EXPERIMENTAL STUDIES CONCERNING WATER MIST FIRE SUPPRESSION IN VENTILATED CLOSED SPACES

Cătălin NETCU[1], Constantin POPA[2], Valeriu PANAITESCU[3], Ion ANGHEL[4]

The paper presents the results of the researches performed by the authors in order to analyze the fire suppression efficiency proven by water mist, when applied to an ethanol burning pan, in an air opposite stream. The presented studies can be applied to closed ventilated spaces, such as underground parkings and subway stations (an actual issue of the fire suppression research community).

Keywords: watermist fire suppression, ventilated spaces, subway fire suppression.

1. Introduction

As many of the specific study states, water mist is used to extinguish fires in all types of spaces: subway tunnels and stations, aircrafts, storage places, underground parking spaces [1...6].

Practically, the water mist fire suppression efficiency in comparison to water sprinklers is based on the fact that the dimension of the water droplet is very small, the number of droplets is large, in conclusion the resulting area of water droplets surface makes a difference when it comes to fire cooling [7].

As stated above, one of the spaces protected with water mist systems is represented by the subway stations where, according to the measurements of the authors, there are air currents with speeds up to 3.5 m/s [2, 3].

The problem, still, comes when some of the water mist droplets, as they are small, are taken away by the air currents, so they don't get involve in fire suppression. In the scientific community, the attitude in this matter is spliced in two directions: some of the researchers agree with using water mist systems, others don't agree, [8...10].

2. The lifetime of a fire mist evaporating droplet

In the present chapter are presented some mathematical aspects concerning the kinetics and evaporation of water drops in air namely the lifetime of an evaporating water droplet [10]

[1] PhD Student, University POLITEHNICA of Buchaest, e-mail: catalin_victor@yahoo.com
[2] Lecturer, Fire Officers Faculty, Buchaest , Romania
[3] Prof. Emeritus,University POLITEHNICA of Buchaest , Romania
[4] Lecturer, Fire Officers Faculty, Buchaest , Romania

$$t_{life} = \frac{2}{q_0 {q_1}^2 \Delta T} \cdot [q_1 D - \ln(1 + q_1 D)] \quad [s] \tag{1}$$

For small drops ($q_1 D << 1$; i.e. $D << 230 \mu m$) the logarithm can be approximated by:

$$\ln(1 + x) = x - \frac{1}{2} x^2 + 0(x^3) \qquad [-] \tag{2}$$

where x can be assimilated to $q_1 D$ and q_0, q_1 are two parameters explained below.

In that case the lifetime of a small drop is approximately:

$$t_{life} = \frac{D^2}{q_0 \Delta T} \qquad [s] \tag{3}$$

where

t_{life} - droplet lifetime [s]

D - initial drop diameter [m]

ΔT the difference between the dry-bulb and the wet bulb temperature

$$q_0 = \frac{2a}{\Delta T}(1 + b s_0) \qquad [m^2 s^{-1} K^{-1}] \tag{4}$$

$$q_1 = \frac{b r_0}{1 + b s_0} \qquad [m^{-1}] \tag{5}$$

where $r_0 \approx 64{,}65 s^{-0{,}5}$ and $s_0 \approx -1{,}117 \cdot 10^{-3} m \cdot s^{-0{,}5}$ are two constants. Here a and b are also constants depending on ambient conditions and liquid properties only, according to Holterman [10].

As a water droplet travels towards the ethanol burning pan, it decreases in volume, disappearing at last, as it transforms itself into vapors. The air current has a direction opposed to the water mist cloud; this may speed up the evaporating process, leading in the end to a more effective suppression in the vicinity of the flames, [10, 1].

3. The experimental setup

As it is almost impossible to use subway station for experimental burning studies, authors recreated in a laboratory, the conditions that can occur in case of a fire in such places.

Only the data about maximum air speed was practically taken from onsite measurements and then recreated in the laboratory.

The other conditions as flame temperature, water mist droplets dimensions, air volume of the considered environment were all considered according to fire researches on real large tunnels, presented extensively in references [1] and [3].

After the laboratory analysis with an axial fan, the authors created inside the research area belonging to Fire Officers Faculty Bucharest, an experimental stand which gives information concerning the way the three following factors influence one another, in the suppression activity:

- air current
- temperature of the flame
- water mist droplets

The complex influences of the three factors are analyzed by collecting temperature data from two thermocouples situated on the centerline of the fire burner, in the center of the flame and at the high point of the flame. The temperature values are collected in real time with a thermometer coupled to a computer.

In order to obtain the air current one used a ventilator powered at 220 V and placed so as, in the points of temperature measurement, the speed should have the value of 3.5 m/s (according to the real measurements in the subway station).

As stated above, the authors insisted on this maximum speed because of two main reasons: in international fire safety studies, the accent is given always on the “worst case scenario” [1, 3, 5, 7] and a stronger speed is more likely to negatively affect the efficiency of fire suppression, as some authors say [1, 9]

For the fire burner, similar to fires that can occur in subway stations, one has chosen an ethanol square shaped fire pan with the following dimensions: 30 mm × 40 mm.

The water mist is created with a water mist generator pump, that, according to standards, at a pressure of 120 bar creates droplets with dimensions of at most 1000 μm [11].

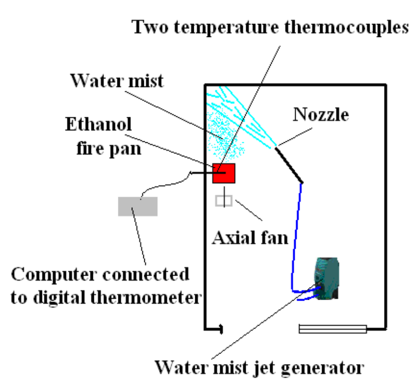

Fig.1. The experimental setup

Fig. 1 presents the experimental setup used to study the different influences on the fire suppression efficiency. Using this experimental setup, authors obtained temperature – time graphics that helps a lot in understanding and comparing the two situations: 1 – suppression only with water mist and 2 – suppression with water mist and air currents.

As one can see, in this paper authors considered the worst case scenario, meaning that the water mist cloud orientation coming from one side of the fire burner, was the same as the orientation of the wind, but with opposite direction.

4. Results of the fire suppression experiments

In the paper the authors discuss the influence of the three factors presented above, in the specific conditions given by the experimental setup (fig. 1)

During the tests, the different elements were kept at the same values: the initial temperature, times of suppression activity etc.

All the graphics in this chapter (figures 2, 3 and 4) contain two curves: one of the curves, similar in all three graphics, represents the burning curve without any suppression actions involved and the other curves depicts the values resulted after applying different suppression methods: water mist (fig.2), air current (fig. 3) and water mist with air current (fig. 4).

As one can see in the three graphics, all three methods have a good influence on the fire suppression, but there are some slight differences that are to be discussed in the following.

The air current effect is inferior in effectiveness (fig. 3), as it permits the fire to reach back to a temperature of 140 °C. The other two situations presented in figure 2 and 4, have close values (in interval 70 – 130 s), and this is why the following chapter contains further discussions on the subjects.

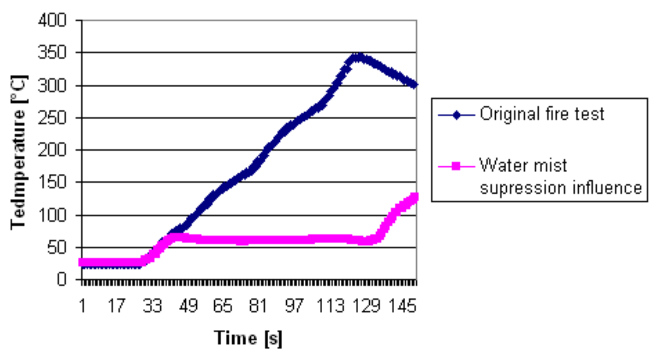

Fig. 2. The influence of water mist droplets on the fire suppression efficiency. Experimental temperature values

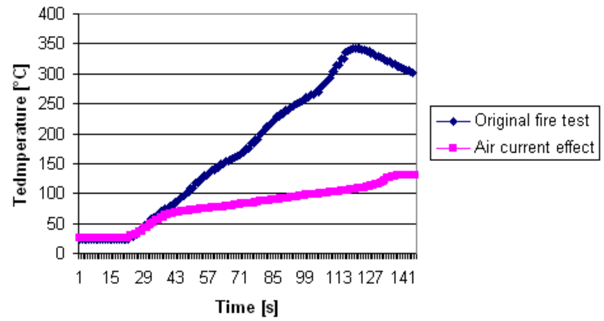

Fig. 3. The influence of air currents on the flames. Experimental temperature values

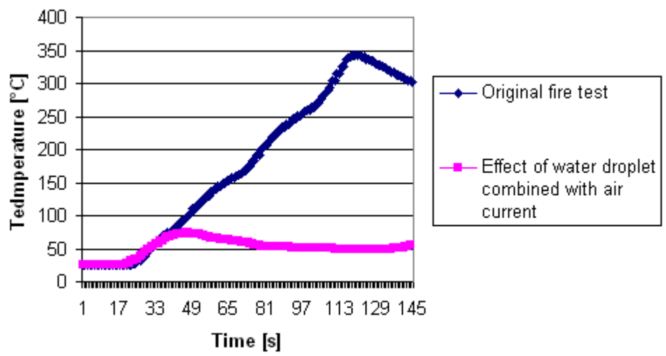

Fig.4. The influence of water mist droplets combined with air currents, on the fire suppression efficiency. Experimental temperature values

The water mist was sprayed in all cases, starting approximately with second 20 until second 130 - 145. In case of figure 2, the water mist application was stopped at second 130. This is why the fire bursts to such values (125 °C).

5. Results assessment

As stated above, figure 5 below contains the two curves in figure 2 and 4, presented on the same graphic, for a better comparison.

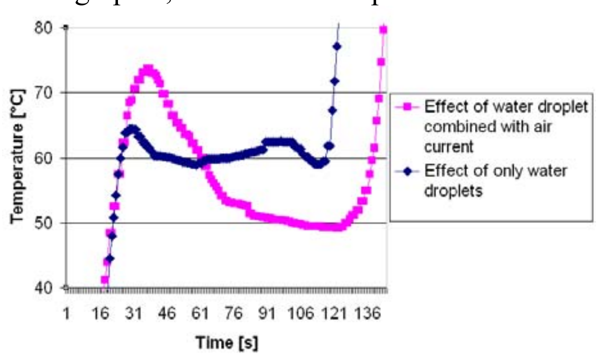

Fig.5. Comparison between the two fire suppression curves

Also, the graphic is zoomed to present exactly the area of interest: from second 16 to second 100. As one can see, for around 50 seconds, from second 50 to second 100, the water droplet combined with air current gives a better fire suppression. This may happen because of the fact that the air current increase the generation of vapors, and that dislocate oxygen. Without oxygen, the flame diminishes in force.

6. Conclusions

The authors obtained in the laboratory, an environment similar to the one in certain spaces belonging to subway stations. In this environment, they studied in the same space and in the same interval of time, the combined influence of water mist and air currents on the fire suppression efficiency. In the conditions of the presented fire experiment, the air current helps water mist in suppressing the fire, being, as one can see form the graphs, around 19 % more effective than plain water mist. This is not a big difference in temperature, but in real fires these little differences give specialists the seconds that can help preventing a disaster from happening. The study is only a beginning; it can evolve and can be used to design the fixed fire systems in underground parking spaces, subway stations and other similar spaces.

R E F E R E N C E S

[1] *R. S. Sheinson, A. Maranghides, J. W. Fleming, B. A. Williams*, Fire protection with water mist-the NRL approach, 2-4 Mai 2000, USA

[2] *C. Netcu*, Experimental and fire simulation studies for fire research in subway stations, Second scientific PhD report, Politehnica University Bucharest, Energetics Faculty, Power Engineering Department, march 2012

[3] *C. Netcu*, Contributions concerning the prevention and management of emergency situations at subway stations, PhD Thesis, Politehnica University Bucharest, 2012

[4] *A. Chisacof et al,* Clean fluid jet that change the structure of the environment – CNCSIS Grant ID_1708/ 2009

[5] *M. Vuorisalo,* Water mist concept for road and railway tunnels, Marioff Corporation

[6] *** Labmate Spotlight, Droplet size analysis in the development of enhanced water mist fire suppression systems, 2009

[7] Z. Liu et al, Challenges for Use of Fixed Fire Suppression Systems in Road Tunnel Fire Protection, 2007

[8] *B. P. Husted, G. Holmstedt, T. Hertzberg*,**,** The physics behind water mist systems, 6-8 October 2004, Roma, Italia, 2004

[9] C. Beyler, Sprinkler Vent Interactions, 2000

[10] *H.J. Holterman,* Kinetics and evaporation of water drops in air, Report 2003-12/Wageningen UR, Instituut voor Milieu- en Agritechniek; 2003, ISBN 90-5406-234-7

[11] *C. Popa*, Contributions to fire modeling, simulation and fire suppression in vertical developed structures, PhD Thesis, Politehnica University Bucharest, 2011.