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Innovative fire protection systems

Inovatívne systémy v protipožiarnej ochrane

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Abstract:

Fire is a complex of physicochemical phenomena based on combustion, heat transfer and gas exchange processes; it is the uncontrolled combustion of substances and materials that cause damage. According to the temperature-time characteristic we divide the fire phases into 4 phases. The first phase of flame-free decomposition is the time from fire to intense combustion (ignition) according to the type of material. The second phase of the developing fire is the time from the intensive development of the fire (ignition) until to get hold fire of all combustible materials. The third phase of the developed fire is the time from the volumetric flare-up until the time when the burning intensity begins to decrease and the fourth is the phase of the fire demise, ie the time from the reduction of the intense burning until the complete burning of the combustible material. Methods of interrupting combustion are the chemical and physical processes of gradual and purposeful action that cause combustion to cease. Fire extinguishing is a measure that interrupts the combustion process. It is recommended to extinguish with fog devices which are divided into low pressure systems and high pressure systems.

Keywords*:* *Fire protection, Water fog, Fire, Fire extinguishing equipment, Fire fighting*

Abstrakt:

Požiar je komplex fyzikálno-chemických javov, ktorých základom sú procesy horenia, prenosu tepla a výmeny plynov, je to nekontrolovateľné horenie látok a materiálov, ktoré spôsobuje škody. Podľa charakteristiky závislosti teploty od času rozdeľujeme fázy požiaru na 4 fázy. Prvá fáza rozkladu bez plameňa je čas od vzniku požiaru do intenzívneho rozvoja horenia (vznietenia) podľa druhu materiálu. Druhá fáza rozvíjajúceho sa požiaru je čas od intenzívneho rozvoja požiaru (vznietenia) až po zachvátenie požiarom všetkých horľavých materiálov. Tretia fáza rozvinutého požiaru je čas od objemového vzplanutia až do času, kedy sa začne znižovať intenzita horenia a štvrtá je fáza zániku požiaru, čiže čas od zníženia intenzívneho horenia až do úplného vyhorenia horľavého materiálu. Spôsoby prerušenia horenia sú chemické a fyzikálne procesy postupného a cieľavedomého pôsobenia, v dôsledku ktorých horenie zaniká. Hasenie požiaru je opatrenie, ktoré zabezpečí prerušenie procesu horenia. Odporučené je hasenie hmlovými zariadeniami, ktoré sa delia na nízkotlakové systémy a vysokotlakové *systémy.*

Kľúčové slová: *Protipožiarna ochrana, Vodná hmla, Požiar, Hasiace zariadenie, Hasenie požiaru*

Introduction

Active systems in the practice of an integrated rescue system, in fire protection are water fog systems that can be used in rescue operations after the occurrence of an emergency.

Water fog systems have recently been subject to a wide range of research and scientific research, but further development needs to focus more on understanding the relationship between the type of flammable substance, the room conditions where the fire is taking place and the characteristics of the active fire protection system used. Conventional sprinkler systems cannot in many cases be fully replaced by fog devices, where the most important parameter is the amount of water to extinguish. However, there are cases where water fog competes significantly with other equipment, especially the volume of extinguishing agent needed, where in many cases the extinguishing agent flows into the surroundings and does not fulfill its basic function, piping installation and price. This is the reason for the preference of fog equipment especially in areas with valuable technological equipment, interior equipment and historical objects.

1. Division of fog fire extinguishers

The basic distribution of fog fire extinguishers is according to working pressure - pressure in the pipeline in case of activation of the device [1]:

- Low pressure <12.5 bar (1.25 MPa),
- Medium pressure 12.5 - 35 bar (1.25 - 3.5 MPa),
- High pressure ≥ 35 bar (3.5 MPa).

According to the method of water mist formation [1]:

- Single-phase - the extinguishing medium is supplied to the end elements through separate piping,
- Two-phase - water mist generators in ending elements using water and gas.

Both media are supplied via separate piping.

By end elements:

- Open heads,
- With closed heads.

According to the nature of the protected area:

- Systems for local applications,
- Bulk fire extinguishing systems.

According to time of extinguishing:

- Fire-extinguishing equipment,

- Devices for placing fire under control (fire location).

2. Principle of extinguishing by fog devices

A water mist can be defined as a water spray in which 99% of the total volume is contained in droplets with a diameter of up to 1 mm at the minimum working pressure of the water fog nozzle that generates it. Water mist as an extinguishing agent is a relatively new concept. Trade barriers appeared only in the early 1990s, mainly due to the gradual abandonment of halons, which seemed to be the perfect extinguishing medium for all kinds of flammable substances. [1]

Water is the most widespread extinguishing agent and is mainly used for its availability, ease of distribution and low cost. One important feature is its ability to mix with many substances to improve the extinguishing effect. The extinguishing effect can generally be divided into primary and secondary.

3. The primary effect of extinguishing by fog devices

3.1. Cooling

In this case, cooling refers to direct cooling of the flame of hot gases and vapors, which results in the temperature of the water particles being raised to the boiling point and subsequent evaporation. This effect is improved when using water fog systems compared to conventional conventional systems due to the reduced particle size of the water, which increases the surface area at a certain volume, thereby maximizing heat transfer and evaporation rate.

Two thermal specifications determine the ability to absorb heat. The first technical parameter is referred to as the specific heat capacity and is given as 4180 J.kg J..K^{-1} at 20 ° C, this value being dependent on the initial temperature, which by definition is the heat consumed to heat 1 kg of substance with one Kelvin (to heat 1g of water with one ° C, 1 cal. is needed).

The second technical parameter is latent heat or also specific latent heat. It is the energy consumed only to change the state of the substance without changing the temperature. The latent heat of water when converted to steam is 2257 kJ / kg. Mathematically, the total amount of heat absorbed by water can be calculated as [4]:

$$e = k_1 . w(t_{2\_} t_1) + k_2 . w_{(1)}$$

Where:
e = total energy absorbed [cal]
k_1= specific heat capacity [cal/g °C]
w = weight [g]
t_2 = initial temperature [°C]
t_1 = boiling point [100 °C]
k_2= latent heat [cal/g]

3.2. Oxygen displacement

After evaporation, the volume of water vapor expands in all directions and may directly and indirectly affect the disappearance of fire. As water vapor approaches fire, the volume expansion of water vapor may dilute the flammable gases and vapors present and reduce their entrainment into flame, directly affecting the presence of the flammable mixture.

The increase in the volume of water vapor is dependent on the end temperature of the gas (vapor). If the resultant vapor temperature is close to 100 ° C, it will increase its volume over the liquid phase by 1,700 times; if the resulting temperature is about 800 ° C, it will expand up to 4700 times. As the volume increases, the gas phase virtually expels air to isolate flammable substances from the oxygen approach.

The results of the calculations show that the oxygen concentration in a 100 m^3 room can drop to approximately 10% when 5.5 l of water is converted to steam. The reduction in oxygen concentration is dependent on the size of the fire, the duration of the fire before the extinguishing, the volume of the room and the ventilation conditions.

If fire extinguishing is initiated in the initial phase of the fire, only a small amount of water is converted into steam and the displacement of oxygen is almost non-existent. In the advanced stage of the fire, the conversion to steam and thus the displacement effect is more significant. [4]

4. Secondary effect of extinguishing by fog devices

4.1. Prevention of heat transport by radiation

If the burning object is wrapped with a cloud of water mist, a barrier will be created to prevent heat transport by radiation and thus the spread of fire. The degree of radiation limitation depends on the fog current density and droplet size. Water mist falling on objects not affected by fire cools and moistens their surface, increasing the intensity of the radiant heat required to ignite them.

4.2. Kinetic energy of fog current

Kinetic energy can be used to knock fire where short distances between the terminal elements of the distribution system and the protected equipment are considered. Experiments conducted in large-scale tests have shown that an undersized fog system design results in a higher rate of heat release than a rate of heat release without the proposed system. This is due to the contact of the rapidly moving fog stream with the level of the flammable liquid, thereby increasing the volume in which the combustible vapor is mixed with oxygen and thereby more rapidly generating the released heat.

4.3. Effect of drop size

The total amount of drops released into the protected area can be divided into [4]:

- Drops diverted by the hot gas stream away from the place of fire,
- Drops that penetrate the flames to the burning surface,
- Drops falling on surrounding structures,
- Droplets converted into water vapor while cooling the burning object,
- Drops to cool surrounding objects and prevent them from catching fire.

Tab. 1 Specific surface of drops created from 1 liter of water (Source: Author)

Specific surface of drops created from 1 liter of water			
Droplet size [mm]	6	1	0,1
Droplet size [pcs]	$8{,}8 \cdot 10^3$	$1{,}9 \cdot 10^6$	$8{,}8 \cdot 10^9$
Droplet size [m²]	1	6	60

Droplet size affects the surface area relative to the volume of water. The larger the surface area, the faster and more efficient the conversion of water into steam. The table shows the effect of droplet size on their surface area. Smaller sizes easier to fill the space, while larger sizes more easily penetrate through the flowing flammable gases and vapors.

4.4. Design

The end elements of the fog extinguisher can be divided according to the activation method into:

- Heads - fuses closed by fuse responding to ambient temperature, operate on a similar principle to conventional sprinkler systems with fuse or glass ampoule,

Fig. 1 Head (Source: Author)

- Nozzles - open heads which are triggered by a device other than the nozzle itself, generally by an electric fire alarm or by a detection device which is part of the system,

Fig. 2 Nozzle (Source: Author)

5. Comparison of individual systems

Fixed fire extinguishers, as mentioned above, are systems that actively prevent the occurrence and spread of fire. There are two basic water jet technologies that are commonly used, low pressure systems (sprinkler systems) and water fog systems. They are terminologically differentiated as flood and water fog systems, where the principle of function is their activation either automatically by means of a detection device or by means of a fuse. [2,3]

5.1. Low-pressure systems

Low-pressure systems usually use open sprinkler heads with operating pressures below 12 bar. These systems operate with relatively large droplets with low kinetic energy when discharged through a sprinkler. Droplet size can be reduced if higher pressures and special nozzles are used. Each nozzle type has different spray characteristics in terms of droplet distribution and coverage area. Application rates are based on the surface coverage rate in l / min / m^2. [2,3]

5.2. High pressure systems

The high pressure water mist system operates at pressures above 35 bar. This system uses water with significantly smaller droplets than conventional low-pressure systems, plus the droplets are discharged at high speed and kinetic energy to fill the protected space. Drops achieve an excellent level of coverage throughout the space, at the same time fill the entire protected cross-section above and below the nozzles. Each type of nozzle has different spray characteristics, and the systems are usually designed as volumetric, where the parameter is liter per minute per cubic meter. [2,3]

6. Comparison of tests

There are many comparisons of these systems, as an example, the test in the Asturias tunnel in northern Spain conducted by IFAB (Institute for Applied Fire Safety Research) is analyzed. Testing included different application rates, with test results of 12 liters per minute per m^2 for a low pressure system using the same fire scenario and a high pressure system where the flow rate was less by 30% ~ 0.65 l / min-1 / m^3 (<3.5 l / min / m^2).

Tab. 2 Comparison of system-specific aspects (Source: Author)

	Low pressure systems	**High pressure systems**
Flame extrusion	+	+
Ambient cooling up to 2 m	+	+
Reduction of radiant heat	+	+
Prevention of flame spread to the surroundings	+	+
Improved visibility	+	+
Prevention of smoke spread	Sustainable conditions	Sustainable conditions
Smoke back layering	None	None
Temperature	+	+
Preventing the spread of fire	+	+
Surface wetting	+	-
Ceiling protection	-	+

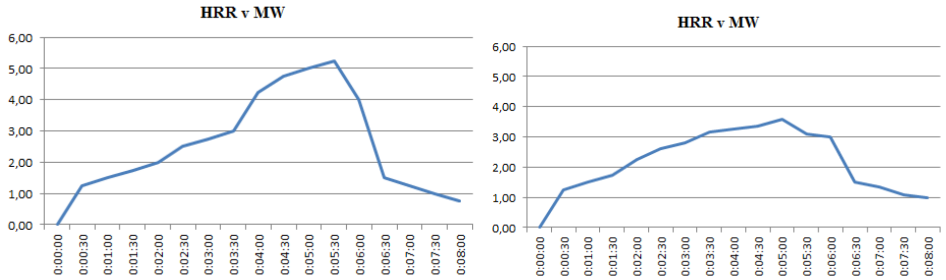
Euro-wood pallets covered with a floating sheet were used as a combustible substance. A total of 408 pallets (9600 kg and an energy content of 140 GJ) were used, a longitudinal ventilation rate of 3 m / s was used in the test, and the combustible material was ignited with 40 l of gasoline.

The classic low pressure system (sprinkler) was activated in the 4th minute of fire regardless of the measured HRR value (released heat flux value), at which time the HRR value was in the range of 2-5 MW.

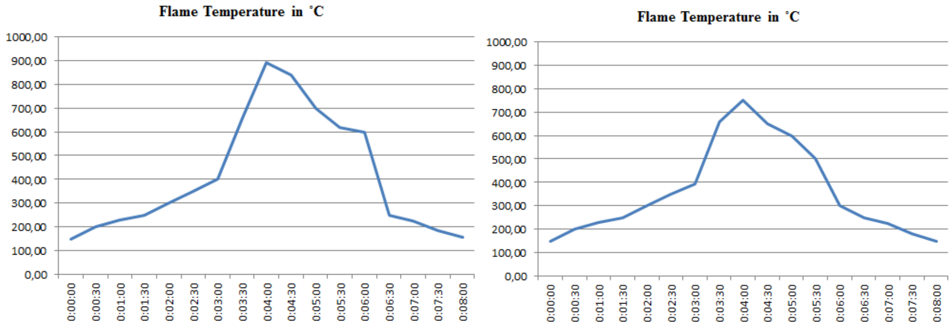
The high pressure fog system was also activated within 4 minutes of the fire.

The graphs show the classic system on the left and the fog system on the right.

Graph 1 Value of heat flow in classical systems and fog systems (Source: Author)



Graph 2 Temperature in the center of the flame using classical and fog systems (Source: Author)



The most popular and basic types of stationary fire extinguishers are low pressure conventional sprinkler systems and high pressure water mist systems. Both types of systems underwent full-scale testing, where both systems operate in open-head operation and in most cases use clean water. The main difference in these systems is the water flow, the distribution of water droplets and the kinetic energy at startup.

Low pressure conventional systems work more on the principle of cooling and wetting the fuel surface, while water mist also works on the principle of three-dimensional impact on flammable gases and vapors, ie on the principle of diluting and insulating flammable gases and vapors. Both systems have shown excellent abilities to prevent radiant heat and flame propagation, where water mist-based systems have shown less water consumption and cooling of the upper structures.

Fig. 3 Example of high-pressure object protection system (Source: Author)

Conclusion

In conclusion, water fog systems provide a good alternative for the protection of objects, premises and materials where there is a need to protect objects and materials of historical value. Large flood flows would cause further material damage.

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