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Fire safety instructions as a tool supporting rescue operations in workplaces

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ABSTRACT

Fire safety instruction is an integral part of the safety of people staying in the building in case of fire. Created in accordance with the Regulation of the Minister of Internal Affairs and Administration of 7 June 2010, the Ministry of Interior and Administration regarding fire protection of buildings, other construction objects and sites and implemented in the building for which it was developed is a helpful tool that can significantly affect the effectiveness and safety of emergency operations.

***Keywords*:** fire safety instructions, fire detection, internal fire, rescue operations, support tools

1. INTRODUCTION

The progressing fire carries with it a real threat to health and life, not only of people in or near the building, but also of rescuers arriving at the scene, whose aim is to save the life and property at risk. A fundamental on health and safety and the relative preventive measures is that health and safety must be approached as 'the promotion and maintenance at the highest degree of the physical, mental and social well-being of workers' and not only as retention of their work ability. [6] In times of increasing intensity of internal fires, an inherent aspect in ensuring an acceptable level of human safety is among others knowledge about the formation and spread of fire. Workplaces are more and more often equipped with many flammable elements and materials which mostly consist of plastics, characterized by a greater amount of

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produced toxic and also flammable smoke in relation to natural materials. Unfortunately, despite continuous advances in knowledge about internal fires and their governing phenomena, as well as the development of technologies (including various types of fire-fighting equipment) and tactics to combat them, it is very difficult to determine the priorities of the rescue operation without knowing the exact specification of the building. Opposite this issue Article 4 of the Act of 24 August 1991 on fire protection (Journal of Laws of 1991, No. 81, item 351, as amended) and § 6 of the Regulation of the Minister of Interior and Administration of June 7 2010. on fire protection of buildings, other construction objects and areas (Journal of Laws of 2010, No. 109, item 719) comes out. The first act sets out, among others responsibilities of the owner of the building, regarding the familiarization of employees with fire regulations, as well as proceedings in the event of a possible fire, while the second implementation and update of fire safety instructions depending on the type and specificity of the object.

2. CHARACTERISTICS OF INTERNAL FIRES

Elements which take part in the process of initiation and supporting combustion are quantity and type of combustible material (fuel), an oxidant which is usually oxygen present in the air, heat and free radicals generated by the interaction of the mentioned factors simultaneously. In addition, focusing on the dynamics of the fire, which also depends on the number and size of inlet and outlet openings on the border of the external environment and the building that provides gas exchange, and more often limited number of walls inside the building, in order to maximize the total internal surface, the occurrence of fully developed fire is a matter of a few minutes. Recalling the research carried out at the UL Firefighter Safety Research Institute, in the Institute of Firefighters Research of Underwriters Laboratories, a modern internal fire curve has been created over the past years, which in combination with the traditional fire curve is shown in Figure No. 1. Developed an integrative perspective on the empirical evidence supporting the influence of particular variables on the warning process based on a broad review. [5]

Analyzing the course of this curve since the initiation of fire (phase I), in which the temperature of fire gases is usually relatively low, and the need for a oxidizer is rather small, the dynamics of its development is influenced primarily by the location of combustible material, as well as its quantity. Due to the sufficient amount of oxygen in the fire environment, the fire is called a fire controlled by fuel (KPP). Over time and increased intensification of combustion, the demand for these factors increases and the further development of the fire depends on their general access. Providing the right amount of oxidizer and combustible material, the fire goes into the next phase (phase II), which is usually preceded by a flashover phenomenon, which indicates the thermal distribution of all elements of the workplace equipment due to thermal radiation from hot fire gases, flame, as well as cumulative heat in building elements. The amount of heat released is proportional to the amount of air reaching the combustion zone, according to the rule of William M. Thornton [4]. The last phase (phase III) is in the case of a lack or limited amount of fuel, which usually results in an incandescence, and as a consequence - the combustion process is stopped or significantly reduced due to the loss of load-bearing capacity of building elements that may occur in earlier phases of fire.

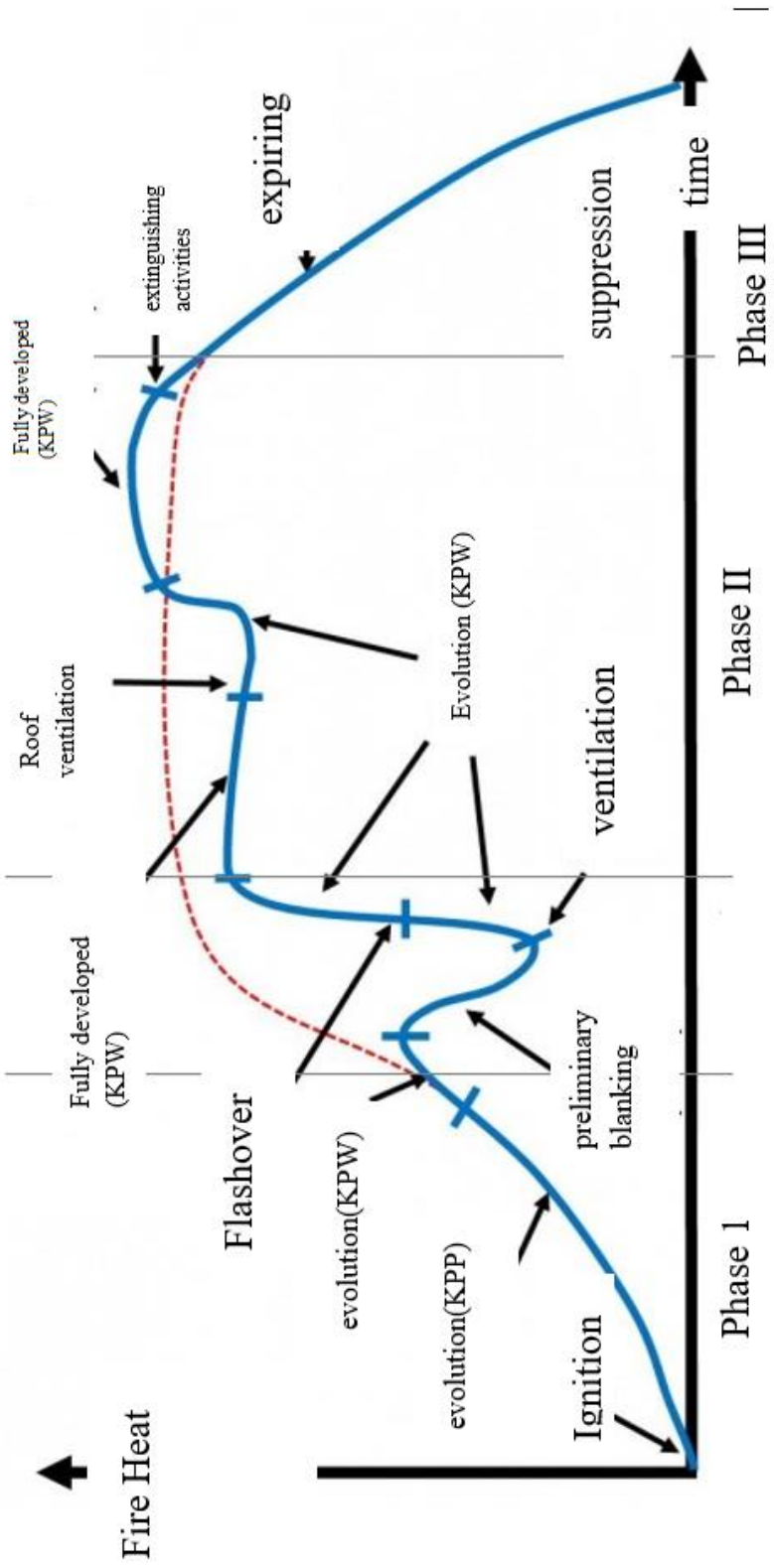

Figure 1. The characteristics of modern (blue) and traditional (red) internal fire curve.
Source: Own study based on: Kokot-Góra Sz., *Get to know your tool* (part 2), Fire Review, 2014, No. 9, 32-35.

When comparing both curves, special attention should be paid to the intensity of the combustion process, which plays a key role today. In addition, due to the overwhelming number of buildings of workplaces characterized by an open spatial and redundant layout, as a rule, the amount of stored materials, the intensification of a possible fire will be much faster compared to buildings with limited space.

3. TOXICITY OF FIRE GASES

Widespread storage of plastics and non-natural materials is associated with higher heat production, smoke formation and toxicity of smoke subjected to inflammation. The type and presence of various types of compounds produced in the combustion process depends on the nature of combustion (flame burning or flameless combustion) and the type of material stored. Depending on what we are dealing with, it stands out, among others:

a) narcotic gases, such as: carbon dioxide (CO_2), carbon monoxide (CO), hydrogen cyanide,
b) irritant gases, such as: hydrogen bromide (HBr), hydrogen chloride (HCl), sulfur dioxide (SO_2), hydrogen fluoride (HF), nitrogen dioxide (NO_2),
c) aerosols of various origins and soot particles, the size of which allows penetration into the body.

Taking into account the conducted statistics of events with various types of internal fires, it can be concluded that the leading cause of deaths is the interaction of toxic compounds [8].

The development of a safe and effective plan of action to evacuate people from a building covered by a fire, and to start effective fire fighting to reduce it, and after quenching, is possible due to accurate assessment of fire conditions at the scene and analysis of the building, which is possible thanks to familiarization with previously developed fire safety instructions.

4. PHENOMENA ACCOMPANYING INTERNAL FIRES

The purpose of the object may suggest probable ways of spreading a possible fire, therefore, it is worth to introduce the characteristics of fire phenomena that may occur in the event of its initiation.

a) Fire gas ignition - a phenomenon occurring as a result of the ignition source or high temperature effect on the mixture of oxygen and flammable fire gases. The dynamics of occurrence of this phenomenon depends mainly on the proportion of air mixing with combustible fire gases. In the case of shortage of flammable combustion products, the discussed phenomenon takes the form of rolling flames in the ceiling zone. Excess, on the other hand, takes the form of a combustion that is sustained at a given time, similar to the fire phenomenon described below, which is the backdraft. Creating a mixture in ideal proportions may result in a rare phenomenon such as smoke explosion [13]. As a result of moving combustible combustion products

through various types of culverts, ventilation grids, suspended ceilings or leaks, it may result in a temporary and sudden intensification of the fire, which is likely to initiate combustion in another part of the building.

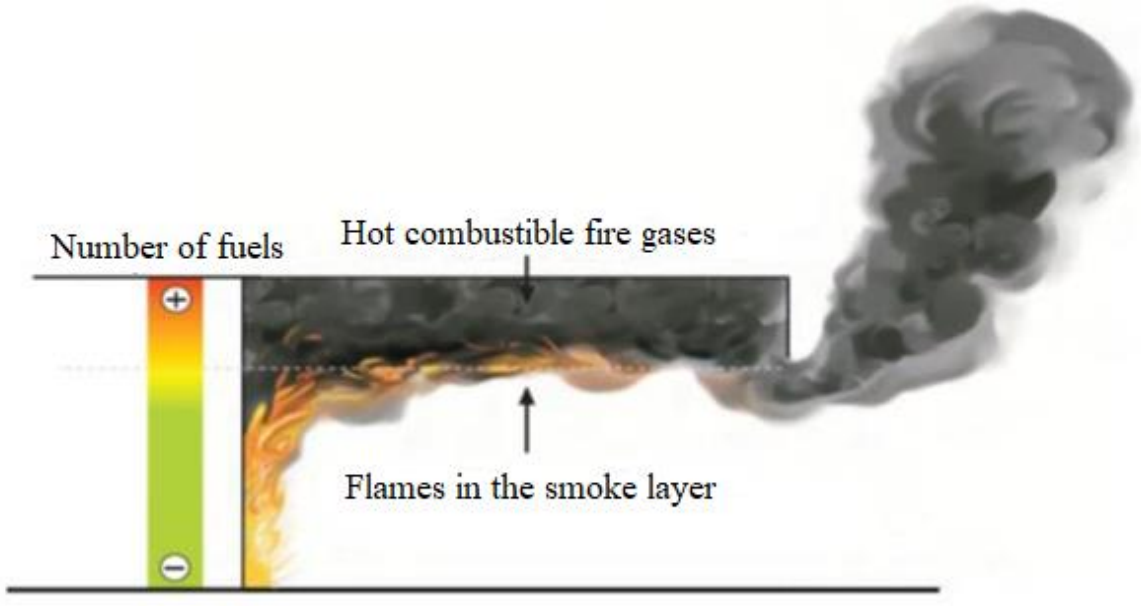

Figure 2. Ignition of fire gases as a result of progressive fire spread.
Source: Own study based on: Bangtsson L.G., *Enclosure Fires*, Karlstad 2001.

b) Flashover - a phenomenon based on the thermal distribution of all elements of the facility's equipment due to thermal radiation emanating from hot fire gases, flame, and cumulative heat in building elements. The amount of heat released is proportional to the amount of air reaching the combustion zone, according to the rule of William M. Thornton [4]. The progressive flashover is characterized by the waving of the gradually decreasing layer of accumulated fire gases as a result of the constant confrontation of the expansion resulting from the demand for oxygen in the combustion zone. There is also a noticeable increase in the concentration of carbon monoxide, which can significantly affect the safety of evacuating people from the building. It is worth to take into account that in the case of internal fires occurring in various types of workplaces, the occurrence of flashover is only a matter of time, due to the sufficient amount of oxidant and combustible material as a rule.

c) Backdraft - a phenomenon characterized by sudden flame burning occurring as a result of contact with products of incomplete combustion of thermal decomposition and air. Progressive building technology focused on, among others on leveling all kinds of building leaks is associated with an increased probability of its occurrence. This phenomenon results from the lack of free air exchange in rooms functionally connected with the workplace, which usually results in gradual fading of the fire. As a result of the decrease in the oxidizer concentration, the fire becomes a fire controlled by ventilation. However, despite its decline, the fire still affects the

equipment elements by producing flammable fire gases. As a result of breaking the window or falling out, creating the hole, eg by opening the door to the room covered by fire, at the interface between the layers - air flow and convectionally rising flammable fire gases, a mixture is produced in the flammable range. As a result of providing a sufficient energy stimulus, the mixture between the lower explosion limit (LEL) and the upper explosion limit (UEL) ignites creating a significant increase in pressure and gas volume. The resulting deflagration may result in the ignition of equipment elements in another part of the facility or in structural damage of the building.

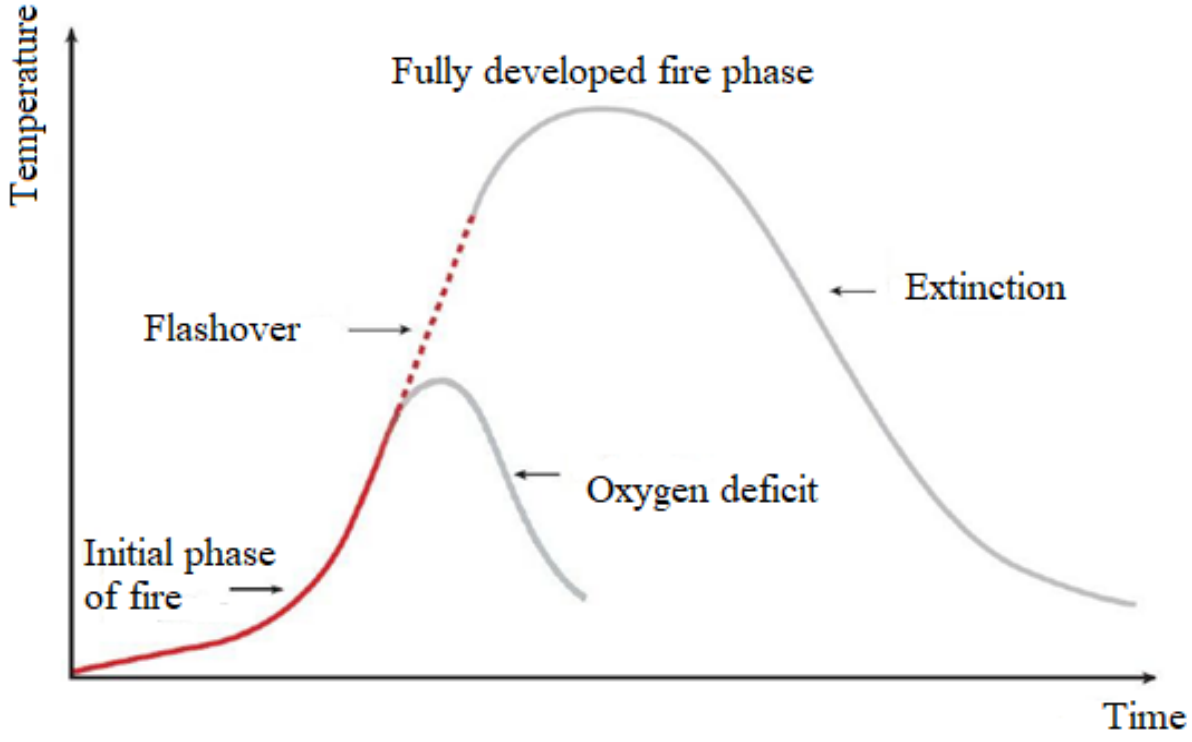

Figure 3. Characteristics of the internal fire course taking into account the occurrence of flashover.
Source: Own study based on: Bangtsson L.G., *Enclosure Fires*, Karlstad 2001.

Below is a chart to raise awareness of the dynamics of the phenomenon described. A ventilation-controlled fire needs only an oxidizer, thanks to which it is able to self-produce a mixture of gases carrying a considerable threat to people, including rescuers equipped with personal protective equipment and compressed air cylinders with compatible masks

The described phenomenon depends mainly on the size of the hole through which gas exchange, the type of combustible material, duration of fire, and the tightness of the room can occur.

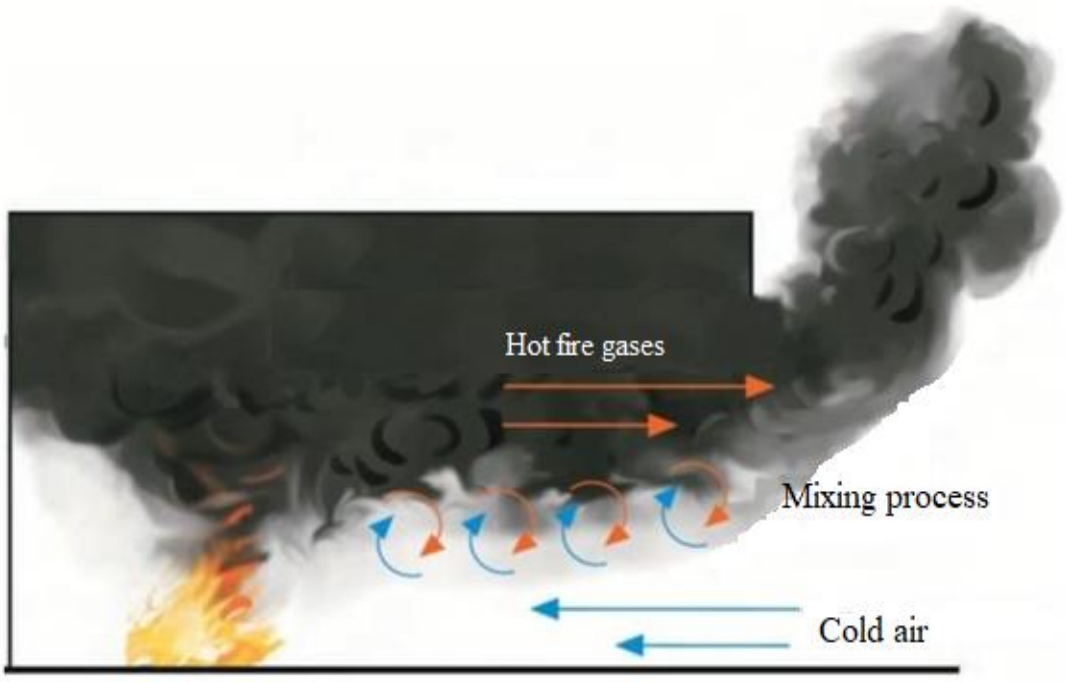

Figure 4. The mixture formation process in the range of flammability due to gas exchange.
Source: Own study based on: Bangtsson L.G., *Enclosure Fires*, Karlstad 2001.

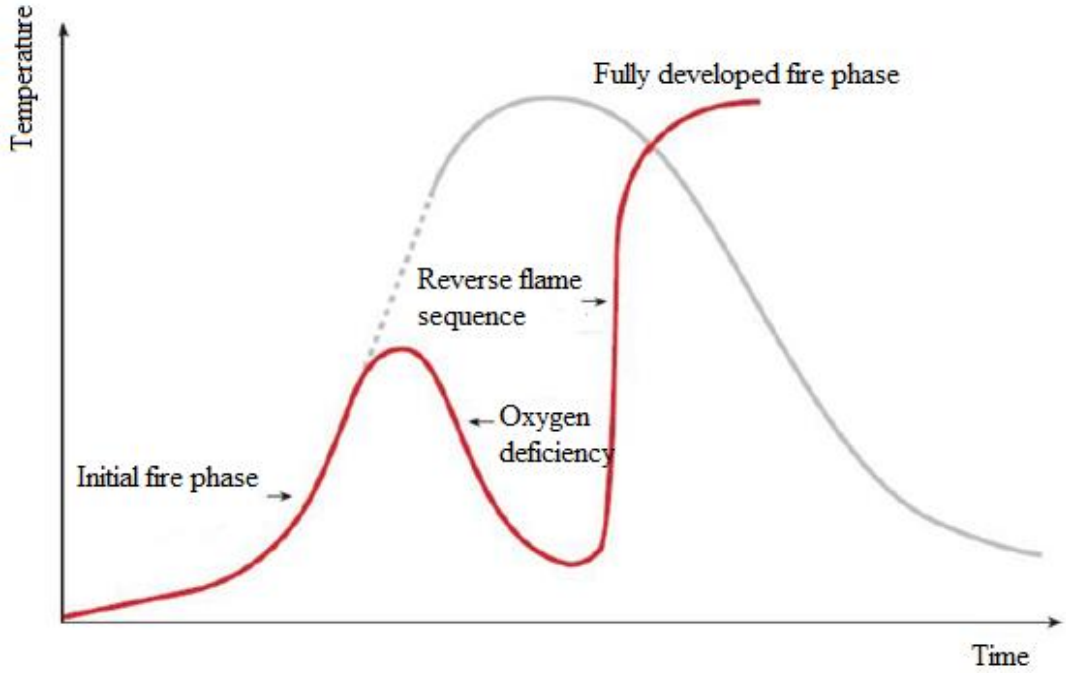

Figure 5. Characteristics of the fire course taking into account the occurrence of the backdraft.
Source: Own study based on: Bangtsson L.G., *Enclosure Fires*, Karlstad 2001.

5. FIRE DETECTION OF THE BUILDING

Considering the above aspects, arrived at the scene Head of the Rescue Operation (Regulation of the Minister of Internal Affairs and Administration of 3 July 2017 on the detailed organization of the national rescue and fire-extinguishing system (Journal of Laws of 2017, item 1394) in the first place should focus on identifying the most important components affecting the dynamics of the fire, such as:

a) building construction - the type of materials from which the building was made. There are materials with different capacities and thermal conductivity. A material having a high heat capacity coefficient is characterized by slower heating. The same is true for thermal conductivity. The increase in insulating properties is associated with a lower probability of thermal energy penetration outside the building covered by fire. This is important because thanks to this, Head of the Rescue Operation can determine, among others, the degree of structural stability of the building in question,

b) smoke - volume and color. The volume of generated smoke due to the combustion process depends on the size of the room or building covered by the fire, the combustion process, air access, and the location of the fire center. The greater the displacement of smoke, the higher the temperature. The color of the smoke depends on the form (gas, solid, particles, dust, liquid, etc.) of the combustible material, as well as the combustion process that is currently taking place. It has been assumed that dark smoke means a mixture rich in products of incomplete combustion, in contrast to the brown color, which is usually the result of a reduced amount of soot in the smoke, which usually results from gas exchange. The smoke of a bright color usually results from the impact of a fire source on interior design elements, as well as partial mixing of dark smoke with air reaching the convective column of fire, or as a result of the resulting water vapor as a result of fire exposure.

c) gas exchange path - the movement of air and fire gases between the room or building affected by the fire and the external environment. The location of inlet and outlet openings allows you to determine, among others fire phase, as well as the intensity and direction of the fire spread. A gas exchange characterized by a stable course usually means that we are dealing with the initial phase of a fire. The quick and turbulent exchange is usually characterized by a fully developed fire phase. The alternating cyclical pulsation of air in all the crevices of the room or building results in insufficient amount of the necessary oxidizer supporting the combustion process, which can result in various types of dangerous fire phenomena.

d) heat - a temperature change during the activities carried out, observation through the impact of the building structure or the speed of its discharge, can be a significant sign of fire behavior. Due to the fact that the resulting heat can not be observed, it is necessary to pay attention to possible cracks in the windows, change in the color of the paint, blisters, deformation of the structure, etc.

e) flame - the color of the flame usually determines the type of flammable material which is burning. We should pay attention to the fact that the amount of oxidant in the combustion zone affects the color of the flame. In the internal fire, which is characterized by an oxygen deficit, the color of the flame usually takes the orange-

red color, while in the case of the amount adequate to the combustion process - the color of yellow. In addition, the shape and form of the flame determines with which combustion we deal at a given moment. Rapid, turbulent flames indicate incomplete combustion (a fire usually controlled by ventilation), while flames that burn out freely- total combustion (possible only locally due to the ideal conditions prevailing there).

6. ANALYSIS OF THE BUILDING IN TERMS OF FIRE PROTECTION

Taking into account the above elements recognized by the Head of the Rescue Operation who arrive at the scene is also necessary to analyze the building through mentioned at the beginning of this study fire safety instruction. Familiarization with a reliable document guarantees obtaining all necessary information in order to carry out effective and at the same time safe rescue and extinguishing operations, taking into account the rescuers entering the fire-covered object. The objective of informing and educating the public about risk issues seems easy to attain in principle, but, in practice, may be difficult to accomplish. [7]

Therefore, referring to the above and the provisions cited in the introduction, the Fire Safety Instruction should contain informations about:

a) fire protection conditions resulting from the manner of use and destination of the object, technological process, storage as well as technical conditions of the building, including the explosion hazard,
b) equipping with the required fire-fighting devices and extinguishers, including their maintenance and technical inspections,
c) behaviour ways of people staying in the building in the event of a possible fire or other emergency,
d) methods of protection of fire hazardous work, if such works are foreseen at all,
e) conditions and organization of evacuation of people, as well as practical ways to check them,
f) ways of familiarizing object users (including employees) with the content of the instruction and fire regulations,
g) tasks and responsibilities of people who are permanent users of a building in the range of fire protection,
h) building plans, taking into account its location, and adjacent land, including graphic data, such as:

- area, number of storeys and height,
- fire parameters of localized combustible substances,
- the occurring fire load density (thermal energy that can be released during material combustion) in the fire zone or fire zones (the building or its part separated from other buildings or other parts of the building with fire separation elements, or with free land stripes of appropriate width),
- the category of people's threat, and the expected number of people on floors and in rooms of the building,
- location of external spaces and premises classified as explosion hazard zones,
- division into fire zones,

- evacuation conditions including evacuation directions and exits,
- the location of fire extinguishers and fire-fighting equipment, fire-hazardous materials, taps of the main gas installations, as well as the location of controls for fire-fighting devices,
- access to lifts for rescue teams,
- external hydrants, including other water sources for fire protection purposes,
- fire roads and other access roads with entries of gates into the fenced area,

i) indication of persons or entities preparing a fire safety instruction.

As you can see, the approximate document defines all necessary information that may be necessary while conducting various types of rescue operations. In addition, combined with the information given by persons appointed by among others the building manager, an object worker performing the function of a security guard, or an evacuation coordinator and handing over instructions that should ensure the possibility of its immediate use, provides considerable support in the coordination of appropriate rescue and firefighting activities at the scene. For new buildings, fire safety management should be planned at the design stage of fire safety provisions using the 'engineering approach'.

The fire safety objectives should be stated clearly in a fire safety manual as proposed through [8] the occurrence of various types of internal procedures as well as devices or fire protection systems such as:

a) fire alarm system, used for automatic detection and transmission of information about a fire compatible with the fire alarm receiving devices, as well as receiving devices for fault signals,

b) fire protection switch, which is designed to disconnect the electrical installation in the object, with the exception of the supply circuits of the equipment and installations whose operation is necessary during the fire.

c) automatic smoke removal devices, which main purpose is to remove smoke with intensity enabling safe and at the same time effective evacuation of people, focusing primarily on not exceeding critical values that may affect the health or life of people in the building 11],

d) self-acting water extinguishing systems, which are used to detect and extinguish a fire with water at its early stage or to keep the fire under control, so that its extinguishing could be finished by other extinguishing agents given by rescue teams,

e) emergency escape lighting to ensure optimal visibility to allow a safe and effective evacuation in an automatic, immediate and specified time in the event that the primary lighting supply fails,

f) the installation of fire water supply system by which the collected water extinguish the fire. Hydrant valves and internal hydrants are an integral part of the system, which are usually used more often in the case of different types of workplaces,

g) hand fire-fighting equipment used to fight fires in the embryo in a number adequate to the surface of the zone with a specific purpose,

h) fire-fighting water supply and fire roads, aimed at determining the location of external hydrants providing water to extinguish the fire or fire-fighting tanks, as well as accessing rescue and firefighting vehicles through the fire road to the area of the building covered by the fire,

i) an evacuation point, whose task is to gather all people evacuating from the building to check if everyone is safe,

j) various types of fire separations in the form of walls and ceilings constituting elements of fire-fighting made of non-combustible materials, including closures of a defined fire resistance class of all the holes therein, constitute an inseparable aspect of ensuring an acceptable level of security of people staying inside, as well as property which in combination with a properly chosen tactic by the Head of the Rescue Operation they are a sophisticated key to success. Moreover, taking into account that according to § 17 of the Regulation of the Minister of Interior and Administration of June 7, 2010. on the fire protection of buildings, other construction objects and areas (Journal of Laws of 2010, No. 109, item 719) An owner or manager of a given workplace intended for more than 50 persons who are its permanent users should at least once every two years to perform a practical check of the organization and evacuation conditions of the entire object to determine possible necessary changes aimed primarily at increasing the safety of people staying inside, which usually significantly affects the effectiveness of proceedings in the event of a possible threat. Such a perceptions of safety climate can influence employees' attitudestoward safety. [4] Removal of flammable and also toxic fire gases using smoke removal devices, or limiting the spread of fire or its slowing down through the use of various types of security, including water-extinguishing devices, as well as checking the nature of the plant, the type of material stored and its quantity, significantly improves not only the conditions for evacuating people from a building covered by a fire, but also carrying out rescue and fire-fighting operations adequate to the situation. Audits are required, say once a year, to ensure fire safety management is sufficient. [9]

7. CONCLUSION

Fire safety of buildings can be ensured by meeting fire protection requirements in a variety of ways. The reference point determining the minimum level of fire safety has been defined in broadly understood regulations, and compliance with the requirements of the regulations combined with a proper reconnaissance of the building, including through fire safety instructions and information obtained, gives the opportunity to ensure an optimal level of safety for people in the building covered by fire. Although there is a growing international movement toward the use of engineered or performance-based fire safety design, current practice is dominated by prescriptive-based design. In prescriptive-based fire safety design, only those requirements prescribed by appropriate building regulations, installation standards, or approved documents tend to be applied. [3] Only after 1987 The fire safety provisions have been enhanced. For example, sprinkler systems are required in almost all buildings. [2] With reference to the above, fire and technical and construction regulations based on systematic

conducting of evacuation, taking into account different types of fire scenarios, as well as implemented and available in case of possible burning with fire safety instructions, will allow to achieve an optimal level of fire safety, which it should be key in every workplace.

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