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RESEARCHES REGARDING USING SPRINKLER AND WATERMIST FIRE SUPPRESSION SYSTEMS IN CLOSED CAR PARKING SPACES

Costel – Marian PIETREANU[1], Constantin POPA[2], Valeriu PANAITESCU[3]

This paper represents a summary of the experimental researches realized by the authors for testing two fire suppression systems, in the situation of a screened fire burner. The situation is similar to the closed parking spaces where cars are parked one on top of the other. The tests proved that the watermist fire suppression system is more effective in suppression, than the sprinkler system, in the specified type of spaces (car parking).

Keywords: sprinkler, watermist, temperature, fire.

1. Introduction

Given the theory that in the underground parking areas the watermist fixed fire suppression system is more effective in suppression than the sprinkler system, and that literature recommend watermist fire suppression systems, specifically in closed parkings where cars are parked one on top of another, two experimental tests were performed by the authors, [1, 16].

The objectives of the experimental studies are:

- determination of the temperature in the fire burner, for the same period of fire suppression (comparison of two situation: watermist and sprinkler);
- determination of the temperatures recorded at the height where the smoke layer is present;
- determination of the temperatures recorded at ceiling level;
- determination of the quantity of water consumed in both presented situations (sprinkler vs watermist).

2. The experimental stand

The experimental stand consists in a concrete building with length 5.50 m, width 3.10 m and a height of 2.30 m. In this space the authors have installed a fire

[1] Eng., General Inspectorate for Emergency Situation, Bucharest Romania, e-mail: pietreanuc@yahoo.com
[2] Assist., Fire Officers Faculty, Bucharest Romania
[3] Prof. emeritus, University POLITEHNICA of Bucharest Romania

suppression system provided with two sprinkler heads (test 1) and two watermist heads (test 2). It was chosen this number (two heads) because the protected area for one sprinkler head is 12 m², respectively 13.4 m² for one watermist head and the garage area is 17.05 m². The fire suppression system was connected to a fire fighting centrifugal pump. The pump ensures a flow rate of 3600 l/s at a pressure of 8 bar for the normal pressure and a flow of 400 l/min at a pressure of 40 bar, high pressure. For the performed tests, authors have chosen standard response sprinkler head type 21 MX5 - SP - 24, DN 15 mm diameter, discharge factor $K = 80$, the operation temperature of 68 ºC and the maximum mounting height is 5 m. The sprinkler heads operates at a pressure between 0.35 bar and 12.5 bar. With regard to watermist heads, they are AM 29 type, DN 15 mm diameter, the operation temperature is 68 ºC and the maximum mounting height is 5 m. The watermist heads operates in a pressure range between 7.6 bar and 17.2 bar.

3. The designing of fire fighting systems

In accordance to standard SR EN 12845:2004 + A2: 2009 [2], table A2, parking areas fall into Ordinary Hazard 2 (OH2). According to table 19, maximum area protected by a sprinkler head, A_p, is up to 12 m² and the distance between sprinklers is maximum ($S \times D = 4.6m \times 4m$). For a discharge factor of $K = 80$, measured in [l/ minute·bar$^{1/2}$], the design density of the sprinkler head for protection of an area within an OH2 is $i_S = 5$ mm/ minute (0.0833 l/s·m²). Also, for wet system, the area of operation for OH2, A_{ds}, is 144 m^2.

The spray curve of sprinkler shows:

- the pressure at the sprinkler head, $p = 4$ bar;
- the spray radius, $R = 4$ m;
- the real area protected by a sprinkler head, $A_{spk,real} = \pi R^2 = 50.24$ m².

For to determine the area protected by a sprinkler head, one need to calculate the flow of a sprinkler head (q), in [l/s],

$$q = \frac{K \cdot \sqrt{p}}{60}; \tag{3.1}$$

substituting in (3.1) the above data, one obtains

$$q = \frac{80 \cdot \sqrt{4}}{60} = 2.66 \text{ l/s}; \tag{3.2}$$

Checking the design density of the sprinkler head $i_{s,spk}$ in [l/s·m²]:

- the case when we consider the real area protected by a sprinkler head, according to the spray curve,

$$i_{s,spk} = \frac{q_{spk}}{A_{spk,real}}; \tag{3.3}$$

substituting in (3.3) the above data, one obtains

$$i_{s,spk} = \frac{2,66}{50,24} = 0.0529 \text{ l/s·m}^2 < i_s = 0.0833 \text{ l/s·m}^2; \tag{3.4}$$

- the case when we consider the area protected by a sprinkler head, according to technical regulations,

$$i_{s,spk} = \frac{q_{spk}}{A_p}; \tag{3.5}$$

substituting in (3.5) the above data, one obtains

$$i_{s,spk} = \frac{2,66}{12} = 0.2216 \text{ l/s·m}^2 > i_s = 0.0833 \text{ l/s·m}^2. \tag{3.6}$$

Therefore, the area protected by a sprinkler head is the same like as the one provided in technical regulations ($A_p = 12$ m²), because it ensures a design density over the one established in the standard.

The number of sprinkler heads operating together is obtained with the following formula:

$$N_{i,spk} = \frac{A_{ds}}{A_p}; \tag{3.7}$$

substituing in (3.5) known date, is obtained

$$N_{i,spk} = \frac{144}{12} = 12 \text{ pieces.} \tag{3.8}$$

In our case, the surface of a space is only 17.05 m², so a number of two sprinkler heads is enough,

$$N_{i,spk} = \frac{17,05}{12} = 1.42 \approx 2 \text{ sprinkler heads.} \tag{3.9}$$

Regarding the watermist system, the designing phase goes the same like the case of sprinkler fire suppression system [3]. There are two sprinkler heads which protects the space,

$$N_{i,ceata} = \frac{17.05}{13.4} = 1.27 \approx 2 \text{ sprinkler heads.} \tag{3.10}$$

The number of heads for both firefighting systems is the same.

4. Test 1. Sprinkler system

For this test authors used a quantity of 5 liters of ethanol in the burning pan, as fire burner. The ethanol is ignited at 12 hours, 52’ minutes, 00” seconds time (12 h52’00”).

The fire pan is situated in the corner of the space and it is shielded by a metal construction in such manner that the direct contact between the drops of water and flame is almost impossible.

Relevant for this test is the evolution of the temperature at 0.22 m and 0.60 m above the surface of burning ethanol in the fire pan about 3 minutes from the moment the sprinkler head operates. At the same time authors use thermocouples to obtain the temperature at 1.75 m and 2.20 m (at ceiling) above the base of the fire. All temperatures were taken by using state of the art technology (4 channel Lutron thermometer with fire resistant thermocouples), directly connected to a computer.

At the time of the test activity, the atmospheric conditions were as follows: the temperature 38 ºC, the relative humidity 29% and the pressure 1.004 bar. Other relevant conditions: the water temperature used to extinguish fire is 30.9 ºC, the pump is in operation, the pressure is 8 bar. The pressure was measured at the entrance of the water in the fire suppression installation, by using a manometer and the linear and local friction losses in the entire installation were neglected.

After 227 seconds from the fire ignition, time 12h55’47”, the sprinkler head near the fire burner operates.

After 170 seconds from the sprinkler head operates and 397 from the fire ignition, time 12h58’37”, the fire is manually suppressed, but the sprinkler system doesn’t stop.

431 seconds after the fire ignition, time 12h59’11”, the pump stopped.

The temperatures values recorded at 0.22 m, 0.60 m, 1.75 m and 2.20 m are presented in fig. 1.

As seen in figure 1, 227 seconds after the fire was ignited (the beginning of the first test) authors recorded the following temperatures:

- 129 ºC at 2.20 m;
- 75 ºC at 1.75 m;
- 321.4 ºC at 0.60 m;
- 673 ºC at 0.22 m.

The temperature recorded at 2.20 m elevation was 129 ºC for a temperature of a sprinkler head of 68 ºC. This issue is very important for the choice of the thermal initiation device for the natural smoke and heat exhaust ventilators. In *rule APSAD 17 – March 2010*, Annex 3 - *Operation mode of the natural smoke and heat exhaust ventilators*, the temperature of the thermal initiation device is minimum 93 ºC [4]. At this temperature, in our case, the sprinkler head doesn’t operate. If a thermal initiation device of the natural smoke and heat exhaust ventilators operates before a sprinkler head, the sprinklers won’t operate. Certainly, after the natural smoke and heat exhaust ventilators will be open, the fire grows due to increased air circulation.

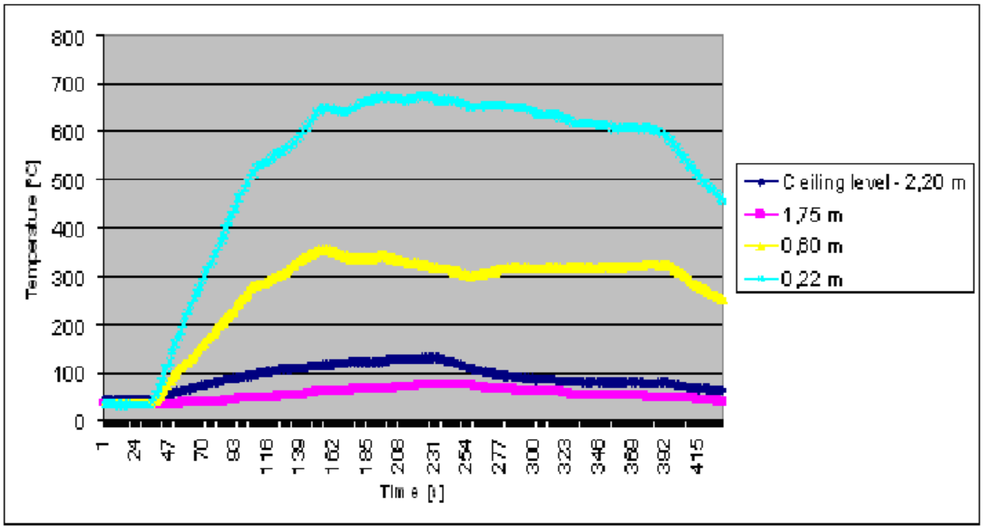

Fig. 1. The values of temperature recorded for sprinkler system, at different elevations above the ethanol surface of the burning pan

Further analyzing the chart above in figure 1, 397 seconds after the fire was ignited (the beginning of the test), 170 seconds after the moment when sprinkler head operates, one recorded the following temperatures:

- 75.7 ºC at 2.20 m;
- 47.5 ºC at 1.75 m;
- 314 ºC at 0.60 m;
- 574.9 ºC at 0.22 m.

After 170 seconds from the sprinkler system is in operation, the temperatures decrease:

- with 53.3 ºC from 129 ºC to 75.7 ºC , at 2.20 m;
- with 27.5 ºC from 75 ºC to 47.5 ºC, at 1.75 m;
- with 7.4 ºC from 321.4 ºC to 314 ºC, at 0.60 m;
- with 98.1 ºC from 673 ºC to 574.9 ºC, at 0.22 m.

Therefore, the biggest decrease in temperature is 98.1 ºC recorded at 0.22 m, above the fire.

During the suppression test, 200 liters of water were discharged.

5. Test 2. Watermist system

For the second test activity, authors ensured the same conditions as in test 1. The atmospheric parameters are the same like in test 1. The water temperature used to extinguish the fire is 30.9 ºC, the pump is in operation and the pressure is 9 bar.

The fire was ignited at 13h30’00” time. After 348 seconds from the fire ignition, time 13h35’47”, the watermist head situated near the fire, operates.

After 160 seconds of fire suppression, the watermist head operates and 508 seconds after the fire was ignited, time 13h38’27”, the fire is covered, but the watermist system doesn’t stop. 558 seconds after the fire was ignited, time 13h39’29”, the pump is stopped.

The temperature values recorded at 0.22 m, 0.60 m, 1.75 m and 2.20 m elevations are presented in fig. 2.

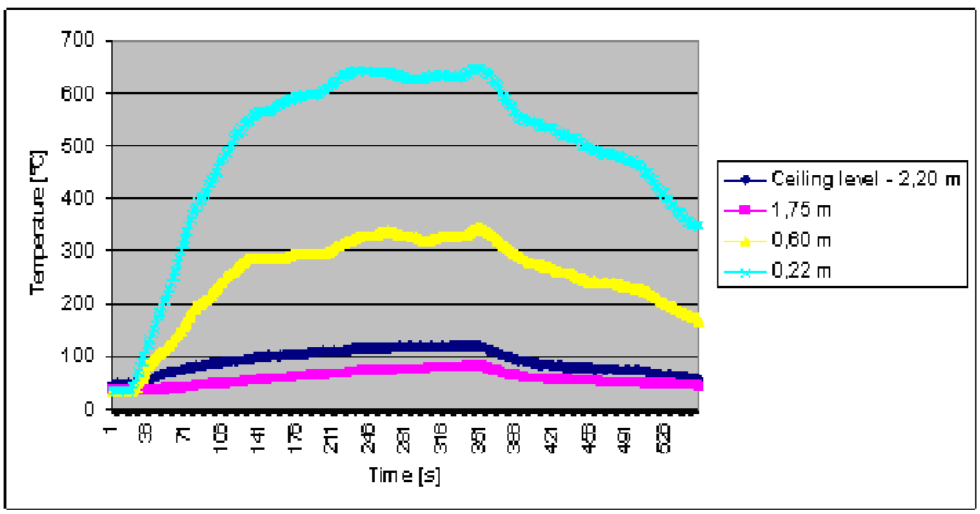

Fig. 2. The values of temperature recorded for watermist system, at different elevations above the ethanol surface of the burning pan

The chart discloses that in 348 seconds from the fire was ignited (the beginning of the test) there were recorded the following temperatures:

- 120.8 ºC at 2.20 m;
- 81 ºC at 1.75 m;
- 344.6 ºC at 0.60 m;
- 648 ºC at 0.22 m.

From the analyze of the chart, Fig. 2, after 508 seconds from the fire was ignited (the beginning of the test), 160 seconds from the watermist head operates, there were recorded the following temperatures:

- 70.3 ºC at 2.20 m;
- 49 ºC at 1.75 m;
- 223.9 ºC at 0.60 m;
- 450 ºC at 0.22 m.

After 160 seconds from the watermist system is in operation, the temperatures decrease:

- with 50.5 ºC from120.8 ºC to 70.3 ºC, at 2.20 m;
- with 32 ºC from 81 ºC to 49 ºC, at 1.75 m;
- with 110.7 ºC from 344.6 ºC to 223.9 ºC, at 0.60 m;
- with 198 ºC from 648 ºC to 450 ºC, at 0.22 m.

Therefore, the biggest decrease for temperature is 198 ºC recorded at 0.22 m, above the fire.

During this second suppression test, 120 liters of water were discharged.

6. Conclusions

For almost the same time of operating, for both firefighting systems (204 seconds for sprinkler system and 210 seconds for watermist system) the water quantity was different, ranging from 200 liters for sprinkler system to 120 liters for watermist system.

By analyzing the charts above (figure 1 and 2), for the same time of operating, the temperature recorded at 2.20 m, respectively 1.75 m was not influenced significantly by any of fire fighting systems.

The temperature measured at 0,6 m above the fire, drops with 110.7 ºC in 160 seconds for watermist extinguishing system when comparing to sprinkler system where temperature drops only with 7.4 ºC in 170 seconds. For sprinkler system on the temperature chart it is easy to observe that temperature values drops after the head of sprinkler operates, increases with approximately 20 °C and finally constantly drops until the fire is suppressed unlike watermist system where temperature is constantly dropping. An explanation of this could be the size of water drops which is 1 mm for sprinkler system and much lower for water mist system (0.01 mm) as the ethanol's fire cannot be extinguished with water and the thermometer is not influenced by direct contact with water drops, being fully shielded by the metallic construction. The size of the water drops has a great influence on the thermal transfer because the surface of the drops for watermist is bigger than the sprinkler droplet case [6, 7, 8, 9, 10, 11, 12, 13, 14, 15].

The temperature measured at 0.22 m above the fire recorded a considerable decrease of *198 ºC for* watermist system than *98.1 ºC for sprinkler system, in about the same time (170 seconds for sprinklers and 160 seconds for watermist). This proves that the watermist system is more effective than the sprinkler system at this level and in the presented conditions.*

Given the decrease of the temperature recorded in the fire extinguish operation, in two points (0.22 m and 0.60 m) above the fire, in the shielded space, the tests show that the watermist system is more effective (in terms of suppression) than sprinkler system, in the closed parking spaces where cars are parked one on top of another.

The present research opens the way for other specialists, in order to identify which is the optimum size of the drops to suppress fire in closed spaces, because the literature states that different droplet size distributions give different suppression properties [5].

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