Suggestions

for the

Protection of Persons and Groups of Persons against Lightning Hazards,

with an appendix on generation and characteristics of lightning

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For the JOINT COMMITTEE ON ATMOSPHERIC ELECTRICITY of IAGA and IAMAP in the Union Géodésique et Géophysique Internationale, drafted and with the assistance of many colleagues compiled by

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Foreword:

In the first line, this document is addressed to people who, because of their profession or other activities, are outdoors often and for long periods, such as farmers, forestiers, fishermen, mountain climbers, fire warden, soldiers, hunters, campers - but at the same time, and maybe even more so, to people who take responsibility for groups of persons who are outdoors more seldom such as teachers, commanders of small military units, scout leaders, guides, and to people who have to take responsibilities or are asked for advice such as the managers and employees of mountain hotels, of hostels, of mountain railroads and cable cars, of bath houses, and who organize outdoors activities, festivals, concerts, sports events, etc. We trust, however, that it may also help to dissipate wrong ideas in the general public.

Chairman of Working Group VI:

Lightning and Sferics

of the international "JOINT COMMITTEE ON ATMOSPHERIC ELECTRICITY"

(IAMAP / IAGA; UGGI, ICSU)

During their meeting in Tokyo in May 1968, the Members of the JOINT COMMITTEE ON ATMOSPHERIC ELECTRICITY - who were saddened by the news that eleven children had lost their lives in the flash of a single lightning stroke in the Japanese Alps - resolved to initiate a brochure with advices on protection against lightning hazard for individuals and groups of people.

So far, regulations and recommendations for the lightning protection of buildings had been issued in several countries, and some of them contained sketchy advices for the protection of people, but not comprehensive study and manual had been published. Newspaper articles, sometimes published locally after some tragic lightning accident, had been generally incomplete, occasionally containing wrong advice - and the behavior of persons caught by a heavy thunderstorm usually was directed more by faulty, sometimes dangerous thumb-rules learned in childhood than by reason and sound knowledge.

The present document is not considered to be complete and finalized on all aspects. Thunderstorms show different patterns in different parts of the world, and human activities may increase or decrease the lightning hazard for the individual, so that completion and updating will be desirable. However, this document is submitted to the public as a beginning, providing more information than has been available to most so far.

The assistance of the following scientists from the domain of atmospheric electricity is gratefully acknowledged:

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Introduction

The following remarks concern suggestions for the behaviour in thunderstorm situations in order to minimize the risk of lightning accidents. When these "Suggestions" were finished for distribution to the members of Working Group VI, a book was published by M. Uman: "Understanding Lightning". Its statistics and general descriptions are very useful to complete our document. Some literature and sources are indicated at the end of this report.

The risk of lightning accidents is most severe on mountain tops and mountain ridges. In flat country lightning danger for persons in the open is well-known. If possible, protection should be sought in spaces or buildings with little or no lightning danger. For circumstances in which this is not possible, special precautions will be discussed which may be taken to decrease the possibility or severity of lightning damage - precautions which are not generally known or observed up to now. Such precautions may be especially urgent at certain locations. Furthermore, the longer the duration of stay in the open under a thunderstorm, the more important these rules become.

This report contains the following chapters:

I. Symptoms of lightning danger,

II. Localities which provide good or, at least, a minimum of protection against lightning hazard (a & b) for persons,

III. How to perform in non-protected buildings or for large numbers of people,

IV. Localities and situations to be avoided during thunderstorms,

V. How to perform in the open air when surprised by a thunderstorm,

VI. Appendix: Remarks on generation and characteristics of lightning; consideration of effects of lightning hitting a human being; rescue operations after lightning accidents.

Chapter I: Symptoms of lightning danger

General symptoms of thunderstorms are the well-known cumulus-cloud-towers. Their electrification is especially strong if the grow up in a strong up-draft to regions in the atmosphere, where the temperature is below the freezing point. There are, however, other possibilities for lightning generation, e.g. the eruption of volcanoes.

On mountain ridges or peaks, the appearance of St. Elmos-fire is a very strong warning against lightning strokes; it proves the existence of high electric fields. In full daylight the St. Elmos-fire is not well visible, so that its hissing and the strange feeling of electrified hair on the uncovered head may be the first noticeable warnings even under the blue sky. The appearance of hail grains (Graupeln) or big water droplets within fog (which is the same thing as a cloud) is a very distinct warning against an approaching thunderstorm.

In the flat country these electric warnings are less pronounced; they may not be felt directly on the human body, but they may be registrated by electric warning devices. Many types of such instruments do exist and can be bought at varied costs. They all cannot predict lightning in a certain area with certainty, but they only indicate the possibility of a near thunderstorm. It is not possible, even by means of very complete warning devices, to predict exact time and location of the first lightning stroke within a certain area.

Chapter II: Localities which provide good or, at least, a minimum of protection against lightning hazard (a & b) for persons

a) Localities providing good protection or at least a minimum for persons against lightning hazard

These are the localities which are totally or nearly totally surrounded by coherent metallic surfaces or nets (perfect or imperfect Faraday Cages,*) in particular the following:

*) Faraday Cage: a box or cage made of metallic enclosure in form of sheet metal, metal bars, wires etc., where because of the high conductivity of metal for electricity, no electric fields can penetrate into the interior.

(1) Buildings of concrete with steel reinforcement which is, at least, vertically coherent;

(2) Steel-skeleton buildings;

(3) Buildings covered with sheet metal on roofs and walls, if their parts are connected electrically to get a complete metallic surface;

(4) Buildings with lightning protection equipment;

(5) Automobiles with coherent metal bodies, but not open cars and not convertibles; *)

(6) Railroad cars made from steel or aluminium;

(7) Trailers made totally from metal;

(8) All-metal-cabins of airplains, cable cars, ships, trucks, cranes;

(9) Large caverns in which one can stand without nearing the ceiling with the head.

b) Localities with minimum protection against lightning hazard to persons

(1) Buildings without lightning protection equipment if these buildings are of large or at least medium size. The protective value of such buildings is better when many or at least some coherent vertical metallic conductors exist, such as rain gutters, water mains, steel bracers or reinforcements, rails for elevators, metallic protection for edges etc., electric installations and wires etc.;

(2) Dense forests, if one keeps distance from the individual trees. At best, one stands with feet closed (!) in a free space as large as possible between the trees;

(3) The strip of ground under power lines for very high-voltage which have steel masts and string insulators. One should not stand near these masts, but rather in the middle between them with feet closed.

*) Footnote: Danger when driving fast in a thunderstorm from being frightened by a near stroke and from strong wind impulses makes it advisable to drive at slow speed in a thunderstorm.

Chapter III: How to perform in non-protected buildings or among a large number of persons

a) In non-protected buildings

In residences and houses without lightning protection equipment (lightning rods) the neighborhood of windows and external walls should be avoided, as well as attics or the area of chimneys, stacks, etc. Remain in the center of the interior rooms. Do not touch or stay near radio and television equipment which is connected to outside or attic antennas. Avoid the neighborhood of large metallic bodies, if possible, such as stoves and ranges, furnaces, water and gas pipes, telephone and electric lines; especially at points where these enter the house.

b) The special risk for large numbers of people

It is mandatory to furnish good systems of lightning rods to kinds of buildings in which large masses of people are to be expected during thunderstorms, such as mountain restaurants and inns, mountain shelters, shelters of mountain railroads, cable railroads and skilifts, but also churches, hotels, theaters, bathhouses, houses in drive-ins, stadiums, tribunes, etc. The danger for a large number of people in a small space is very great if lightning hits. It is known, for example, that animals such as cows, pigs, or sheep crowd together in a thunderstorm situation and that many animals have been killed by one lightning strike because of this. If there is only an unprotected shelter, people should keep distances of at least two meters between themselves if possible, the best method is to go into automobils with metallic roofs. See also the advice for groups of people in the open in chapter V.

Chapter IV: Localities and situations to be avoided during thunderstorms

(1) Individual trees in the free country and on mountain tops. The greatest danger is under low branches of trees which have branches extending far sidewise. All kinds of trees are dangerous, the beech (fagus) included. The higher the tree, the greater the danger;

(2) The edge of a forest with large trees;

(3) Unprotected objects in open country such as barns, small churches, chapels, haystacks, loaded cars, observation towers, elevated points, lean-tos, huts, shelters; *)

(4) In small wooden huts with practically no metallic parts but water piping. Avoid nearing this pipe. To avoid danger from lightning, connect all metallic parts of a building together and use water pipes as grounding electrode.

(5) Immediate neighborhood of power line masts;

(6) Neighborhood of high cranes, or other high metallic structures;

(7) Lakes and swimming pools;

(8) Boats and tents without lightning protection;

(9) Extended metallic fences and rails;

(10) Do not ride on horseback, bicycle, motorcycle, open tractors;

(11) Avoid assemblies of people in the open air or in small unprotected rooms;

(12) Do not stand close to the outside of a car;

(13) When flying avoid non-metallic planes. Even with metallic planes avoid high cumulus clouds if your safety depends on the electronic equipment of the plane.

*) Footnote: surrounding high trees are not efficient for protection of buildings, as long as they are not equipped with earthed protection wires.

Chapter V: How to perform in the open air when surprised by a thunderstorm

If during a stay in the open especially among mountain ridges and no protected space can be reached in time, two possibilities of immediate protection are to be considered:

a) Without auxiliary equipment

There are some possibilities that reduce the probability that the electric current of a lightning will penetrate the human body. To achieve this, two principles have to be observed: One should be as low as possible (to reduce probability of a direct hit by lightning), and one should touch as small an area as possible of the ground by one's body (to reduce probability that a considerable portion of the lightning current from nearby lightnings spreading in the ground penetrates the body).

(1) The most favourable position of the body is as follows: Kneel down, with both knees touching, and both feet touching, both hands on the knees, and bend forward avoiding to touch the ground or any object with another part of the body besides knees and feet. By bending forward the overall height is reduced and so is the danger of a direct hit. By touching only a small portion of the ground, the probability of current-flow through the body because of voltage differences in the neighborhood of a stroke (voltage crater) is reduced. Do not lie down on the ground no longer, because probability of death or severe injury is increased by the great area of ground touched by the body. (By the way, when kneeling down, protection against rain by a raincoat is more effective). It may be particularly dangerous to lie down in a ditch or hole because there the ground is often better conducting (wet soil) than in the surrounding of it.

(2) To crouch down on a well conducting metallic basis, such as a rolled metallic grid or a bicycle, or by sitting on a roll of clothing of at least 10 cm thickness of diameter feet closed together and bend forward with the hands on the knees as in 1),

(3) Groups of persons caught by a thunderstorm in the open, especially on mountains, should stay several meters away from each other when walking, running, kneeling or crouching.

b) With auxiliary, portable equipment

The following auxiliary equipment for lightning protection will be applied primarily by persons or groups of persons who are exposed to lightning frequently because of their profession or duties.

(1) Lightning protection tent after Dr. Wiesinger (1*)

(2) Lightning protection sleeping bag.

Many tourists and guardians frequently carry sleeping bags which also protect the head. If such sleeping bags would be built with a fine and complete covering of sufficient conductivity and some fire proof base, a good protection for the person in the bag would be given for both ground currents and direct hits.

(3) Lightning protection rain cape

In particular, people who are moving in mountaineous areas are often equipped with a cape or a poncho for protection against rain and cold weather.

These capes could be modified in order to provide some protection against severe lightning damage. To achieve this, a network of wires or fine strands mainly running vertically in the cloth, made from bronze, copper, etc. (e.g. 20...30 x 1 mm^2 Cu), all connected with each other at many places by horizontal wires or strands. Another solution is to use metallic-covered overcoats as they are used by fire-saveguards (Sweden made). In order to use these capes as a kind of Faraday-Cage, the person must kneel upon the lower part of it, pulling it well under his knees. Of course, the hood must be likewise equipped. If the person is surrounded when kneeling by this Faraday-Cage, an effective protection will be obtained. One condition, however, must be fulfilled: the cloth of the cape must not be flammable or combustible.

It should be remembered, that the danger to be hit by lightning is the same for a kneeling or crouching person, with or without the modified cape, but the severity of bodily damage is greatly reduced. Still, at least an acoustical shock will occur for the person hit.

(4) Lightning protection ribbon

Electric injuries from a direct hit in the kneeling or crouching position (2 & 3) can be avoided by 1 or 2 metallic ribbons surrounding the body on one or both sides from above the head to below the feet or shoes. Even of this method is not as perfect as method (1) it can be shown that only less than 1% of the critical electric charge which causes heart-attaque passes through the human body during a lightning stroke. The ribbon may consist of fine wires with a section of not more than 1 x 16 mm^2 or 2 x 10 mm^2 of copper. It is absolutely necessary to pass it below or around the shoes, and to end it above the head, may be by means of a metal grid cape with asbestos base (published automn 1971 in ETZ).

This solution is the only one for people when walking.

*) Numbers in brackets ( ) refer to the list of literature at the end.

Chapter VI: A p p e n d i x : Remarks on the generation and the characteristics of lightning

a) What is lightning? *) Literature is given at the end of this report.

Lightning is an electrical discharge (spark) either between a cloud which is electrically charged and ground (ground stroke, ground flash, earth flash) or between at least two clouds with charges of opposite polarity, or within a cloud with charge centers of different signs (intercloud discharge or intracloud discharge, respectively). Uman, M.: Understanding Lightning.

b) Why are clouds electrically charged?

At present we do not have a completely satisfactory explanation for this fact. There are a number of different hypotheses, most of which require at least two conditions to be fulfilled: There must be a strong updraft, blowing humid and warm air upward; and the water droplets, created by condensation, must be carried into heights where the temperature is at least several degrees below the freezing point so that ice crystals are generated. In moderate latitudes, the freezing level in summertime is about 3...4 km height, during winter it is much lower. Accordingly, the charge centers in summer thunderstorms are quite high (maximum well above 10 km); They may reach almost the ground in winter thunderstorms. According to one of the electrification theories, the following process explains the generation of charge centers (Workman): When the fine water droplets are freezing to ice and then fall through the cloud of subcooled droplets, electric charges of one polarity are collected on the larger ice particles, while charges of the other sign are found on the fine ice splinters. The fine particles are carried high by the updraft, while the larger particles stay below or fall. In this way, charge centers of opposite signs are separated from each other.

Since there have been reports on cloud electrification occuring at temperatures above freezing, the above statement should not be taken as a guarantee that there is no lightning danger from warm clouds.

c) How is a lightning flash generated?

When the electric charge of a cloud above the ground, or the two charges of opposit signs in two neighboring clouds grow large enough, they are fully or partially equalized by a lightning flash. In the terminology of the electro-physicist, this is expressed as follows: Between charges of opposite signs, an electric field is established measured in volts per meter. If this field exceed a value of the order of 2 million Volt/m locally or a mean value of several 100'000 V/m in a certain region, a spark is generated there. This spark extends in both directions and may reach lengths of several kilometers in the atmosphere - this is a lightning stroke. According to Schonland (3) the complete lightning discharge is called a flash. A fast succession of several strokes is a multiple stroke flash, to compare with a single stroke flash.

d) How is it possible that lightning may be several kilometers long?

The lightning stroke is progressing relatively slowly. From cloud down to ground its velocity can well be measured by photographic means. The lightning stroke progresses from cloud to ground within one to several hundreths of a second. This is called a "downward stroke".

At sharp mountain ridges, the electric field strength under a cloud will reach a magnitude which suffices to create a weak discharge of long duration of several minutes ("St. Elmo's fire"), which can be seen in the dark by the human eye. If this is spreading upwards, the so-called "upward stroke" may be generated. Such lightnings, growing upwards, can be generated in flat country only from very high towers, television towers, buildings, smoke stacks etc., while on montains, objects of only 10...20 m height may be sufficient to initiate such an upward stroke (e.g. metallic flag-poles).

The cause for the fact that lightnings can grow to such lengths is to be seen in the very good conductivity of the lightning channel (which is not much smaller than that of a metallic wire). Any length . . . . .

of a lightning path acts as a short-circuit in the electric field. Therefore, the potential difference between clouds or cloud and ground is concentrated at both ends of the path, generating there electric fields of sufficient strengths for further growth of the lightning stroke.

e) How long does a lightning flash last?

The duration of a complete lightning flash is between one thousandth of a second and a full second. This great variety is explained by the fact that many lightning flashes will be multiple stroke flashes. The strokes in themselves have often varying time durations, and may be divided into two types.

The first type consists of current pulses of short duration (about one millisecond each) and very different current magnitudes which may exceed 100'000 amperes in downward strokes. The second type consists of currents of relatively long duration and magnitudes of 100...300 A, lasting up to some tenths of a second per stroke. Taken all strokes in one flash together, one may find lightning flashes lasting rarely up to one second or even a little more. If a lightning flash is composed of several strokes, we sometimes can see this with the naked eye; the light is flickering.

Lightning flashes from positive clouds consist of only one stroke of usually several milliseconds up to a few hundredths of a second duration. They sometimes have very large currents, up to more than 200'000 A. Positive strokes or flashes are the strongest for electrodynamic and thermal effects, which cause the most damage.

f) What are "cold" and "hot" lightnings? Which lightning flashes ignite?

In a downward stroke, the growing lightning channel is replenished with electric charges from the cloud. When approaching ground, the last several meters or tens of meters are bridged by a "connecting streamer" *)

*) Footnote: See K. Berger, Journal of the Franklin Institute, Vol. 283, No. 6, June 1967, pages 514 and 515.

coming up from earth. Than the whole lightning channel discharges itself somewhat similary to a highly charged copper wire, giving raise to the current pulse with currents normally between 5'000 and 100'000 A and durations of about 1/1000 of a second or less. In this high-current spark the air is heated to many thousands degrees (Celsius or Kelvin). Consequently, it expands explosively and exerts strong forces - in particular, if this does not happen in free air but in narrow channels or small spaces. This is, for example, the case when the lightning hits trees or wooden poles which have fine slits or crevices between wood and bark. Then lightning may destroy such objects in an explosionlike manner without burning them or even blackening them. Time is too short for ignition. Such lightning flashes are sometimes called "cold lightnings", they break to pieces insulating material which is not closely packed. They represent currents of very high intensity but very short duration.

Contrarily, either as a follow-up of these strong-short current pulses or independently, we find lightning flashes which carry only 100...300 A (as mentioned above) but last several tenths of a second. Currents of that magnitude are applied in welding. They may immediately ignite flammable material such as hay, wooden shavings, etc. and they are often referred to as "hot" or "igniting lightnings". The difference between cold and hot lightnings is really a difference of duration and current magnitude; and the denomination "cold" of course, is wrong because the temperature of the lightning channel is very high in all cases.

g) <u>How often do lightning flashes occur?</u>

If somebody have experienced that the poplar tree in front of his house has been hit by lightning two or three times within a few years, he probably will be convinced, that the tree, or the ground under it, "attracts" lightnings. Or when in a forest several neighboring pine trees die after a thunderstorm, people living in the area will feel a suspicion that we have there a "lightning nest", a place where several lightning flashes occurred in a row. We should ask: Does something like this really happen, do we find "lightning nests"?

In a period of ten years, nearly all lightning flashes of the area were recorded during obscurity from the institute on top of the mountain "San Salvatore" near Lugano in Switzerland. This was done in such a way, that the locality of each stroke could be entered exactly in a geographical map. The result was that the distribution of lightning localities was more regular the longer the observation period, and this included all types of underground: Plains, lakes, valleys, slopes and montains (3) and (4).

To assess the distribution of lightning localities one should distinguish between small-scale and large-scale areas. Considering large-scale areas one finds that, e.g. in Switzerland the northern and southern slope of the Alps Mountains has a greater lightning frequency than the valleys between (i.e. the Wallis, the Engadin etc.). At the northern slope of the Alps lightning frequency is in the average 3 to 5 lightning strokes per square kilometer and year, at the southern slope about 7 per square kilometer and year, and probably less than 1 per square kilometer and year in the centre valleys of the alps. These differences are well understood by orographic features, i.e. mountains which give rise to ascending air masses. If we are assessing periods of sufficient duration, we do not find any evidence that there are small places which are more often hit than others. Of course, in doing such assessment, one must exclude localities with very high objects, which may cause additional upward strokes. It has not been possible to prove that either the electrical conductivity of the soil or the ion content of the air (caused by natural or man-made radioactivity) have an influence on the frequency of ground lightnings (5).

The path taken by a lightning stroke from the cloud to ground is determined first by the electric field and in details by the electrical charges residing on visible (fog) or unvisible small water droplets in the air.

The orographical structure of the earth's surface does not play a role before approaching the last ten to hundred meters to ground.

Consequently, considering the question of favored lightning localities one can only state that high objects are more often hit than low ones. However, it should also be mentioned that there are ground strokes which will hit a low object or the flat ground directly even when there is a higher object nearby. Every place in the open can be hit by lightning. It is only a question of probability when this will occur. All theories of "protected spaces" based on purely geometric considerations and neglecting stroke current dates have been refuted by experience.

The question of how often lightning strokes occur in a certain area is connected with the so-called "isoceraunic level" used in meteorology. This level is defined as the number of days when an observer heard at least one thunder. To use the number of "thunderstorm days" as a measure for thunderstorm severity cannot be recommended - one or 100 lightning flashes over an area per day would give the same number which of course is erraneous. At the present time, the best indication of thunderstorm-severity for a certain region is given by lightning-flash-counters, as f.i. the type used in the High-Voltage-Power-Technique.

h) <u>How do we determine where a lightning has occurred? What traces do they make?</u>

Very often, there is no problem: If a lightning has hit a barn and it burns down, there is little doubt. But when a lightning has hit a steel tower or mast and there are scarcely any traces, even an expert may be at a loss.

Bare and insulated wires may be evaporated by the current of a lightning if their diameter is too small. Insulated wires of 1 mm^2 Cu may be evaporated by a lightning without causing any visible damage to the insulation. However, at the lightning research institute on the Monte San Salvatore, a copper wire of 16 mm^2 cross section, or 4,5 mm diameter, could carry all lightning currents without suffering damaging heat. As a rule, lightning hitting a lawn, meadow or pasture will not leave visible traces, but sometimes holes with a diameter of centimeters are found.

Very high lightning current impulses may produce long gliding discharges on a highly resistent ground. If such a discharge reaches a well grounded conductor as f.i. a river, it may produce quite a furrow in the meadow on its way. In sandy ground, long-duration lightning currents may melt the the sandcorns; in this way the fulgurites are created.

When hitting trees or wooden poles, lightning may cause burns, splitters and other traces, especially if the masts have crevices and the trees do not have a smooth, coherent bark surface, but instead a bark with considerable roughness or crevices, or where there are hollow spaces under the bark (as is the case with pines, firs, spruces, poplars, chestnut trees, ashes, willows, oaks etc.). Healthy trees with smooth, fixed bark such as beeches, do not allow the discharge to penetrate into air-filled crevices; it must follow the surface in the air and, therefore, very often leaves no traces. This was probably the cause for the advice to seek shelter under a beech-tree when in a thunderstorm, and to avoid oaks and willows. Such advice, sometimes known in the form of easy-going rhymes, is very dangerous! Beeches are as frequently hit as are other trees of comparable height.

In addition to thermal and mechanical traces, lightning also leaves magnetic traces. For example, steel cables after being hit by lightning do show magnetic poles which can be detected when using a compass needle. Even after several years the exact place where a lightning has hit can be found in this way. This method provides a reliable way to measure the lightning frequency in power lines, etc.

However, the determination of lightning traces, especially after accidents, provides a complicated and intriguing problem. Here, we could only give some superficial hints.

i) <u>What happens when a lightning hits a human being?</u>

We again have to distinguish between the lightning flash with a short current pulse, e.g. a downward lightning in flat country, and a flash on a mountain ridge. In the first case, there will be a "connecting streamer"growing from the human body towards the downcoming lightning, possibly making contact with it. Then, the current pulse injects the human body, which has an electric resistance of about 500...1000 ohms. Since the lightning current reaches many thousand amperes in a few millionths of a second, a great electric voltage is quickly created in the body which leads to a breakdown at about 500'000 volts. After this breakdown, the body has to sustain the arc voltage, being a few thousand volts. The current through the body which, just before the breakdown, was about 500 to 1000 amperes is reduced to several amperes after it, and it remains at this value for the total duration of the lightning.

A different case is that of the upward stroke which may begin at a human body, especially at a mountain top or mountain ridge, or in the case of the long-duration lightning of small current intensity, as described above. Here, the lightning current remains 100...300 A for a period of several hundredths or tenths of a second. The voltage drop of maximally 50'000 to 300'000 V along the body is not sufficient to cause a sparkover outside of the body and therefore all the current flows through the body.

According to present medical experience, the current flow through the body is not necessarily fatal in the first case (impulse current). In the second case the long duration of a high current in general causes death. In the first case, one may find at the body and in the clothing, shoes, zippers and other metallic parts, burns which prove sparkover and may protect the human body from death by reducing the fraction of current through the body. In the second case, internal heating and cardial effects make it more dangerous. Even if it seems paradox, sparkover of a body may prevent it from death. By the way, this second case may not only occur with upward strokes but also with downward strokes which sometimes have current components of long duration.

j) Rescue procedure after lightning accidents

There are two necessary procedures: The breathing should be maintained by mouth-to-mouth resuscitation - and if no pulse beat can be felt, artificial heart massage. There are rules for this - such rules can be ordered from the Swiss Electrotechnical Association (SEV) at Seefeldstrasse 301, CH-8008 Zurich, Switzerland.

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