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REVIEW ON WATER MIST FIRE SUPPRESSION SYSTEM

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ABSTRACT

Water mist fire suppression system (WMFSS) is one of the candidates for substituting the halon-based total flooding system. It uses water as the extinguishing medium which is cheap, easy-obtaining and has no environmental impact. The system with strong spray momentum has a satisfactory performance on extinguishing solid fires, liquid fires as well as kitchen fires under no ventilation. Water mist discharged is assumed to evaporate completely when they meet the flame. Ideally, the WMFSS could be used to extinguish electrical fires without danger. However, it is observed that very fine water drops are very easily affected by indoor aerodynamics. The mist might not be able to reach the flame when there is a strong upward air movement caused by the plume as well as the mechanical ventilation. Therefore, understanding this phenomenon is important for integrating the design of a WMFSS with a mechanical ventilation system. Measuring the extinguishing time could also indicate the effectiveness of the WMFSS under different conditions. This paper will review some characteristics of the WMFSS like interaction with ventilation conditions, extinguishing time as well as the further study plan. Currently, to develop a practical design and testing guide for general applications in premises is the most urgent need.

1. INTRODUCTION

Water mist fire suppression system (WMFSS) is an active fire extinguishing system using water as the extinguishing medium. It was originally developed in 1950s and regained the attention from the researches and industries again due to the phasing out of Halon 1301 in 1987 [1]. As an alternative to the halon-based total flooding system, the WMFSS could extinguish both Class A fires and Class B fires as well as the fires that occur in the kitchen, i.e. Class K fires [2]. As defined in NFPA 750, 99 % of the water drops from the water mist nozzle should be smaller than 1000 microns [3]. The WMFSS utilizes the very fine water droplets discharged from the nozzle to extract the heat by evaporation and smoother the fire by displacement of the oxygen [4,5]. In the past decades, many studies have been done on WMFSS. In this paper, some reviews on WMFSS will be carried out.

2. EXTINGUISHING PRINCIPLES AND MECHANISMS

When water drops are discharged to the fire, they would extract heat from the surrounding and evaporate into water vapor. The whole process could reduce the temperature and control the fire growth. The total heat extraction by the mist mainly results from heat transfer and mist evaporation. The heat extraction q_1 due to conduction, convection and radiation from the fire can be expressed (e.g. [5]) in terms of the temperature difference Δt, (where $\Delta t = t_2 - t_1$), the heat transfer coefficient U and the total surface area of the water droplets.

$$q_1 = UA(t_1 - t_2) \tag{1}$$

With enough discharging momentum, the heat transfer coefficient could be maximized mostly. As the diameter of the water droplets from the WMFSS is very small, the total area A is also increased. The heat extraction due to water drops evaporation q_2 can be expressed in terms of weight of water W, specific heat of water C_{pw}, specific heat of steam C_{ps}, latent heat of vaporization of water and temperature differences Δt_1, (where $\Delta t_1 = t_B - t_L$) and Δt_2, (where $\Delta t_1 = t_S - t_B$).

$$q_2 = W(C_{pw}(t_B - t_L) + L + C_{ps}(t_S - t_B)) \tag{2}$$

The heat from the fire heats up the water drops to the temperature of vaporization (sensible heat) and continues to provide heat for the change of state from liquid to vapor (latent heat of vaporization). As the water drops change the phase as they extract the heat, their volumes expand for about 1700-fold upon evaporation (at temperature 95 ^oC and 1 atm pressure) [6]. The rapid expansion of the water vapor forces the oxygen away from the fire source. Therefore, from some researches view, WMFSS has a better heat extraction capability than the sprinkler system [7].

Heat extraction, oxygen displacement and radiation attenuation are the three extinguishing mechanisms of the WMFSS. As in most cases, these three mechanisms have a dominant effect on control, suppression and extinguishment of the fire. The vapor/air dilution and kinetic effect supplement the main mechanisms to help extinguish the fire [4]. The terminal velocity of the water drops from the WMFSS is not large enough to reach the seat of the fire; it is assumed that they could evaporate completely without wetting the fire source. Therefore, the WMFSS could be used to extinguish liquid fires without explosion [8].

3. INTERACTION WITH VENTILATION CONDITIONS

As the water droplets are so fine that they are very easily affected by the aerodynamic circumstances inside the compartment, therefore how mechanical ventilation affects the performance of the WMFSS should be studied in more detail. The ventilation conditions could affect the extinguishing time, gas concentration, water discharge pattern as well as other performances of the WMFSS. In several design guides, like NFPA 750 and SPFE handbook, it is generally assumed that all the MVAC systems for thermal comfort should be shut down upon activation of the WMFSS [3,6,9]. If the MVAC system was still working or there was some natural ventilation existing, the performance of WMFSS might be affected [10].

A more detailed study on the performance of WMFSS under ventilation conditions was carried out by Liu et al. [11]. Three ventilation circumstances including no ventilation, natural ventilation and forced ventilation were tested. From experiments, they showed that ventilation would not have so a big impact on the water mist discharged with strong spray momentum and vice versa [11,12]. It concluded that in order to achieve a better fire extinguishing performance, enough spray momentum should be offered. A series of experiments were conducted to investigate the performance of the low pressure WMFSS and it was concluded that it was most difficult to extinguish a low flash point liquid pool fire in a ventilation compartment [13].

When the ventilation system in the compartment is operated, the main extinguishing mechanisms might be changed as the ventilation rate [6]. With limited ventilation and heat entrapment, the oxygen concentration in the compartment can be reduced rapidly. However, for well-ventilated fires, the total amount of water discharged should be enlarged dramatically even to 10 times.

4. EXTINGUISHING TIME

WMFSS could be applied as different kinds of fire extinguishing systems like total-flooding system, local application and portable extinguisher. For portable extinguisher, it was found that the extinguishing time for liquid fires like cooking oil and flammable liquid fires was much shorter than that for solid fires. When the fire was located away from the mist nozzle, the extinguishing time would increase. The mist was blown away by the fire plume and could not reach the fire surface [8].

For the total flooding system application, many researches have been carried out to verify the effectiveness of the WMFSS by measuring the extinguishing time in different cases. A series of experiments were conducted by Pepi to reveal the extinguishing performance in the case of natural ventilation [13]. For a 1 MW spray fire, the extinguishing time was 1.5 times longer for natural ventilation with the door open than when under no ventilation with the door closed [14]. In 1998, a study on intermediate pressure WMFSS for extinguishing flammable liquid fires was continued to be carried out [15]. Compartments of three different sizes of 500 m^3, 800 m^3 and 1280 m^3 were included. The extinguishing times were much longer for the high pressure spray than that of the low pressure spray. For extinguishing Class A fires, the extinguishing time exceeded 10 minutes. It was concluded that the intermediate WMFSS did not have a perfect performance in extinguishing liquid fires because the fire could exit for quite a long time after discharging the system.

For the local applications, not so many attentions were paid in the past. The minimum Spray Heat Absorption Ratio (SHAR) was defined for a WMFSS to extinguish the fire [16]. The concept was that with certain mean droplet diameter, the water application rate should be big enough to reach the minimum SHAR to extract the heat. For some tests, it was also found that for the local application cases, the extinguishing time was very short, that was in the order of seconds. However, if the burning objects have a longer pre-heat period, a much longer spraying time is required to prevent re-ignition.

5. FURTHER STUDIES

As the WMFSS is a new option for some traditional fire protection solution, there lacks general design and test criteria. Several research organizations and insurance companies such as National Fire Protection Association (NFPA), Society of Fire Protection Engineers (SFPE) and Factory Mutual (FM) have developed their own regulations and design guides [3,6,17]. Different versions of regulations were focused on different hazard premises and therefore having different application regions [18]. Only FM APPROVAL protocol can be used as the design and testing guide for the combustion turbines (up to 260 m^3), computer room sub-floors, industrial oil cookers, and wet benches. For ordinary hazard, only International Maritime Organization (IMO) is applicable. However, for the light hazard, local application and machinery spaces premises, IMO, FM APPROVAL protocol and Underwriter Laboratory (UL) have similar design guides.

For different premises, the requirements for fire extinguishment, fire suppression, fire control, temperature control and exposure protection determine that which type of the system should be used, how many spray momentum should be provided as well as the ventilation conditions inside the compartment. In order to save the resources and break down the obstruction in applying the WMFSS, developing a design and testing guide for general application in premises becomes an urgent task. In the future, more efforts will be paid on developing the design and testing protocols through experiments as well as computer modeling.

6. CONCLUSION

WMFSS is a good alternative for the Halogen-based total flooding system. It has no damage to the environment. It also has a strong capability in extinguishing liquid fires under no ventilation conditions which is not like other water-based fire suppression systems. However, the case-dependent and varying performance of WMFSS under ventilation conditions create a significant problem in practical application. Therefore, more studies including experiments and modeling work should be carried out for a better understanding of the WMFSS.

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Q & A

Q1: Did you use the same nozzle for all kinds of water mist fire suppression system?

Zhu: No, depending on the system type and cost.

Q2: What are the advantages of water mist comparing to other common water system such as sprinkler system?

Zhu: For liquid fires, sprinkler system cannot be used. For marine application, sprinkler system may cause water damage due to the larger amount of water. Water mist system can avoid that.