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THE REVIEW OF THE WATER MIST FIRE EXTINGUISHING TECHNOLOGY

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О ТЕХНОЛОГИИ СОЗДАНИЯ ВОДЯНОГО ТУМАНА ДЛЯ ПОЖАРОТУШЕНИЯ

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Abstract. Due to the signing of the Montreal Convention, people have been looking for alternatives to the halon fire extinguishing system. The water mist is widely concerned because of its unique advantages. Many scholars have conducted extensive research on water mist fire extinguishing technology. This paper makes a review of the development and research results of the water mist.

Аннотация. В связи с подписанием Монреальской конвенции идет поиск альтернативных технологий существующим системам пожаротушения. Водный туман, как способ тушения имеет ряд уникальных преимуществ. Многими учеными проведены исследования технологии пожаротушения водяным туманом. В данной статье дается обзор результатов разработки и исследования водяного тумана.

Keywords: water mist, halon, fire extinguishing system, alternatives.

Ключевые слова: водяной туман, галон, система пожаротушения, альтернативы.

Introduction

Since the advent of halogenated alkane fire extinguishing agents in the early 20th century, they have been widely used in aircraft, ship cabins, computer rooms, archives and other important places due to their low fire extinguishing concentration, high fire extinguishing efficiency and non-conductivity. Until 1973, Professor Rowland and Dr. Molina pointed out in their paper that halogenated alkane compounds severely damaged the ozone layer over the Earth, which is an important cause of the ozone hole and destroys the living environment of human beings [1]. In 1987, the United Nations Environment Program (UNEP) developed the *Montreal Protocol on Substances that Deplete the Ozone Layer*, which eliminated the use of halon fire extinguishing systems. Therefore, people have been actively seeking alternatives to the halon fire extinguishing system since the signing of the agreement. The water mist is widely favored because of its non-polluting, small water consumption, convenient material selection and low destructiveness to the protected object. In this respect, many scholars have conducted extensive research on water mist fire extinguishing technology. For example, Mawhinney et al. [2-4] discussed the fire extinguishing mechanism of water mist. They are heat extraction, oxygen replacement, radiation attenuation, air dilution and kinetic effects. The first three play an important role in the extinguishment of spray fires. Downie et al. [5] studied the interaction of a water mist with a buoyant methane diffusion flame and found that the plume-to-spray thrust ratio was large which would result in negligible direct penetration of the droplet into the fire region. There was a significant decrease in O_2 and an increase in CO concentrations along the plume centerline upon application of the spray. Myung et al. [6] performed an experimental investigation of fire extinction limit and enhancement for a gasoline pool fire interacting with a water mist. The result showed that there were two distinct regions in the relationship between the distance from the nozzle to the fuel pan and the injection pressure, i.e. a fire extinction region and a fire enhanced region. Ndubizu [7] performed an experiment on water mist fire suppression mechanisms in a gaseous diffusion flam by adding independently various quantities of nitrogen, steam and water mist in a co-flow arrangement. The result showed that a co-flow arrangement the addition of small quantities of fine water mist had more gas phase cooling effect on the flame than oxygen dilution effect. Back et al. [8] developed a quasi-steady-state model to predict the effectiveness of a water system for extinguishing fuel spray and pool fire. The steady-state temperatures and oxygen concentrations predicted by the model can be used to determine the smallest fire that can be extinguished. Kim et al. [9] investigated the fire suppression characteristic using a water mist fire suppression system in an enclosure. The result revealed that there were two different regimes in the temporal variation of the smoke layer temperature. One was the initial sudden cooling regime, and the other was the gradual cooling one. Makoto Murakami et al. [10] simulated the impact of tunnel water mist curtain on personnel escape, and found that water mist curtain can suppress the spread of smoke, improve fire visibility, and facilitate evacuation. Horst Starke [11] experimentally studied the water mist extinguishing fire in the tunnel and found that after releasing the water mist, the heat release rate of the flame decreased rapidly, the oxygen concentration of the tunnel dropped below 18%, and the fire spread was controlled. Blanchard [12] studied the interaction between water mist and hot gases in a longitudinally ventilated tunnel. The result showed that roughly half of the heat released by fire was absorbed by water droplets, and 73% of them was absorbed by the gaseous phase cooling. Jenft [13] studied the effects of water mist before and after full development of the oil pool fire through experiments and numerical simulations. The result showed that water mist extinguished fire faster after the oil pool fire was fully developed. So far, previous studies have found that water mist can effectively suppress the spread of fire, reduce the temperature and the concentration of smoke, and improve the visibility of the fire and so on. This shows that water mist will play a significant role in the fire extinguishing technology. It is an inevitable trend that the water mist system will replace halon fire extinguishing system in the future.

Water mist fire extinguishing features

(1) It is friendly to the environment because of no pollution;

(2)The water consumption is small, compared with the water spray fire extinguishing system. The water consumption of the system is 10%-20% of the water spray system during the same working time;

(3) The working medium is water, which is convenient to take;

(4) It can be used to extinguish electrical fires and has less damage to the protected objects;

(5) The water mist adsorption ability is strong, which can improve the visibility of the fire scene and is conducive to fire rescue.

Water mist classification

The NFPA defines water mist as a water spray for which the $D_{v0.99}$ for the flow-weighted cumulative volumetric distribution of water droplets less than 1000μm at a distance of 1m below the nozzle within the nozzle operating pressure range.

Water mist is divided into three classes according to the diameter of the droplets (Figure). The cumulative percentage volume distribution curve for the "Class 1" water spray is to the left of the line connecting Dv0.1=100μm and Dv0.9=200μm. The cumulative percentage volume distribution curve for the "Class 2" water spray is to the left of the line connecting Dv0.1=200μm and Dv0.9=400μm. The distribution curve extending to the right of the line is considered to be a "Class 3" water spray [14].

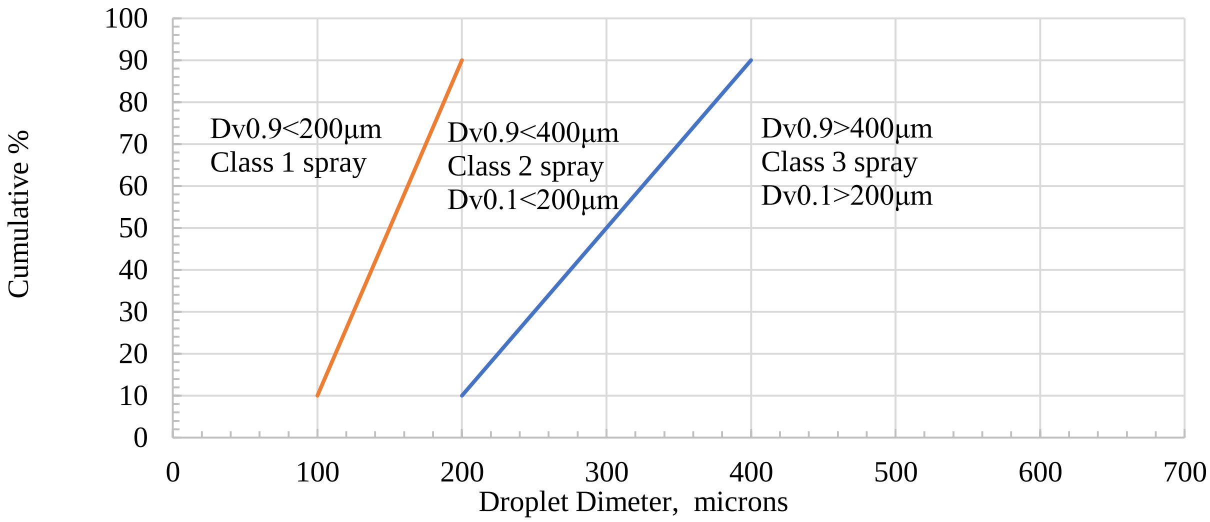

Figure. The classification of water sprays by drop sizes distribution

Water mist characteristic parameters

1. Droplet size

The droplet size of the water mist largely determines its vaporization endothermic capacity. The droplet diameter formed by nozzle atomization varies in size, but its distribution has a certain regularity and can be characterized by a percentage or mean droplet size. The mean droplet size can be divided into a volume mean diameter (VMD) and a Sauter mean diameter (SMD). The cumulative volume percentage refers to the volume of all droplets smaller than a certain diameter as a percentage of the total droplet volume, which better describes the spray distribution, compared to the mean diameter.

2. Mist flux

The mist flux of water mist is the mass flux, which refers to the total mass of water droplets passing through a unit area per unit time. It determines the amount of heat that can be absorbed by the water mist and the amount of vaporization. It has an important influence on the interaction between water mist and flame.

3. Spray angle

The spray angle is the atomization flow divergent angle with the nozzle as the origin, which directly affects the speed and direction of the droplet as it leaves the nozzle. Namely, it affects the initial velocity and initial momentum of the water mist.

4. Spray momentum

The ability of a spray to cross an obstacle in space to interact with the flame depends on the spray momentum. The spray momentum includes the spray mass, the spray velocity, and the direction relative to the fire plume. The spray momentum determines the distance travelled by the droplet and the ability to penetrate the flame. It also determines the air entrainment rate of the flame during motion. The disturbance caused by the spray momentum causes the droplets and water vapour to enter the combustion zone, thereby reducing the oxygen concentration and the fuel vapour concentration in the combustion zone, and improving the fire extinguishing efficiency of the water mist.

Water mist extinguishing mechanism

Water mist can extinguish the fire, which is related to many factors. So far, research finds that the following several factors play a major role.

1. Cooling effect

According to the three elements of fire extinguishing, fire extinguishing can be achieved when the temperature drops below the ignition point. Since the water mist has a small diameter and a large relative surface area, it can be rapidly vaporized after being heated. It can be known from thermodynamics that the heat absorbed by the latent heat of water vaporization is much larger than the heat absorbed by the increase of the water temperature. Therefore, the heat absorbed by the unit area of the water mist is large, and the temperature is lowered rapidly so that rapid fire extinguishing can be achieved.

2. Oxygen displacement

The evaporation will occur rapidly after injection of the water mist into the fire scene. The water droplets expand approximately 1700 fold, which will displace the air in the vicinity of the fire. If the oxygen concentration available for combustion is reduced below a critical level, the fire will be easy to extinguish.

3. Thermal radiation attenuation

During the action of the water mist and the fire source, the vapour formed by the evaporation quickly surrounds the combustion, the flame and the plume, which will reduce the amount of heat radiation of the fire. Then, the radiation attenuation will reduce thermal feedback to burning and unburned fuel surfaces, which can suppress the spread of fire.

4. Wetting effect

Larger water droplets will directly impact the surface of the combustion object and wet the combustion object, which will prevent the solids from volatilizing to produce flammable vapours. Thereby preventing the flame from spreading and extinguishing the fire. In addition, high-pressure water mist can also remove macromolecular particles from the smoke, reducing harmful gases.

5. Emulsification

When fighting oil fires, the water mist impacts the oil surface to form an emulsion layer, which on the one hand can reduce the evaporation rate of the fuel, and on the other hand, can block the combustion.

Actually, the fire can be extinguished by water mist which is the result of above several factors working together.

Conclusion

The scholars have conducted in-depth research on water mist technology and know the fire extinguishing mechanism of water mist. Now, the water mist has been widely used in various places because of its non-polluting, small water consumption, and low destructiveness to the protected object. It has a very broad development prospect and will definitely replace the halon fire extinguishing system in the future.

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