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Development of a personal lightning shelter

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Abstract

This paper describes the design, construction and testing of a lightning shelter made of conductive textiles, ensuring it lightweight, portable and quickly deployable. It also describes some of the computer simulations and experimental tests performed in various high-voltage laboratories. To assess the protection of the shelter occupants and to avoid the use of animals as test objects, an instrumented dummy was developed to measure the voltages, currents and energy to which a user may be exposed during a direct lightning strike on the shelter. Finally, it is mentioned that future work should focus on evaluating the overall reduction in shelter costs for the use of the tested textiles, as well as the possible effects of intense electromagnetic fields generated by direct or nearby lightning discharges on the occupants of the lightning shelter.

1. Introduction

The electromagnetic fields generated when lightning strikes close to the human body can induce currents and voltages that can cause strong effects such as electric shocks or burns that can even lead to permanent disability or death. In outdoor or backcountry conditions, during or when a thunderstorm is approaching or leaving, the people are exposed to the risk associated with lightning strikes.

The study of its possible effects, the analysis of the most lethal lightning coupling mechanisms with humans, and the consideration of the principles of lightning protection help in the design of protective devices and measures, and even safety guidelines.

In this paper we present the work associated with the development of a personal lightning shelter for use in environments where access to other protective measures is not possible, such as sheltering inside bulky buildings or a metal-enclosed vehicle. To achieve the objective of reducing the risk of lightning, an instrumented phantom was developed and implemented, several computer simulations were carried out and several laboratory tests with high voltages and currents were performed on materials and a shelter model. The use of a dummy to assess the currents that could flow through the human body was considered in the computer and laboratory simulations.

2. Design and construction of the shelter

In isolated, remote or backcountry locations, various activities such as camping, military and security operations, and outdoor sports, require lightweight and portable lightning protection systems for personal use. By mitigating the risk of the ground currents coupling (or earth potential rise by indirect strikes), the overall likelihood of permanent injury from lightning strikes is reduced [1].

Considering the possibility of using conductive materials so that all surfaces have the same electrical potential (aka equipotentialization and Faraday cage principle) we design and develop a lightning shelter with dimensions and shape following the Colombian Army's own standard for personal tents [2], with an A-frame shape as shown in Figure 1. This simple model makes it easy to install and use. The use of electroconductive fabrics with very low resistivity makes it possible to create a lightweight and portable shelter with the required equipotential surface.

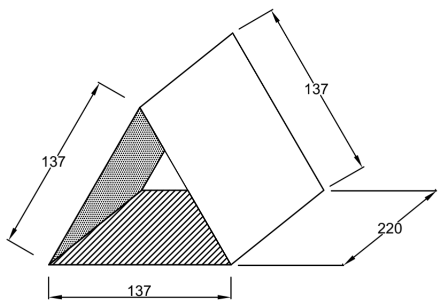


Figure 1. Shape and dimensions in cm of the proposed A-frame shelter.

The shelter has an A-frame shape or triangle shape, consisting of two walls and a floor made of electroconductive fabric from fibers of nickel-copper with a polyester core. It remains installed between two vertical structures such as poles or trees, pulled by two tensioned cords (guy lines) located at the upper corners, and by four main pegs or stakes placed at each of the bottom corners.

The tent is large enough to accommodate one or even two people inside.

The shelter functions like a Faraday cage conducting lightning currents, from the outside to the ground, as it is represented in Figure 2. In this way, the conductive shelter walls divert safely the lightning current to the ground protecting its occupants from direct strikes and side flashes, such as in a lightning protection system. The conductive floor establishes an equipotential surface, protecting from large step voltages due to ground currents which can flow inside of a conventional camping tent.

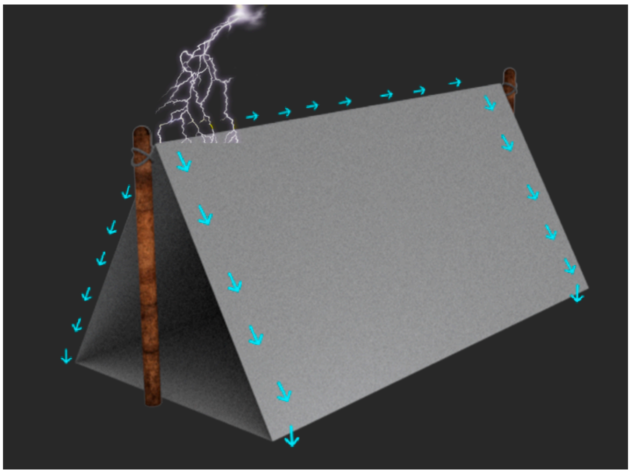


Figure 2. Illustration of a shelter made entirely of electroconductive fabric, which conducts lightning currents to the ground and functions as a Faraday Cage, mitigating the risk for its occupants from both direct lightning currents and induced ground currents.

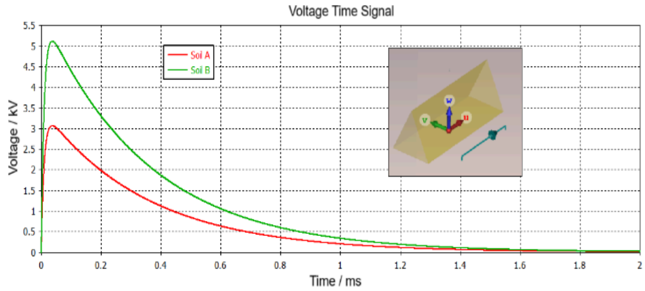
3. Shelter simulation

A full-wave simulation of the shelter at 1:1 scale was carried out with the lightning attached in the middle of its ridge. A current of 100 kA with a 10/350 µs waveform, which represents a strong lightning characteristic, was also considered. An ambient temperature of 20 °C was also assumed. The soil in which the shelter was placed was assumed to be as a homogeneous material, with electrical and thermal characteristics commonly found in some regions of central Colombia and associated with dry clay soils [3]. The electrical and thermal characteristics of the two soils considered are shown in Table 1, data taken from [4].

Table 1. Electrical and thermal characteristics of soils used in full-wave simulation

Soil	εr	$\sigma[\frac{S}{m}]$	$\lambda[\frac{W}{Km}]$
A	1	0.01	0.2
B	29.86	0.0081	1.5

Although the proposed shelter is designed to reduce the risk of indirect lightning strikes, the simulations are intended to estimate the step potential in areas close to the shelter, as well as the temperature rise within the shelter in the event of a direct lightning strike. Figure 3 shows the step voltages one meter outside from the shelter when it is struck by lightning. Note the peak values around 3 kV for soil A and 5 kV for soil B.



Figures 4 and 5 show the developed temperature of the shelter and surrounding soil, in the event of a direct lightning strike when the electrical and thermal properties of the ground are modified after 1 ms the passage of the lightning pulse. As previously said, these simulations are a very simplification of a real scenario, as they assume a homogeneous, non-stratified soil with no porosity or inhomogeneities.

Figure 3. Step voltages at one meter from the shelter, for soil A (red line) and soil B (green line).

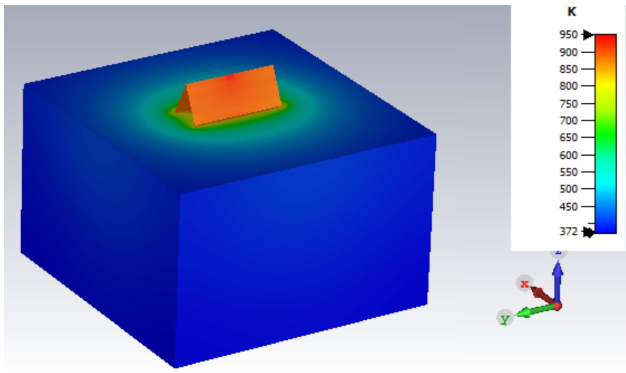


Figure 4. Temperature increase in the shelter when the thermal conductivity of the soil is 0.2 W/m.K (Soil A). Note the maximum value of 950 K or 677 °C.

The results of the electrical and thermal simulation for the two considered soils A and B are summarized in Table 2.

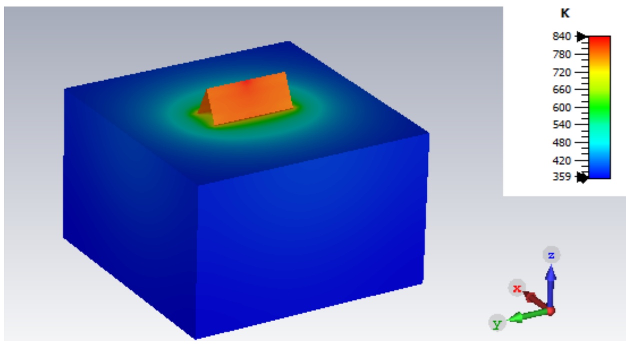


Figure 5. Temperature in the shelter when the thermal conductivity of the soil is 1.5 W/m.K (Soil B). Note that for this soil the highest value is 840 K or 567 °C.

According to these results and as expected, the different electrical and thermal parameters of the soils conduct to a different step voltage and temperatures in the shelter. It is observed that if the soil has low thermal conductivity, the shelter temperature increases.

Table 2. Step voltages and developed temperatures.

Soil	Peak step voltage [kV]	Maximum temperature [K]
A	3.05	385
B	5.10	340

4. Dummy development

For conducting the various tests that assess the effectiveness of shelter in protecting individuals from the potential direct lightning strike, without endangering nearby people or test subjects, the design and fabrication of an inert material object in the shape of a human body is required. This object is referred to as a human phantom or dummy.

The phantom was constructed based on the dimensions of one of the group members with an approximate weight of 80 kilograms and a height of 1.70 meters and it was named Ed. Also, Ed was instrumented for allowing the remote and safe measurement of potential currents and voltages in the body when a current impulse is applied, simulating the lightning strike on the shelter. The tests were conducted at the Fabio Chaparro Industrial Testing Laboratory (LABE) at the Universidad Nacional de Colombia, as shown in Figure 6.

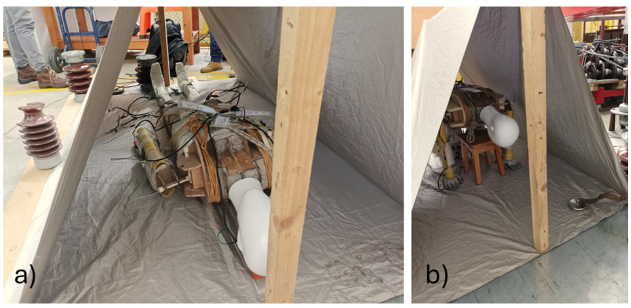


Figure 6. Instrumented phantom setup inside the shelter, a) in lying position and b) in crawling position.

Ed simulated the pressure points exerted by the human body on the conductive fabric floor inside the shelter. For this work, the lying and crawling positions were emulated.

5. Experimental work in the laboratory

The experimental work has been developed in two stages. First, the conduction of the electroconductive fabrics made from fibers of polyester core with a nickel-copper alloy coating was evaluated. For this purpose, a Lightning Impulse Current Generator (LICG) was used. High currents impulses were applied to fabric samples and their voltage responses were measured [5]. Figure 7 shows a schematic of the circuit used for the measurement system where two channels of an oscilloscope, CH1 and CH2, were used to acquire the current and voltage signals respectively.

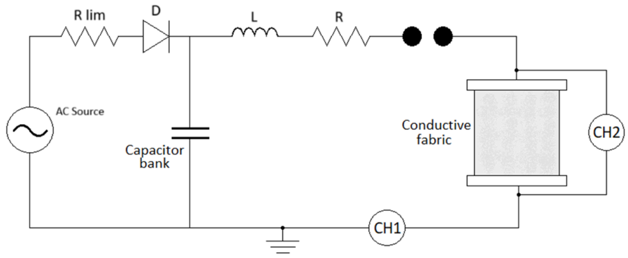


Figure 7. Schematic of the Lightning Impulse Current Generator (LICG) setup used to test the electroconductive fabric samples

The results showed that despite the effects on the fabric, the impulse current flowed through the samples at relatively low voltages for the controlled laboratory conditions. Figure 8 shows a still image of a 24.5 kA test with 10/350 µs waveshape over a 30 x 30 cm sample.

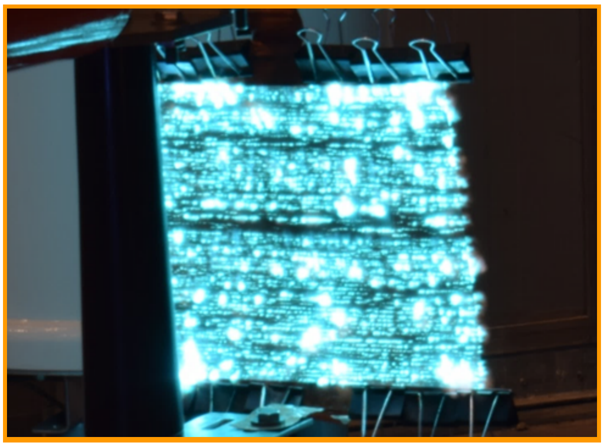


Figure 8. Image recorded with the digital still camera for fabric sample subjected to a 24.5 kA Lightning Impulse Current (10/350 us).

In the second stage, prototype shelters were manufactured using the tested conductive fabrics. Both shelter walls and floor were made with conductive fabric. The current was applied on the floor at one entrance edge of the shelter to simulate a lightning current flowing on the ground and through the shelter base.

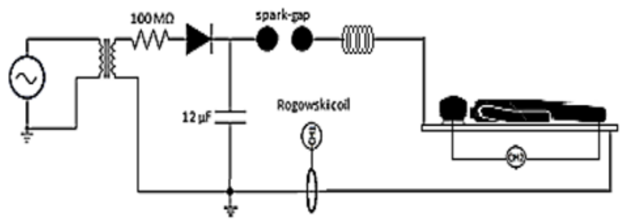


Figure 9. Experimental set-up for lying position

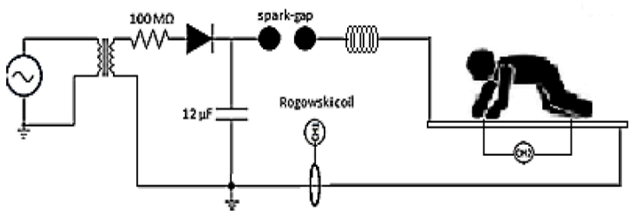


Figure 10. Experimental set-up for crawling position

Those tests were carried out for two possible positions of the dummy inside the shelter, lying position and crawling position as shown in Figure 6. Figures 9 and 10 show the schematics for measurements.

The maximum voltage differences on the dummy due to the lightning impulse current through the shelter floor were measured. From the current and voltage signals acquired, the maximum energies on the dummy were estimated for each of both scenarios (lying and crawling position). Tables 3 and 4 summarize the currents applied and the maximum voltages and estimated energy for the two scenarios. From these data, it is possible to observe that the maximum voltage developed on the shelter floor is below 600 V for the worst case of head-to-feet. This relatively low voltage suggests that it is possible to use a basic insulation layer to completely isolate the body from dangerous voltage levels. The low estimated energy levels imply that the person inside the shelter is protected against lightning currents, at least for 11.5 kA peak currents.

Table 3. Maximum voltages and energies estimated on the dummy inside the lightning shelter for lying position

Points of measurement	Maximum current [kA]	Maximum voltage [V]	Energy [J]
Head-to-feet	+ 11.5	578	< 1
Hand-to-feet	+ 11.5	193	< 1
Head-to-hand	+ 11.5	384	< 1

Table 4. Maximum voltages and energies estimated on the dummy inside the lightning shelter for crawling position

Points of measurement	Maximum current [kA]	Maximum voltage [V]	Energy [J]
Right Hand-Left hand	+ 12	469	< 1
Right Hand-Left Knee	+ 12	114	< 1
Left Hand-Left Knee	+ 12	347	< 1

6. Conclusions and future work

A lightweight portable shelter was developed and constructed by using electroconductive fabrics. The A-frame model was simulated considering a lightning strike in its neighborhood for two soil types to evaluate both its thermal behavior and the step voltages induced. Moreover, an instrumented dummy was constructed and successfully tested with the setup to measure the current and maximum induced voltage, and to estimate the energy on the dummy for lying and crawling positions. The results of the high-voltage laboratory experiments performed suggest that it is possible to guarantee that conductive textile shelters can protect people against lightning discharges, reducing the risk to the health of lightning currents. Therefore, future works are oriented to evaluate the possibility of using other electrically conductive fabrics or materials with different properties to improve the protection and to reduce the weight and price of the shelter. In addition, more accurate electromagnetic simulations are needed to evaluate the radiated electromagnetic fields and their behavior in the neighborhood and for the shelter occupants.

7. Acknowledgements

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References

[1] J. A. Cristancho C., "Analysis and Development of a Personal Portable Lightning Protection System," Tesis de Doctorado, Universidad Nacional de Colombia, Bogotá D.C., 2023.

[2] Ministerio de Defensa Nacional, *NTMD-0171-A2:2015 Norma Técnica Sobrecarpa*. 2015, p. 22. [Online]. Available: https://www.mindefensa.gov.co/

[3] P. S. Cannon, "Extreme Space Weather—A Report Published by the UK Royal Academy of

Engineering," *Space Weather*, vol. 11, no. 4, pp. 138–139, 2013, doi: 10.1002/swe.20032.

[4] I. N. Hamdhan and B. G. Clarke, "Determination of Thermal Conductivity of Coarse and Fine Sand Soils: World Geothermal Congress 2010," *Proc. World Geotherm. Congr. 2010*, pp. 1–7, 2010.

[5] J. A. Cristancho, C. A. Rivera, J. E. Rodriguez, J. J. Pantoja, L. K. Herrera, and F. Roman, "Lightning Impulse Current Tests on some Electroconductive Fabrics," *J. Appl. Res. Technol.*, vol. 21, no. 2, pp. 241–255, Apr. 2023, doi: 10.22201/icat.24486736e.2023.21.2.1605.