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INCREASING EXTINGUISHING EFFECT OF WATER MIST BY ELEKTRIFICATION

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ABSTRACT

This paper describes extinguishing experiments to verify the possibility of increasing the fire-extinguishing efficiency of low-, medium- and high-pressure water mist by its charging by the electric field of high DC voltage. The experimental results confirmed the effects of the electrical voltage, the configuration of electrodes (anode, cathode), the volumetric water flow rate, water pressure and the type of mist nozzle. Higher fire-extinguishing effect of electrically-charged water mist was shown by a shorter extinguishing time, a smaller volume of water to extinguish the fire and a higher percentage of successful extinguishing attempts. Benefit: faster and more efficient fire-fighting with a smaller risk of injury of persons and smaller subsequent damage in the protected space.

KEYWORDS

Low-, medium- and high-pressure mist, fire-fighting nozzle, DC high-voltage generator, cathode, anode, extinguishing time.

INTRODUCTION

A well-known method of extinguishing fires is fire- fighting by water mist. After the ban of Halon fire extinguishing by the Montreal Protocol and the search for effective alternatives to gas fire-extinguishing agents fixed and semi-fixed fire extinguishing systems started to win recognition dynamically in the last decade. They were sprinkler, diffusing water in the form of a shower through sprinklers or nozzles, and the fog ones with fog nozzles forming water-mist spray. Studies have confirmed the following main properties or mechanisms of its extinguishing efficiency. This method has a high **cooling effect**, manifested by heat removal from the combustion zone and its cooling below the reaction temperature of combustion: water has a specific heat capacity c_p = 4.2 J/ (g. K) and the latent heat of vaporization φ = 2442 J/g. The cooling effect is greater with flammable liquids with a flash point above the ambient temperature, such as with diesel with flashpoint (FP) ~ 55 °C. It is smaller with flammable liquids with a flash point below the normal ambient temperature, such as with heptane ~ - 4 ° C, and with solid combustible materials forming the carbon residue. Inertizing effect due to displacement of oxygen from the combustion zone by water vapour resulting from the rapid evaporation of fine water droplets, where their volume increases about 1900 times at 95° C and the barometric pressure of 1 at, also depends on the type of flammable substances. Hydrocarbon-based substances burn at O_2 concentrations of still below 13 vol%, whereas those with a carbonaceous residue burn still below 7 vol % of O_2. It is also obvious that when you burn a bigger flammable file, it consumes oxygen present in a closed space faster than in the open one.

As for the **insulating effect** blocking the effect of radiant heat from the flame to the yet-not-burning flammable surfaces, it can be considered again that this effect is less evident, for example with burning flammable liquids with the flash point below the normal ambient temperature. Studies have confirmed that reducing radiation is < 10 % if the diameter of water droplets is > 100 microns, while the drops with the size < 50 microns can reach the radiation decrease > 50%. One must mention the advantages of water mist for extinguishing compared to the other extinguishing systems: it is not toxic, it does not pollute the environment, it causes minimal subsequent damage, it has a high extinguishing efficiency with certain fires compared to the other fire-extinguishing agents.

Another still-studied phenomenon is **combustion and interaction of electric field with the flames** without the presence of a commercial fire-extinguishing agent. Combustion process consists of chemical reactions of initiation, propagation, branching and termination. Radicals participate in these reactions. Cations are most represent in the flame. The concentration of anions and free electrons is much smaller. Anions predominate in a luminous flame zone. The electric field having an effect on the flame causes the so-called ion wind, which is the movement of radicals, ions, including free electrons by acting of coulomb electrostatic forces of the electric field. Collisions with neutral molecules occur during their motion. Furthermore, the electric field having an effect on the flame produces chemical effect by the following mechanism: free electrons increase their energy by the acting of electric field. They transmit this energy for example to oxygen molecules O_2 after their collision. The oxygen molecules increase their vibrational energy and thus even the rate of the primary reaction of the combustion of hydrocarbons. The interaction between the flames and the electric field in the absence of extinguishing agent is still a subject of interest of both basic and applied research. Issues of design, construction and operation of the mist fire-fighting equipment are dealt with in a number of existing international and national standards, including CSN, see for example standards [1] - [8].

According to these standards, fire-fighting equipment consists of components for fire detection, activation of the fire-extinguishing system, water supply, pumps, or metal gas cylinders with gaseous propellant, piping with valves, valve station and nozzles / heads for the fragmentation of water into the small droplets of defined size. Water mist is a water spray consisting of droplets whose diameter $D_{v0,90}$, measured in the plane 1 m from the head at a minimum operating pressure, is smaller than 1 mm [2]. According to the pressure fog fire-extinguishing devices are divided into high-pressure ones, where the pressure is $p \geq 34.5$ bar, medium-pressure ones with the pressure of $12.5 < p < 34.5$ bar, and low-pressure ones with the pressure $p \leq 12.5$ bar. Their water consumption is up to 90% lower than with the sprinkler fire-fighting equipment. Consequently, they show smaller subsequent damage to indoor equipment and building. As they are more efficient, they also reach lower fire-extinguishing times. The significant influence on extinguishment efficiency is also had by: the size of droplets (mm) and their distribution according to their size in the shower / spray flow, the flow of water per unit area of fire (l/min.m^2), the direction of the mist spray flow, the flowing of the surroundings, the spray moment given the flame.

However, none of these standards solves the increase of the extinguishing efficiency of the water mist with the help of an electric field. The literature does not contain references on specific practical applications of these fire-fighting equipment with improved efficiency with the help of an electric field. The literature search for available databases of patents and utility models was also negative.

ELECTRIFICATION OF WATER MIST – POSSIBLE TECHNICAL SOLUTIONS

The authors developed and tested the equipment experimentally in the test rooms of the Fire Technical Institute in Prague (HP) and at the Czech Technical University in Prague - UCEEB in Buštěhrad (LP and MP) to increase extinguishing efficiency of low-pressure (LP), medium-pressure (MP) and high-pressure (HP) water mist with fixed and semi-fixed fire-fighting systems using the electric field. The device is provided with one or more fog nozzles at the given work pressure with the defined size of water droplets connected to water pipes with valves. It consists of a generator DC of high voltage with adjustable output voltage of up to 25 kV, which is located outside the protected space. A positive electrode is connected to the positive terminal of the generator with an electric cable kept in a tubular beam. The negative electrode is connected to the negative pole of the generator with an electric cable, also conducted in a tubular beam. The axes of the positive electrode and the negative one lie in the axis of each mist nozzle. The positive electrode is formed by a metal strip in a ring shape having a minimum internal diameter of about 10 cm, a maximum width of about 20 mm and thickness in the range of 1 mm to 2 mm. Furthermore, this strip is provided with metal screws anchored to a ring at the same distance from each other and with the tips directed inside the annulus; a strip of wire mesh with wires projecting above and below the belt over the entire circumference of (1-2) mm is attached to the inner portion of the band. The surface of the positive electrode is located perpendicularly to the axis of the paraboloid of water mist opposite the orifice of fog nozzle at the distance, which ensures the passage of at least ¾ of mist spray jetting through the annulus. The negative electrode is formed by a 3-4-teeth element. It is formed by straight metal wires directed radially into the fire-extinguished space. The length of the wires is 70 to 100 mm, the diameter is 1 mm to 2 mm, and the ends of these wires are arranged in the tip. The peak of the n-teeth element is located at the verified distance from the mouth of the given mist nozzle. One positive electrode and one negative electrode are used with each used mist jet. The electrodes are connected to their common DC high-voltage generator.

The advantage of the equipment proposed in such a way for the electrification of water droplets in the cone of water mist jetting from fog nozzles of the LP, MP and HP mist fire-extinguishing equipment is a significant increase of its fire-extinguishing effect on hydrocarbon flames, demonstrated by the fire-extinguishing times that are lower substantially, and thus the water consumption is even lower substantially compared to extinguishing the same fire scenario by the same fog fire-extinguishing agent, but without the effect of the electric field.

The equipment for increasing the extinguishing efficiency of HP, MP and LP water mist is realizable with the fixed and semi-fixed fire-extinguishing devices that have at least one fog nozzle with the defined water droplet size at the given pressure.

These mist nozzles are connected regularly to a water pipe provided with valves during the experiments there were used: HP water pump - ultrasonic flowmeter Porto-Sonic 7000 - a gauge DIAPHRAGM by the company Concept with the range of (0-16) bar. In experiments there was used el. DC. Source / generator PZVN 01 that can be energized from the 230 V/50 Hz network, see Fig. 1.

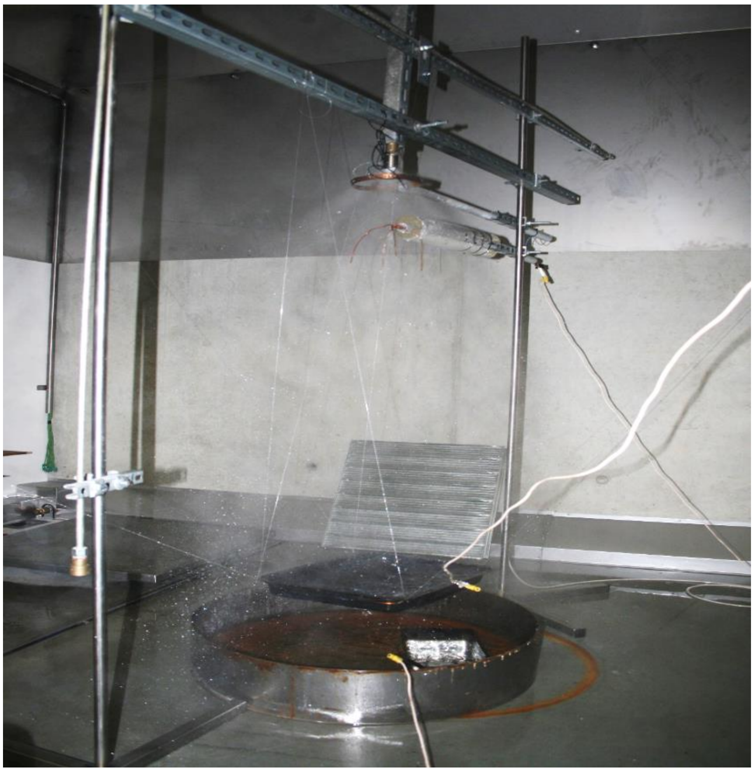

Fig. 1 - A look at the test equipment at the time of extinguishing the burning of n-heptane in a metal tray

The generator is equipped with a switch. There is preferred a system of electric fire alarms before switching, for example, after the bursting of a glass flask of a water jet by the elevated temperature due to fire or by the manual switching by the personnel who notices a fire.

It is obvious that HP, MP and LP mist nozzles of fixed or semi-fixed fire-fighting system must be designed so as the extinguishing sprays of water mist cover the potential area or volume of fire residues completely at the required time. The electrical cables of the supply electrode of the single nozzles are drained into the terminal for plus and minus poles, or more precisely, the positive electrode connected with the mist nozzle is grounded. The terminal blocks are connected with a DC high-voltage generator.

The water pipe with the valve brings water into the fog nozzle at the pressure of for example, (5-16) bar and the flow rate of e.g. (4-6.5) l / min, while the temperature of water is 20 °C. The electric field generated between the negative electrode and the positive one by the high DC electrical voltage supplied by the cables from HV generator charges the fine droplets of water mist, that disrupt the chain burning chemical reactions occurring in them effectively by the interaction with the flames. This is how they increase the cooling and insulating fire-extinguishing effect of the water mist itself significantly. The generated currents are in the order of microamperes, and so there is neither danger of electrical short circuit or more precisely discharge between the water mist spray and the metal objects, which are in contact with mist in the protected space, nor the risk of injury to the personnel from the accidental contact with mist. The experiments were carried out in the close test area, at the atmospheric pressure, at the air temperature of (19 to 21) °C and the relative atmospheric humidity of (40 to 53) %.

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CONCLUSION

When the operating voltage of the DC high-voltage generator is from (5-10) kV, there were extinguishing times on the electrodes within on an average 20 seconds from the moment of the ejection of the fire-extinguishing agent in repeat tests. When turning off the high voltage DC power the extinguishing the same fire scenario under the same test conditions does not occur in 1 min. The registrations of utility models were passed to Prague IPO (Industrial Property Office) on the basis of the positive results of the experiments. Subsequently, they were admitted / registered [9], [10]. The attention of those interested in the practical use of this experiment is attracted to among other things the validity, see also [11].

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