are moving a sphere of given radius in the space around the protected object (building, vehicle, etc.) and where the sphere touches an object, that will be the hitpoint of the bolt.

With this design method the given object can be protected, because the protected surface will get into the protected space, since the sphere reaches the end point of the protective conductor (better known as lightning arrestor) first. For this design method there are different kinds of 3D software available. As a result, we get a blanket-like surface around the given object, behind which is the protected space (Figure 9).

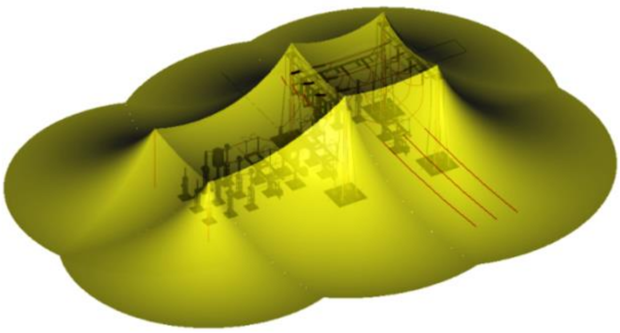

Figure 9: 3D diagram of the rolling sphere design [15]

According to the abovementioned method, lightning is most easily “captured” by a well placed metal body, which therefore is protecting the surfaces. In case of electric vehicles, for this purpose, a mechanically fixed radio antenna is partially suitable. It is important that the leading wind should not bend the antenna in any direction, since this is protecting a part of the body. For this, adequate mechanical fixing is a must. Moreover, the vehicle must be provided with arrestors on several other points as well.

Figure 8 shows an electric vehicle available on the market, currently manufactured with a metal body. On the left side, the actual, original condition of the vehicle is visible, on the right side the rolling sphere design with the planned arrestors (red markings). We should notice that thanks to the arrestors, the sphere is not contacting the vehicle surfaces, therefore protecting not only the automobile, but the passengers as well. The figure shows one variation of the theoretical design and displacement of arrestors. Of course, in case of the vehicle's complete design, the full three-dimensional protection of the body should be compiled. Conducting the lightning current. For the implementation of lightning protection, not only capturing, but conducting the lightning current is also a problem to solve. When speaking about sizing, the largest stress must be considered, in this case this means a situation when only one arrestor and one conductor would conduct the lightning current. The system should be designed to be capable of conducting even 200kA of current without damage and warming. For this, a 50 mm^2 cross section conductor is perfect.

Lightning current must be conducted to the ground from the body. A solution to this might be a movable conductor that automatically reaches the ground at stops. To avoid excessive and unnecessary requisition (opening of this device at every stop, then closing at start), in practice the movement of this device should be controlled by an electric field strength gauge. This means that the mobile conductor would be automatically activated when clouds are starting to develop on the sky and therefore the electric field strength measurably changes.

A further task is the protection of electric appliances against the induced overvoltage that may appear in such cases. Electric devices in different automobiles are very sensitive to overvoltage. Protection of such appliances can be solved by installing them into metal housings, and electric cables may be threaded through protective tubes or provided with electric shielding.

4 Summary, recommendation

Based on the examples presented above, it can be clearly seen that during the formation of a thunderstorm we can easily and quickly get into a number of emergency situations. Many people don't know what to do in such a situation, so my suggestions are:

- Orient public education actors to make the examples mentioned in educational institutions (e.g. physics lessons, class teacher classes).
- To expound these examples at various health courses (e.g. health and safety training, OKJ trainings, vocational training, medical license for obtaining a driving license, etc.).
- Encourage the industry to invest in innovative investments, e.g. for better lightning protection systems.
- It is advisable to consider the possibilities of solving the detected technical problems in the process of international standardization. For example, there is currently no standard for lightning protection for non-metallic bodywork vehicles.
- Information for tourists on different trips (e.g. hiking)

The attention of workers at safety educations is called by the employer, but are we thinking of our leisure activities being at risk of lightning during some outdoor activities? In any case, the goal is to go to the nearest protected space as soon as possible, and if this is not possible we can only reduce the risk. Different degrees of vision and hearing loss may occur. The importance of the topic justifies, on the one hand, that these emergency situations are differentiated into the materials of the top-level professional training, and on the other hand, the current technical solutions are considered in the development of international standards, as this makes it possible to achieve even more secure level of protection.

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