Extinguishing Compartment Oil Fires by Fine Water Mist

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Abstract

The fine mist fire suppression system has been focus the spotlight of attention for the extinguishing fire because of the decently living environment. The droplet size of fine mist spray, the oxygen concentration of fire room, and the fire size are important parameters for the extinguishing fire. We have investigated the relationship among the droplet size of fine mist spray, the quantity of fine mist at the surrounding area of fire source, and the concentration of oxygen in the fire compartment within the various fire sizes of n-heptane. And we have cleared the mechanism of the extinguishing oil fire by the fine water mist.

Keywords

Fine water mist, Water mist, Fine mist droplet, Extinguishing oil fire

1. Introduction

The fine mist fire suppression system for Halon 1301 alternate have the effect of high evaporation and cooling. The aqueous vapors produced by evaporation pushes away the oxygen at the surrounding fire source. In the reason of above the fine mist has directly the effect of the fire suppression. It is well known the effect of the screening action from fire radiation for the suppression effects of the fire growth. Unfortunately we, however, have no fire regulation code in Japan for the water mist fire suppression system. The installation of the water mist fire suppression system is at a standstill for above reason in our country. However we expect the installation of the effective water mist fire suppression systems in disregard of the no methods of effects of the concretely installation and application.

In the present work, we have investigated the relationship among the droplet size of water mist, the spray out quantity of water at the area of fire source and the concentration of oxygen in the compartment with different fire sizes of n-heptane oil fire. The equipment of the water mist fire suppression system has been installed the same of the sprinkler fire suppression system.

2. Experiments

2.1 Materials

The fuel for fire tests consisted of n-heptane. Fire sources are the three stainless steel pans which size are 30cm, 35cm and 43cm in diameters corresponding to 43Kw, 63Kw and 100Kw pool fire respectively. The concentration of oxygen in the fire compartment are controlled uniformly by the flow meter within the N_2 - O_2 gas mixture.

2.2 Apparatus

Figure 1 shows the outline of the experimental apparatus. The fire compartment size is 3m length, 3m width and 2.5m high. The three full-cone nozzles for the fine mist droplets are applied to the extinguishment of the oil fire. The mean values of droplet sizes in diameter are 85, 140 and 190 microns measured by phase doppler particle analyzer. The fine mist droplets are sprayed out with 4kgf/cm^2 or 7kgf/cm^2 at the nozzle pressure. The fine mist nozzles are set on the ceiling shown in figure 1. The nozzles are symmetrically located the square on the center of the ceiling and each nozzle are set at intervals of 20cm. The each nozzle head is located at the 2.2m high above the floor, and the fine mist droplets are sprayed out indirectly into the fire source of oil-pan.

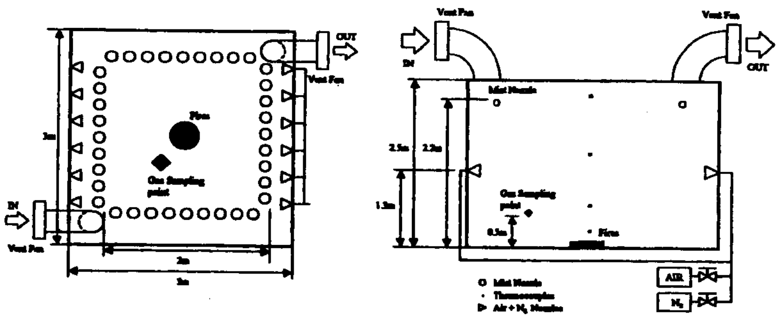

Fig 1. Configuration of test chamber

The temperatures of fire flow and fuel are measured by C-A type thermo-couples, 0.5mm in diameter, in figure 2. The radiation flux are measured at the point of 1.5m length from heat source and 0.75m height above the floor. The gas concentrations, O_2, CO and CO_2, are also measured by infrared at the point of the 80cm far from the heat source and 50cm above the floor.

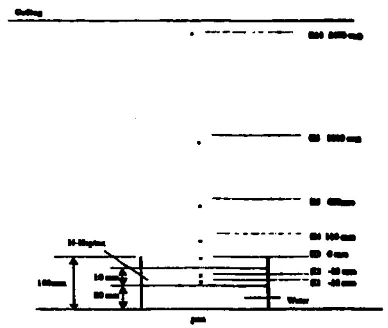

Fig 2. Locations of Thermocouples

2.3 Procedures

The fine mist droplets are sprayed out after reached steady state fire. We measured the extinguishing fire time which is defined interval time from after sprayed out to extinguish fire completely. Where the completely extinguishing fire is defined that the flame after re-ignition of the remaining oil in the heat source pan keeps more than 1 minute.

3. Results

Figure 3(a) shows the time history of the flame temperature at the point of 110 cm (K4 point) above the heat source pan of 43cm in diameter. The sprayed out quantity rates of water (denoted the flow rates of fine water mist) at the area of fire source are 1.1 l/min.m^2, and 0.8 l/min.m^2 respectively and 85μ of droplet size in diameter. Figure 3(b) also shows the time history of the ceiling temperature above the heat source pan and the oxygen concentration in the compartment as the same fire of figure 3(a). In the case of 0.8 l/min.m^2 flow rate of fine water mist, the flame temperature at K4 point shows the damped oscillation and lastly the fire has been extinguished by fine water mist. However we could not see the damped oscillation phenomenon in the case of 1.1 l/min.m^2 flow ate of fine water mist. The concentration of oxygen in the compartment were reached about 18.5% at the extinguishing fire of both flow rate of fine water mist.

On the other hand, figure 4 shows the time history of the ceiling temperature and the oxygen concentration in the compartment with 1.6 l/min.m^2 flow rate of fine water mist and 140μ average droplet size in diameter. In this case the oil fire has not been extinguished by fine water mist recognizing the transition of temperature at the K4 point in spite of the oxygen concentration in the compartment indicated about 18.5%. The very small flame had still kept at the corner of the heat source pan.

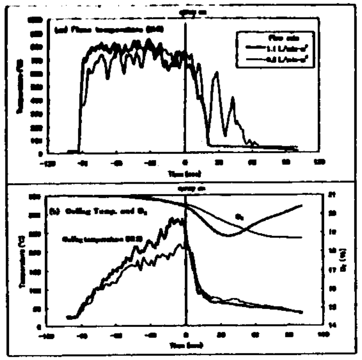

Fig 3. Case of extinguishing fire (SDM=85μandϕ43cm)

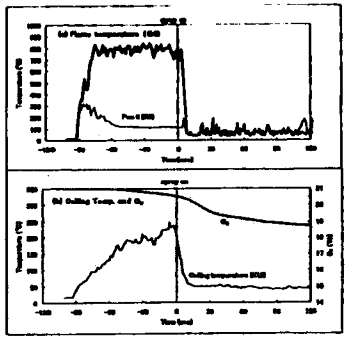

Fig 4. Case of no extinguishing fire (SDM=140μ,ϕ43cm, 1.6 l/min.m^2 flow rate)

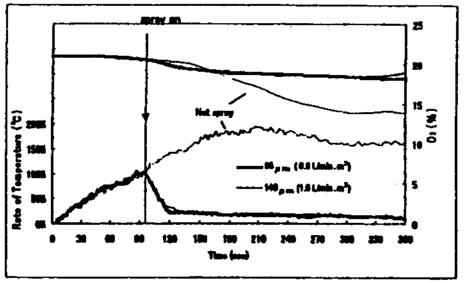

Fig 5. Distribution of Temperature and O_2 concentrations

The time history of the temperature at the ceiling above the heat source pan and of the oxygen concentration in the compartment are shown in figure 5 at the case of the extinguishing fire and of the failure of the extinguishing fire. In the case of the success of the extinguishing fire, the flow rate of the fine water mist is 0.8 l/min.m^2 and the averaged droplet size in diameter is 85μ. And in the case of the failure of extinguishing fire, the flow rate of fine water mist is 1.6 l/min.m^2 and the averaged droplet size is 140μ in diameter.
We recognized no temperature difference between both phenomenon in figure 5. In spite of no differences of temperature, the phenomenon of the extinguishing fire is quite difference between both case, because of the existence of very small remaining flame in the corner of the oil pan.

Figure 6 shows the relationship between the flow rate of fine water mist and the heat release rate at the averaged droplet size of 85μ, 140μ and 190μ with the successful and the failure of the extinguishing fire. It is very interested in the situation that it is very difficult to extinguish the small fire such as less than about 50kW fire using in our experiment for the fine water mist suppression system. We shall roughly obtain the regions of the extinguishing fire by fine water mist for each averaged droplet size of the fine water mist.

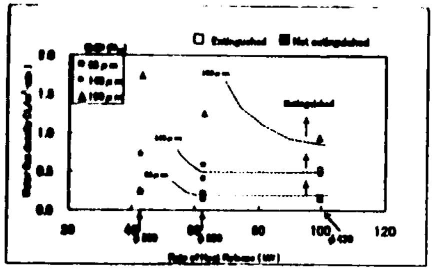

Fig 6. Relationship between RHR and flow density

Figure 7(a) also shows the relationship between the flow rate of the fine water mist and the extinguishing fire time at the avegared droplet size of 85μ and the 40cm in diameter of heat source pan. We shall also obtain the linear relationship between both at the condition of greater than the 0.2 l/min.m^2 flow rate of fine water mist for the 85μ diameter of the averaged droplet size. Figure 7(b) shows the relationship between the flow rate of fine water mist and the concentration of oxygen in the compartment as the same experimental conditions. We shall also obtain the linear relationship between both at the condition of greater than the 0.2 l/min.m^2 flow rate of fine water mist for the 85μ diameter of averaged roplet size.

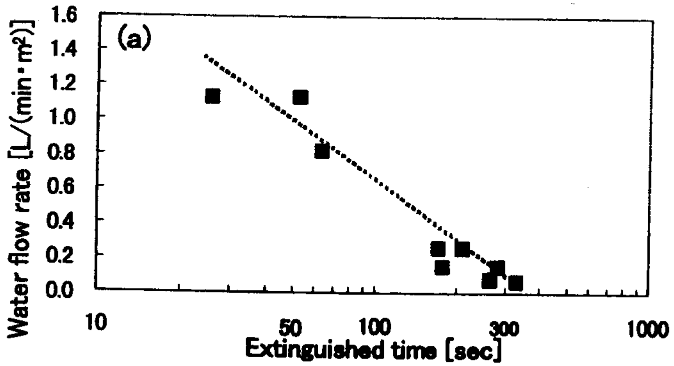

Fig 7(a). Distribution of exitnguished time and water flow rate

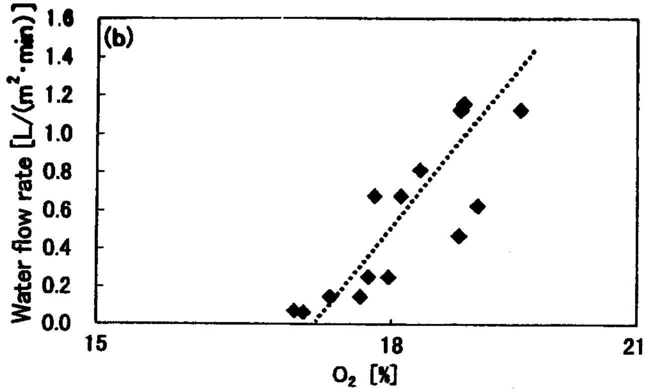

Fig 7(b). Distribution of O_2 concentration and water flow rate

Figure 8 shows the relationship between the extinguishing fire time and the oxygen concentration at the 0.2 l/min.m^2 and 0.4 l/min.m^2 flow rates of fine water mist, the averaged droplet size of 85μ, and the diameter of heat source pan of 35 cm. The larger droplet size of fine water mist, the scarcely faster extinguishing fire time. The limitation of the concentration of oxygen for the extinguishing fire is got the range of 18 to 19% in the compartment under this conditions. None can extinguish the fire more than 19% oxygen concentration in the compartment.

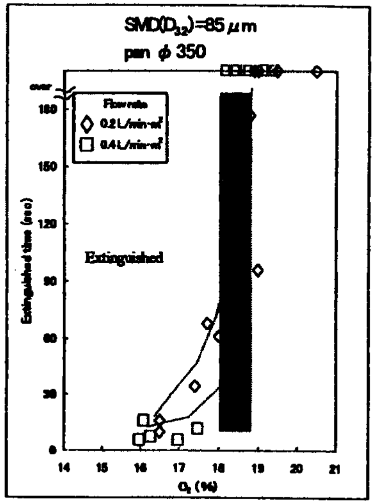

Fig 8. Distribution of extinguished time and O_2 concentrations

Figure 9 also shows the relationship between the extinguishing fire time and the oxygen concentration at the 1.1 l/min.m^2 flow rate of fine water mist, the 85μ averaged droplet size, and the diameter of heat source pans of 30 cm and 35cm.

The smaller fire size, the scarcely harder the extinguishing fire by the fine water mist. The limitation of the concentration of oxygen for the extinguishing fire is also ranged about 18 to 19% in the compartment under this conditions. None can extinguish the fire also more than 19% oxygen concentration in the compartment.

Figure 10 also shows the relationship between the extinguishing fire time and the oxygen concentration at the 1.1 l/min.m^2 flow rate of the fine water mist, the averaged droplet size of 190μ, and the diameter of heat source pans of 35 cm and 43cm. The smaller size of droplet, the higher efficiency of the extinguishing fire.

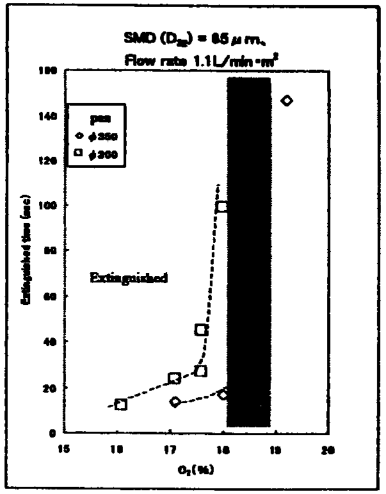

Fig 9. Distribution of extinguished time and O_2 concentrations

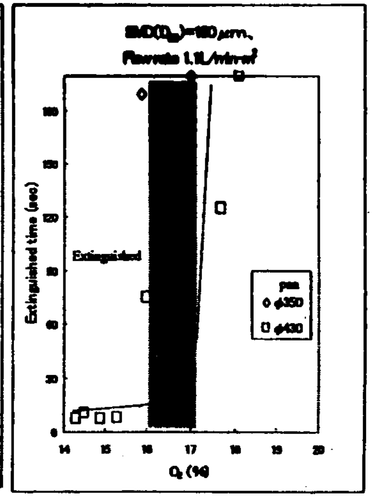

Fig 10. Distribution of extinguished time and O_2 concentrations

4. Discussions

Because of the extinguishing oil fire by the water mist fire suppression system, it is very easy to understand that the mechanism of the extinguishing oil fire might be obviously different from the sprinkler system. In generally the sprinkler could not extinguish the oil fire. The efficiency of the extinguishing oil fire is better the smaller droplet size, because of the vaporization in higher at a moment. The mechanism of the extinguishing fire is following step behaviors:

(1) The fine water mist droplets get into the fire flame by entrainment or/and directly.

(2) The fine droplets are evaporated hastily by the heat of fire flame, and suddenly

are expanded the vapor gas from liquid water.

(3) The expanded vapor gas pushes away the flesh air (oxygen gas) gas by the vaporization force insted of the entraiment air into the heat source by drag force.

(4) The expanded vapor gas also blow out the flame, and push away from the vaporizing fuel gas from heat source by heat flux. The mechanism of the extinguishing oil fire by fine water mist is almost similar by gas agent. The water mist is a kind of the suffocation extinguishing agent.

Above reasons, the efficiency of the extinguishing fire by using the water mist suppression system increases in the enclosure compartment fire, because of the suffocation effect. Furthermore the mechanism of the extinguishing oil fire by the fine water mist also has a cooling effect by vaporizing water as like as sprinkler. However the cooling effect needs that the sprayed out fine mist droplets must be penetrated into the fire flame directly and/or be reached on the fire fuel gas surface directly. the momentum energy of the sprayed out fine water mist flow might need to defeat the drag force of the fire flame.

Co Formation Characteristics of Methane-Air Diffusion Flames Doped with Halon Replacements

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ABSTRACT

To explore the potential risk of increased CO with halon replacements in fires, methane-air diffusion flames doped with suppressants were studied numerically. The suppressants investigated are nitrogen, HFC-23 and HFC-227ea, as well as Halon 1301. When Halon 1301 is doped in the air side of the counterflow diffusion flame at constant oxidizer and fuel flow velocities, little change is observed in the production rate of CO. An addition of nitrogen causes reduced CO production because of decreased fuel consumption, while an addition of HFC-227ea causes a significant increase in both the maximum CO mole fraction and its production rate. CO in the HFC-227ea-doped diffusion flames is formed in two different regions, the methane oxidation region and an additional region on the oxidizer side of the flame, in which CO is produced via the oxidation of the suppressant. When normalized by the total amount of carbon released in the flame, the CO production rate is almost constant with variations of suppressant and its concentration. The increased CO production with HFC-227ea is attributed to the excess supply of carbon into the flame.

KEYWORDS: carbon monoxide, combustion modelling, halogenated suppressant, halon 1301, halon replacement, inhibitor, inhibition, fire suppression, extinction.

INTRODUCTION

Following the ban of halon production to protect the stratospheric ozone layer, several replacements have come into wide use in total-flooding fire extinguishing systems. These