Orientation of the firefighter in the smoky space of the building

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Abstract

Fire protection is essential for the performance of rescue and liquidation work in solving an emergency. The article deals with the orientation of the firefighter in the smoky space. The first part of the article defines the space and types of space. The next part of the article is focused on determining the necessary equipment of a firefighter in the smoky space of the building. The following section describes the preparation and training of a firefighter for proper and effective orientation in the building's space. The next part is conceived as the identification of technologies that can be used in the building's space. Next part of the article is devoted to the firefighter's practice orientation in the smoky space. The last part of the article analyses the experimental development of the topic.

Keywords: Smoky Space, Firefighter's Orientation, Firefighter's Equipment, Positioning Technologies, Fire Safety

Introduction

As one of the oldest types of safety, fire protection is frequently in demand for society's proper functioning. The main threats in this regard include fire and the explosion of hazardous substances. When these threats are exposed, smoke is generated in the area, harmful to people and endangering health. Therefore, fire protection units must be prepared for effective management of orientation in the building's smoky space. It is important to characterize what type of space it is, who and what is in the space, and whether there are any other objects or substances that could cause the spread of fire or explosion. The orientation itself follows these actions in the given space of the building.

1. Space characteristics

Space can generally be defined as a place of specific dimensions. Dimensions may be unlimited or defined. Space can be defined from various disciplines such as philosophy, geometry, architecture, physics or information system. Space can be divided into several types of fire protection. According to the defined dimensions, the first division is determined whether space has specifically defined dimensions or not. According to the place, the second division is divided into the interior, exterior, or a combination thereof. The third division is according to the presence of persons divided into space with a high, increased and low number of persons or space without persons' presence. The last fourth division of the space is according to the

property's nature, which is divided into space where hazardous substances, open fire, machinery and equipment, electrical office equipment, supplies and logistics, financial assets, administration and their combination.

2. Firefighter's equipment

Firefighter's equipment is necessary for the performance of their activities in the field of fire protection. Firefighter's equipment consists of 2 main parts: equipment and armament. The article defines the parts of equipment and armaments needed for rescue and liquidation work in emergencies.

Firefighter's equipment can generally be understood as what firefighters wear when performing their profession in rescue and liquidation work in the event of an emergency. The available equipment of the firefighter includes single-layer emergency clothing (trousers and coat), multi-layer emergency clothing (trousers and coat), firefighter helmet with face protector, emergency footwear, emergency gloves, fire belt, protective Nomex helmet, heat-resistant suit, disposable respirator, disposable gloves, rubber boots, functional (thermal) underwear, work clothes (trousers and coat), work winter jacket, work gloves, work coat and work shoes. Within the building's fire, the necessary and most important equipment includes multi-layer emergency clothing (trousers and coat), a fire helmet with a face protector, emergency shoes and emergency gloves. The rest of the equipment is recommended or determined according to the situation. [1]

The armament of a firefighter can generally be understood as what firefighters use during the exercise of their profession in rescue and liquidation work in an emergency. The available equipment of the firefighter includes material means (hose, jet, ladder, rope, fire extinguisher, foam, pickaxe, etc.), means of communication technology (vehicle radio, portable radio and mobile phone), means of gas service (self-contained breathing apparatus with protective mask and spare compressed air tanks), means of fire rescue service (hand release tool, crowbar, seat belt cutter, chain saw, loose sorbent) and flood rescue service means (lifebuoy or belt, sludge pump and life jacket). [1]

Firefighting equipment includes a motor vehicle with a motorized syringe, a tanker car syringe, a portable motorized or floating syringe, a portable smoke extractor or pressure relief valve, and a portable lighting station. [1]

3. Preparation and training of a firefighter

For a firefighter's performance in an area where dangerous smoke is present, the firefighter must be equipped with a self-contained breathing apparatus during an intervention. For a firefighter to use this device, it is necessary to complete training for it.

The self-contained breathing apparatus consists of a carrier, a face mask and a bottle containing compressed air. The carrier contains carrying straps and a waist belt. These straps and belts should be made of abrasion-resistant, pressure-moulded and non-combustible material. They should also be resistant to cuts, water and chemicals. Better instruments also include displaying the current cylinder pressure via a manometer. The dial of the manometer should be illuminated in case of darkness. In the case of low pressure, an acoustic signal occurs in the form of a whistle. Pulmonary automation and a reduction valve are used to supply air from the bottle to the mask for inhalation and exhalation. The second part of the breathing apparatus is the face mask. The mask is pressurized and must be made of non-hazardous material. It should have a

simple and reliable construction and should not be fogged. The last essential part of a breathing apparatus is the pressure bottle. It is a compressed air tank. The most commonly used cylinder pressure is in the range of 20 to 30 MPa. It is made of lightweight steel, and its volume usually ranges from 2 to 7 litres. At the end of the bottle, there is a valve for releasing the bottle's air pressure. The weight of the device should be up to 3 kg without a bottle. The total weight of the device is around 10 kg. [2]

As part of firefighters' training, there is training with breathing apparatus with a safe return, orientation in an unknown environment, development of a hose line, search and rescue of persons, and search and closing of energies. The training is carried out through a polygon - a cage trainer. This simulator is used by firefighters and other components of the integrated rescue system. The most common activities within this simulator are regular training of all members of fire protection (professional and volunteer firefighters), practical training in courses of acquisition and extension of professional competence, admission procedure to the components of the integrated rescue system and regular initial training of members of the integrated rescue system. This equipment consists of several parts: gym (endless ladder, hammers, exercise bike and endless belt), release - trained hoses, cage polygon (adjustable as needed), two floors - walking and crawling zone, bridges and cistern, central energy shutter, infrared heaters for heat load, production of fog for orientation load, audio system with noise for sound load, strobe for psychological load, infrared camera and thermal camera for control of trainers (camera system), air conditioning with the possibility of emergency ventilation from the real simulator and control panel (security and surveillance system including eavesdropping with voice input). This training for the use of self-contained breathing apparatus during an intervention should be completed by a member of the fire brigade each year. As part of future training, it would also be useful to use virtual reality for more effective progress in a given space and situation. [2]

4. Positioning technologies

Position detection has evolved. Cartography was one of the first methods of recording location. It was a manual recording of the position on the map. Over time, this method of manual recording has switched to digital using photos and videos. The current way to record and locate on a map is a satellite system and a GPS. Ideal technologies for position detection in fire protection are described in this section. The most commonly used methods to determine fire protection are the use of radar and space mapping.

Radar is ideally used for more demanding terrain. Mostly it is the exterior. Radars can be used on different frequencies. The most common radars with an operating frequency are 10 GHz or 24 GHz. These types of radar are used to locate moving people and vehicles. The area covered by the detection signal is usually up to 1.5 km^2 or up to 22,500 m^2 in radar with a higher operating frequency. Also, these types of radar can independently track around 20 moving objects. Communication usually takes place via the RJ45 connector. This connector is also used for the PoE power supply (terminal equipment). More detailed technical parameters for both types of radars are given in the following table. [3] [4]

Tab. 1 – Technical parameters 10 GHz and 24 GHz radars [3] [4]

Item name	10 GHz radar	24 GHz radar
Detection range for person detection	1 400 m	150 m
Detection range for vehicle detection	2 000 m	200 m
Frequency	10 – 10,6 GHz	24 – 24,5 GHz
Horizontal detection angle	90°	90°
Vertical detection angle	20°	10°
Resolution detail	3,75 m	1 m
Perimeter scanning	8 x/second	8 x/second
Power supply	PoE or 18 – 30 V DC	PoE or 12 – 30 V DC
Temperature	- 40°C to + 60°C	- 40°C to + 60°C

Space mapping can most often be used through visual perception or technology. In this case, it is specific to SLAM and ROS technologies.

Visual perception is a fundamental way of mapping space. Space can also be recorded via a photo or video and then applied to a program designed to create rooms or objects.

SLAM (location and mapping simulation) technology covers several areas, such as electronics, robotics, mathematics and statistics. The SLAM process's goal is to use the environment to determine the location of the robot in space with the next update in the next time, including the creation of a map of the surrounding space. It is a complex algorithm that is very complex and continuously variable due to the increasing number of solved functions. The result is a two-dimensional or three-dimensional map. It uses a laser scanner. The whole SLAM process can be divided into four steps: extracting landmarks from the environment, associating data, estimating the status, and updating the landmarks' status. The whole process is repeated cyclically. [5]

ROS (robotic operating system) technology consists of several parts that can be combined or supplemented. The system facilitates the work of robotic system developers. It provides various freely available codes that can be used in robotics. This system consists of 3 levels: file, computational and community level. [5]

5. Possibilities of orientation in space

For the correct orientation of firefighters in a smoky space, a visual sensation, a light battery, a rope, a smoke extractor or a thermal camera are usually used. Within the future state's design, a new complete method is not proposed, but the application of the given new design already to the current state of orientation of the firefighter in the smoky space.

In the event of an emergency declaration, the fire protection units are informed of the type of emergency within the fire protection framework upon arrival at the given place. Before entering the building, the necessary firefighting equipment and equipment is determined. The fire brigade commander should be provided with information regarding the premises of the building through a fire evacuation plan. If no fire evacuation plan of the given space is created in the building, it is ideal if the person present, who inhabits this building or is well oriented, describes

the given space in a hurry. It is essential to draw attention to the possible hazardous substances in the building, the gas supply where the fire is located, other people or animals in the area and others.

In the event of a smoky space, the member of the fire protection unit shall be equipped with a self-contained breathing apparatus. In the case of a very smoky area, a member of the fire protection unit may be tied with a fire rope. This rope is used in a given situation, and mainly if the member loses orientation in the given space and does not know how to find the way back, the other members would start pulling on the rope. If the firefighter could not get out of the area even after pulling the flax, another member, which would also be equipped with a self-contained breathing apparatus, would effectively reach the lost member in the smoky area with the help of a rope as quickly as possible. This rope can also be used to rescue people from heights or depths. The most common length of this type of rope is 30 meters.

Another option used in the orientation in the smoky space of the building is the use of a smoke extractor. It is a combined ventilation device designed for ventilation of smoky spaces by suction or overpressure. It is used against the smoke of the space and reduces the temperature in buildings, to supply clean air, which causes ventilation of the room and other enclosed spaces. It is also used to supply compressed air as a filling medium (for example, life-saving rescue mattresses) and direct combustion products or gaseous substances in the event of fires and the escape of dangerous substances. [6]

If a fire is detected from less accessible places, a thermal imager is used. As part of fire protection, there are several types of thermal cameras for a given case. These cameras are used to detect the outbreak of fire from less accessible places. They can also see through the smoke. This helps to orient and find people more quickly. In the case of less accessible places, it may be various shafts, pipes, cellars and other areas in the building. In this case, two examples are given. In one case, it is a cheaper version of the thermal imager, and in the other, it is a professional thermal imager and the related basic technical parameters. [7] [8]

The cheapest emergency thermal imager designed for firefighters is called FLIR K2. For a lower price, it is a widely used type in fire protection. It has an ergonomic design for easy operation and is capable of full operation at + 500 °C for 3 minutes. It offers various image modes for the needs of a given intervention operation. It is equipped with an LCD with a picture frequency of 9 Hz and high contrast and provides sufficient lighting during emergency operations. Fall resistance is up to 2 meters. It is equipped with lithium-ion batteries, which can last 4 hours in operation. The camera's total weight is 700 grams, and the dimensions of the camera are 250 x 105 x 90 mm. [7]

The second type of thermal imager is called FLIR K65. It is an advanced thermal imaging camera with a large number of functions. It also has an ergonomic design for easy operation and is capable of full operation at + 500 °C for up to 5 minutes. The picture frequency is 60 Hz. It contains up to 7 image modes: IR image, primary fire extinguishing mode, black and white fire extinguishing mode, search and rescue mode for people or animals, heat detection mode and photo gallery. It can store up to 200 files containing photos or videos, depending on their size. The battery type and operating time are the same as in the previous model type. The camera's weight is about 1.1 kg, and its size is 120 x 125 x 280 mm. The disadvantage of this camera is the high purchase price. [8]

As part of the design of the future state of orientation of the firefighter in the smoky space, it would be applying a measuring device. A member of the fire brigade located in a smoky space would have a device placed on top of him to record the distance between the device and the endpoint. The measurement would be based on the principle of a laser distance meter. A fire brigade member should place 4 of these meters at equal distances and angles from each other. Ideally, a member of the fire brigade would have this device placed around the belt in case of objects or people of lower height to be aimed. An example of what this might look like is shown in Figure 1 below. The figure is shown from above, where the red circle shows the firefighter and the black lines show the laser transmission to calculate the distance.

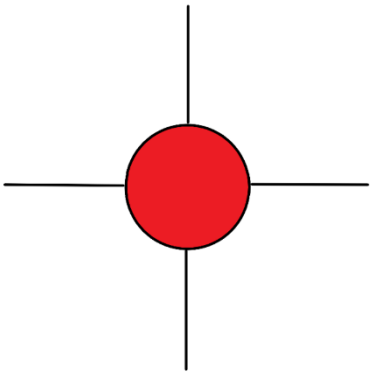

Fig. 1 – Location of meter [source: author]

A device worn by a firefighter in a smoky space would transmit a signal, and a firefighter's device would receive this signal outside that space which would have an image from that device. An example of displaying an image from a device is shown in the following figure.

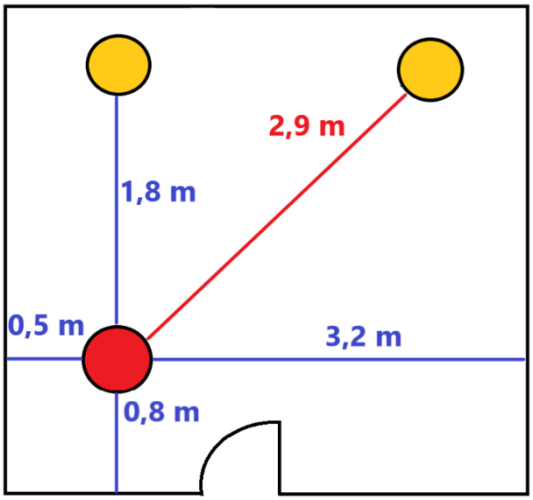

Fig. 2 – Display the image from the device [source: author]

Figure 2 shows the image output from a device transmitted by a firefighter in a smoky space. The picture shows a firefighter in a red circle and people living in a yellow circle. The device transmits 4 points with the nearest distances displayed in purple. The line segment of a person who is more distant from the firefighter than a closer person is shown in red. This means that the laser beam does not detect this person because it is not at the viewing angle. To record this person, the firefighter must turn a few degrees and the person appears on the device. This would apply if the device emitted four beams. If there are more beams on the device, equipment is more likely to see both people at once. The ideal situation would be if the broadcast were in the whole circle, i.e., the full 360 degrees. The disadvantage would be the overall computational

complexity, given the number of points of view. The display frequency is also important. It is ideal for displaying the current position of the firefighter in the smoky space every second. Another major disadvantage would be the absorption of the laser beam in the smoke. Therefore, it is essential to apply a smoke extractor in the room simultaneously for a better passage of the laser beam. Also, a suitable combination is applying a distance measuring device to thermal cameras as one integrated device.

For proper communication about the firefighter's current position in the smoky space, navigation via a transmitter is ideal, combined with a thermal imager. It is essential that the firefighter, who would have the image from the device, effectively navigate the firefighter through the transmitter about each movement. For a more efficient procedure, another member of the fire brigade is essential, who would use a thermal camera directly in the smoky space, and another member would use a smoke extractor.

6. Analysis of experimental development

This chapter is an analysis of experimental development regarding smoke in the building within the fire protection. Based on the development of extinguishing and elimination of fire and smoke, fire protection units described ventilation methods in a smoky environment, where natural and forced ventilation is defined. The most common risks in the event of emergencies where smoke is present in the building include zero visibility due to the resulting smoke, the presence of toxic gases and vapours, reduced oxygen content in the air, and flammable gases vapours. Other factors influencing the building's ventilation include the number and size of openings in the walls of buildings, the number of floors, stairs, shafts, elevators, pipes and roof openings, and the number and types of escape routes. The natural ventilation of the building is divided into vertical and horizontal. Vertical ventilation allows the combustion products to escape into the surrounding environment through roof openings. The most common types of roofs are flat, saddle or vaulted roofs. Horizontal ventilation enables the escape of combustion products into the surrounding environment through gaps in the walls (windows or doors). Forced ventilation consists of creating overpressure or underpressure in the building using extractors or overpressure fans. These devices are most often powered by an internal combustion engine, an electric motor or a water turbine. Both methods of ventilation have advantages but also disadvantages. It is essential to determine what these procedures should use firefighting equipment to eliminate fire and smoke effectively. [9]

Based on fire protection units' development and smoke elimination, type activities aimed at evacuating the population in a smoky environment began to be created. The most common types of exercises include the evacuation of employees in the smoky environment of the company's premises or the evacuation of a particular group of people who would be at risk of damage to health or life due to the escape of smoke or dangerous substances. [10]

Conclusion

The orientation of the firefighter in the smoky space is fundamental and must be effective. In the first part, the article described space and its types. The next part was focused on defining the equipment and technique of a firefighter, which he uses in rescue and liquidation work in an emergency. The following part of the article is designed as preparation and training of a firefighter through a simulator. The next part is focused on the characteristics of technologies for position detection, specifically radar and technologies for mapping space. The last part of the article dealt with the possibilities of firefighter's orientation in the smoky space. This section

defined the current state and the proposal for the future state. The proposal for the future state does not deal with creating a new complete procedure for the orientation itself. It is an application of a new possibility to the current state. In the future, with a more practical orientation, it is also possible to use virtual reality to facilitate progress in a smoky space as part of firefighter training for a given specific situation. The last chapter deals with the analysis of the experimental development of fire protection units for the elimination of fire and smoke in the object.

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