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## Voltage Detection During Fire and Rescue Operations

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Omówienie

In the article the electrical shock prevention of firemen during fire and rescue operations was described. Experimental data concerning chosen voltage detectors for emergency responders was presented.

W artykule omówiono problematykę związaną z ochroną przeciwporażeniową strażaków podczas akcji ratowniczo-gaśniczych. Przedstawiono wyniki badań detektorów napięcia dostępnych na polskim rynku.

**Keywords:** voltage detection, electric shock prevention, fireman safety.

**Słowa kluczowe:** detekcja napięcia, ochrona przeciwporażeniowa, bezpieczeństwo strażaka.

### 1. Introduction

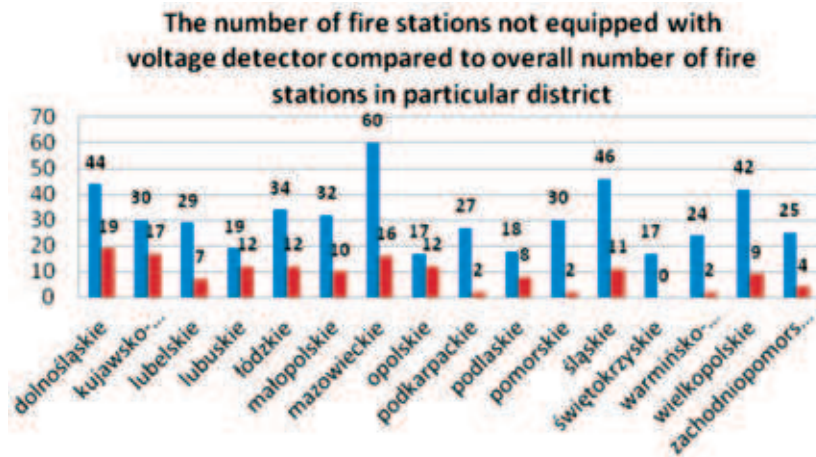
One of the hazards firefighters are exposed to during fire and rescue operations is electrical shock. The greatest hazard should be expected during enclosure fires, various farm buildings fires, dealing with windfalls, urban search and rescue operations, road accidents with electric driven vehicles involved or forest fires near electrical transmission lines. Live objects may pose a serious danger, if they are not detected in advance. When dealing with windfalls, firefighter operating a chain saw may incidentally touch unseen downed power line covered by branches.

The extent of an electric shock hazard will mainly depend on weather conditions (e.g. humidity) and the type of operations. In some buildings electrical installation bypassing the switchboard is still reported. Same problem concerns old buildings, illegally inhabited, with unauthorized electrical terminals connected in.

In conditions of low visibility, electric shock hazard is even more serious. Every year there are several accidents reported, concerning electric shock of firefighters. It should be noticed, that official statistics include the ones that were officially reported. Sometimes superiors are not even informed about less severe electrical shocks.

In 2011 in Poznan, a firefighter died during an operation, as a consequence of electric shock. The firefighters were dispatched after a call from a man reporting some unusual electrical sparking he had seen on the fence around the construction field. Firemen were equipped neither with dielectric self protection equipment nor with the voltage detector. They did not dispatch electricity emergency service as well.

As a result of this serious accident, a thorough analysis of dielectric personal protective equipment and voltage detectors being used in fire stations in the whole country has been ordered by the National Headquarters of the State Fire Service. The outcomes were terrifying: 57% of fire stations in Poland did not possess any kind of voltage detector.



**Fig. 1.** The number of fire stations not equipped with voltage detector (red) compared to overall number of fire stations in particular district (blue)

Source: The National Headquarters of the State Fire Service.

The effectiveness of fire and rescue operations is deeply dependent on the protection level of involved firefighters. If no recon is carried out, there is a serious danger there might be live objects in the area of operations. Especially in that kind of events, firefighters should be equipped with measures to prevent incidental electric shock. It is required by Polish regulations of national level.

On the Polish market, there is a number of devices available to measure an electric field, as well as the AC voltage (50/60 Hz) detectors. However, it is usually difficult to determine location of a live device of installation precisely. Other disadvantage of available voltage detectors is short distance from which the voltage detection is effective.

According to the article, to fulfill regulations concerning protection measures against electric shock during fire and rescue operations, that follow, decision makers were given a free hand. There are no specific requirements (e.g. AC or DC voltage, detection range) concerning any kind of detectors (including voltage

detectors) that fire stations should be equipped with. The result of the lack of, at least, most basic requirements concerning voltage detectors leads to the conclusion, that sufficient level of firefighters protection against electric shock might not be achieved, especially when fire and rescue operations take place in an unrecognized area.

## **2. Expected technical specification of a detector designed for emergency responders**

Voltage detector designed for emergency responders, especially firefighters should meet technical specifications laid down below:

- Detect live objects under load and when lying idle.
- Should have directive gain.
- Detect live objects having contact with water, what is especially important during basement fires.
- Detect live objects that operate at the voltage exceeding 50 V and frequency of 50 Hz.
- Detect objects from a distance of minimum 50 cm, what guarantees relatively early warning for a rescuer.
- Give early audible (beeper) and visual (flashing red LED) warning of the presence of dangerous voltage. The closer the source of voltage is, the more rapidly the device should beep and flash.
- To be highly resistant to corrosive products of combustion process and to high temperature (up to 100°C for at least a couple of second).
- Not to constrict movements of a firefighter.
- Should provide operation comfort (reduced size and weight of a device), it should not be necessary to hold a device.
- Should be reliable, should have sufficient mechanical strength, should be resistant to high humidity, dustiness.
- Should be battery-powered, should indicate battery's depth of discharge (at least critical one).
- Should not become an effective ignition source, when working in potentially hazardous (explosive) areas.

A device fulfilling technical specifications given above would guarantee highest protection level against electrical shock of a firefighter during fire and rescue operation, if for some reason, electricity has not been cut off before engaging dangerous area. Currently, such a device is unavailable on the market.

## **3. Researched voltage detectors**

As it is impossible to produce universal gear for firefighter, that has dielectric properties in real-life conditions (especially in increased humidity), the authors of this article judged a research on chosen voltage detectors available on the

Polish market necessary: AC HotStick (made in USA, most frequently used by Polish State Fire Service, according to) and DPPE-1 (made in Poland, alternative to previous one). It is crucial to use highly reliable voltage detector during fire and rescue operation to reduce the risk of electric shock hazard. The devices, the research was conducted on are shown in the figure 1.

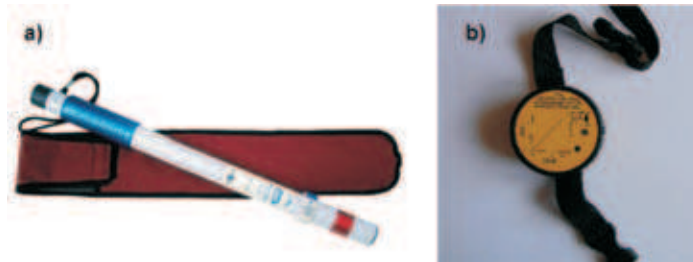


Fig. 2. Researched voltage detectors  
a) AC Hotstick; b) DPPE-1

Source: own work based on and.

AC Hotstick voltage detector was produced by Hotstick USA Inc. It is designed to protect firefighters from electric shock hazard. The device consists of the AC amplifier of high sensitivity for the frequencies between 20 and 100 Hz. Four AA type batteries power the device. The device has PVC plastic housing (45 mm diameter  $\times$  521 mm long). The producer ensures, the device is splash water-proof and designed for intrinsically safe operation. The weight of the detector ready to be used (including batteries) is 570 g. There is a mode switch that can be set on high sensitivity, low sensitivity and front-focused sensitivity. Detected voltage is indicated by both audible ('beep' sound) and visual (LED) signals. The beep rate increases as the distance from live object decreases. The declared operating temperature ranges:  $-30$  to  $50^{\circ}\text{C}$ .

The voltage detector DPPE-1 was produced by Electrical Power Equipment Factory AKTYWIZACJA Cooperative. It detects the presence of electric field surrounding live installations and objects. The range of detected voltage is 0,23 to 400 kV, for the frequencies between 50 and 60 Hz. Previously the device is designed for the people who choose to work for power engineering, but presented version of the detector is also recommended for emergency responders. Operating conditions are: temperature range between  $-25$  and  $70^{\circ}\text{C}$  and humidity between 20 to 96%. The device is rated IP5X. Two AAA type batteries power the detector. The device weights 100 g. It is not necessary to carry the detector in one's hand, as it is possible to mount it on user's helmet or wrist. The diameter of the device is 67 mm, its length: 30 mm. Minimal electric field intensity to be detected is about 400 V/m. The voltage is indicated both by audible ('beep' sound) and visual (LED) signals. The beep rate increases as the distance from live object decreases. Most important technical data concerning both detectors was compared in the table 1.

**Table 1.** Comparison of AC Hotstick and DPPE-1 detectors

	<b>AC Hotstick</b>	<b>DPPE-1</b>
Power supply	4 × AA	2 × AAA
Operation temperature	between -30 and 50 °C	between -25 and 70°C
IP rating	splashwater-proof	IP 5X
Dimensions	ø=45 mm × 521 mm	ø=67 mm × 30 mm
Weight	570 g	100 g
Operation	one hand	mounted on a wrist or helmet
Signal indication	Audible and visual	Audible and visual

Source: own work based on [1] and [2].

#### 4. Research methods and results

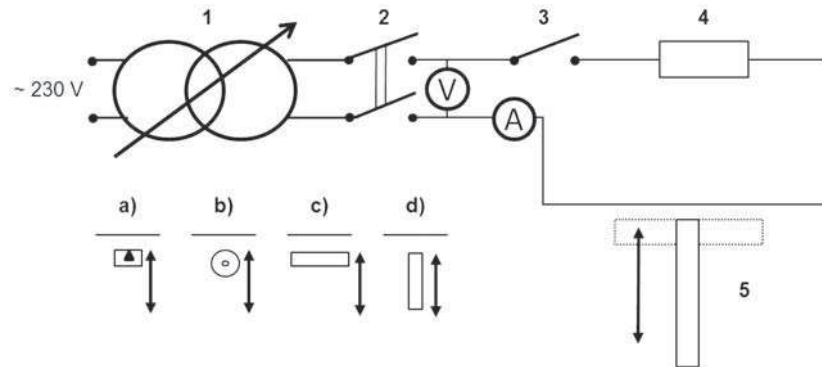
The main objective of a research was to evaluate the usefulness of voltage detectors during fire and rescue operations. Ergonomics, real functionality, but especially the following characteristics of the devices were taken into consideration: sensitivity, electromagnetic shielding conditions.

Two values of voltage were taken into account: 50 V and 230 V. Despite the fact, that the producers of the devices declared detection range starting from 120 V (AC Hotstick) and 230 V (DPPE-1), 50 V is understood as a lowest dangerous voltage value. It enabled authors to assess real-life usefulness of the detector. The other value (230 V) is most frequently met by firefighters engaging fire and rescue operations such as: structural fires, basement fires, windfalls, etc.

The detection of higher voltage would be connected with fire operations in forests or search and rescue groups' activities during building collapse, etc. However, there are several important differences between such operations and more standard (most frequent) ones, as described in previous paragraph. That includes: involved resources, usually much larger, tactics. In such situations emergency responders expect the distance from which they can detect live objects to be greater. However, such situations are beyond the scope of presented research.

In the figure 3 electrical diagram of a test stand, where the sensitivity of voltage detectors was measured, has been presented. Chosen orientations of voltage detectors represent most typical range of firefighter movement during fire and rescue operations. Detectors were placed on a table for the best control of the distance from live object.

The test stand enabled the measurement of detectors' sensitivity depending on the distance from live object. Additional switch (3) was used to disconnect the load from the circuit. The sensitivity was measured, as the optical tachometer counted the number of visual signals (LED) per minute. It is reasonable to acknowledge the detection threshold as 1 signal per second, taking into consideration dynamic nature of firefighters' movement during fire and rescue operations.

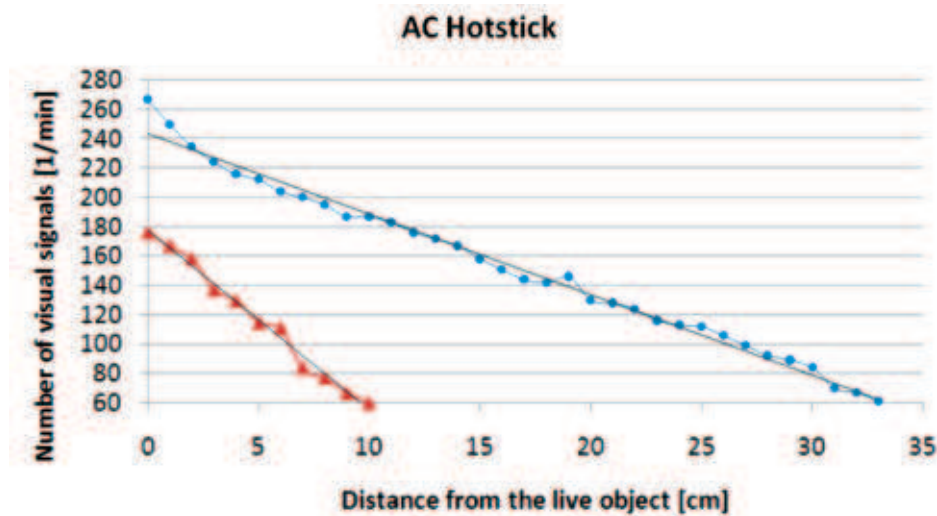


**Fig. 3.** Electric diagram of a test stand

1 – autotransformer; 2 – power switch; 3 – load switch; 4 – slide resistor; 5 – voltage detector; orientation: a) DPPE-1 front faced; b) DPPE-1 side faced; c) AC Hotstick parallel; d) AC Hotstick perpendiculary.

Source: own work.

The outcomes of the research were presented below.



**Fig. 4.** Sensitivity of the voltage detector AC HotStick in front-focused mode: perpendicular (blue) and parallel (red)

Source: own work.

The results for 50 V and 230 V turned out to approximate each other. The differences did not exceed 1%, so presented data is the average of both characteristics.

Another important conclusion from the conducted research is that if the device is somehow covered, even partially, e.g. by hand, it will lead to detection failure, as any cover works as a shielding for detector's aerial.

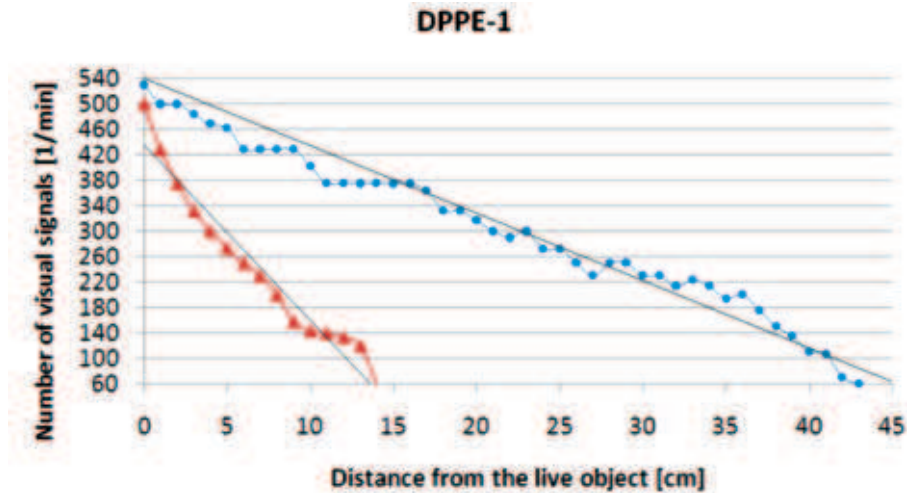


Fig. 5. Sensitivity of the voltage detector DPPE-1: front faced (blue) and side faced (red)  
Source: own work.

Moreover, crucial for appropriate detection is the orientation of a device (as shown in figures 4 and 5), as they are characterized by a directive gain. Also the orientation of a firefighter himself is important, as it affects the value of electric field intensity.

The sensitivity in the range between ten and twenty centimeters is not satisfying, as the detector DPPE-1 should be mounted on firefighter's wrist. It is possible to touch live object, if it is not detected early enough to give the rescuer a chance to react.

The AC Hotstick should be held, it is not possible to mount the device on firefighter's clothing or helmet. It disqualifies the device to be used during fire operations such as structural fire or basement fire, that is when lots of equipment must be taken to achieve best effectiveness of operations.

It should be emphasized that mode 'high sensitivity' and 'low sensitivity' will be useful during forests fires and other operations, where live objects should be detected from greater distance. In a compartment, any mode of sensitivity higher than 'front focused' will indicate the presence of live object continuously.

All remarks described above arrive at conclusion that the usage of these equipment during fire and rescue operation does not ensure sufficient protection level against electric shock.

## 5. Conclusions

1. Currently, there is not a voltage detector available on the market that would guarantee sufficient protection of a firefighter against electric shock.
2. Presented voltage detectors are expected to ensure sufficient protection for power engineering employees. Their primary hazard in the work place is high voltage.

They know very well where to expect live objects, they do not work under the pressure of time. Working conditions are repeatable and predictable, on the contrary to firefighters' profession.

3. Some functional issues concerning the use of the AC HotStick disqualify its application in a number of types of fire and rescue operations, as it must be carried in firefighter's hand.
4. Low sensitivity of the DPPE-1 detector, especially when approaching live object in side-faced orientation, might lead to electric shock, despite the fact, that the device might be mounted on one's wrist.
5. It appears to be reasonable to construct a device that would fulfill the requirements presented in the article. It will guarantee sufficient protection against electric shock of a firefighter.

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### **Zagrożenie porażeniem prądem elektrycznym strażaków podczas działań ratowniczo-gaśniczych**

Artykuł omawia zagrożenie porażenia prądem elektrycznym strażaków. Podejmowany jest problem spełnienia prawnego obowiązku wyposażenia każdej jednostki ratowniczo-gaśniczej w detektor napięcia, wobec braku szczegółowych wymogów. Prezentowane są wyniki badań dwóch dostępnych na rynku urządzeń oraz pożądane cechy detektora, który gwarantowałby pełne bezpieczeństwo porażeniowe strażakom biorącym udział w działaniach ratowniczo-gaśniczych.

STRESZCZENIE