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HYDRO-FOG Fire Fightinh System

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***Abstract:** As Fire Fighting plays a vital role in maintaining the safe working condition of the vessel without any fire hazard, it has to be adopted with advanced technologies to ensure maximum safety for the ship and the crew. Even though Plenty systems and Techniques are available for fighting the fire onboard, fire accidents are inevitable. Many researches are been carrying out by shipping industries to minimize fire accidents.*

This project report deals with the "Fixed Water Fog Fire Fighting System". The progress on the research and application of water mist systems in fire suppression has been substantial over the last decade. To bring this work into focus, a model is made on Total Flooding System with the application of water mist. This report also discusses the properties of water mist, extinguishing mechanisms and the effectiveness of water fog in fire suppression.

I. Introduction

Seafarers will be familiar with the fire triangle, with sides representing fuel, heat and oxygen. Removal of any side results in the collapse of the triangle and the extinguishing of the fire.

Water has favorable physical properties for fire suppression. Its high heat capacity(4.2 J/.Kg) and high latent heat of vaporization (2442 J/g) can absorb a significant quantity of heat from flames and fuels. Water also expands 1700 times when it evaporates to steam, which results in the dilution of the surrounding oxygen and fuel vapor. With the formation of fine droplets, the effectiveness of water in fire suppression is increased, due to the significant increase in the surface area of water that is available for heat absorption and evaporation.

Water mist refers to fine water droplets in which 99% of the volume of the spray is in drops with diameters less than 1000 microns. Advantages of water mist over gaseous agents are that water is non-toxic, readily available, and lower in cost than most chemicals or patented mixtures. Water mist provides effective cooling for fuel and for the compartment that cannot be provided by the gaseous agents, potentially preventing re-ignition that may occur if a gaseous agent concentration cannot be maintained for a sufficient period of time. With effective cooling and less clean-up time, water mist allows the space to be reoccupied and operational in a short time following a fire.

Advantages of water mist over conventional sprinklers include reduced water flow rates and therefore less water damage to sensitive equipment or occupancies. Low water flow rates also provide a clear advantage in terms of space and weight requirement for the water supply. In addition, water mist is able to control flammable liquid fires that conventional sprinklers cannot control due to splashing and spillage of the fuel.

II. Related Work

1. BY Michael J. Gollner Assistant Professor, University of Maryland & Peter Raia Undergraduate Student, University of Maryland on 2010

- Two systems have recently become commercially available

- Systems utilize inert gas and water mist(~100 micron drops) to extinguish fires
- No NFPA Standard covers Hybrid Systems
- Only available guidance is FM 5580 – an approval standard for hybrid systems
- NFPA Standards Council asked for a literature review

2. Introduced in the 1930's for military aviation/maritime applications

- Highly toxic agents used
- US Army Research introduced safer Halons

3. 1989 – Montreal Protocol banned Halons

- Ozone depleting gas

4. 1991 – NFPA 2001 was formed to cover a wide range of clean agent suppression systems Covers the design, installation, maintenance and operation of clean agent systems
5. Minimum design specifications provided for

- Class A, B, C fires as well as safety factors Primarily gas-phase extinguishment

6. Introduced in 1940's for maritime applications

- New interest after 1989 Montreal Protocol
- Droplets < 1000 micron mean diameter
- Droplets entrained into fire plume
- Gas phase cooling achieved by dropletevaporation
- Secondary effect of oxygen displacement through evaporation
- Large droplet surface area = very effective operation

7. Introduced in 1996 after a strong industrydemand for a standard

- Provides design objectives, fire test protocols, documentation, system acceptance criteria
- Test protocols designed around the hazard oroccupancy of the structureNFPA 750 covers design objectives, fire testprotocols, documentation, system acceptance,system maintenance and marine systems
- 5 performance objectives: fireextinguishment, fire suppression, fire control,temperature control, and exposure controlLimitations typically due to the reactive
- properties of water with certain materials
- Combine water mist and inert gas to achievegas-phase extinguishment

8. 1996 – US Navy performed combined halocarbon/mist tests aboard ships

- Very little additional data available except for new FM Approval Standard for Hybrid Water Mist Extinguishing Systems – FM 5580

III. CONCEPT

Generally fire can be extinguished in three ways

1. Starvation: cutting off combustibles
2. Smothering : removal of oxygen
3. Cooling: removal of heat

SMOTHERING

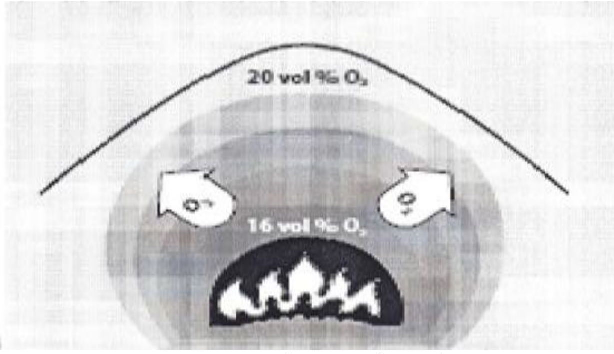

Figure DEVELOPMENT OF HEAT

The very small droplets in a high-pressure water mist system quickly absorb so much energy that the droplets evaporate and transform from water to steam, because of the high surface area relative to the small mass of water. This means that each droplet will expand more than 1700 times, when getting close to the combustible material, whereby oxygen and combustible gasses will be displaced from the fire, meaning that the combusting process will increasingly lack oxygen.

REMOVAL OF HEAT

To fight a fire, a traditional sprinkler system spreads water droplets over a given area, which absorbs heat to the cool the room. Due to their large size relatively small surface, the main part of the droplets will not absorb enough energy to evaporate and they quickly fall to the floor as water. The result is a limited cooling effect

By contrast high pressure water mist consists of very small droplets, which falls more slowly. Water mist droplets have a large surface area relatively to their mass and during their slow descent towards the floor, they absorb much more energy

A great amount of the water will follow the saturation line and evaporation, meaning that water mist absorbs much more energy from the surroundings and thus the fire.

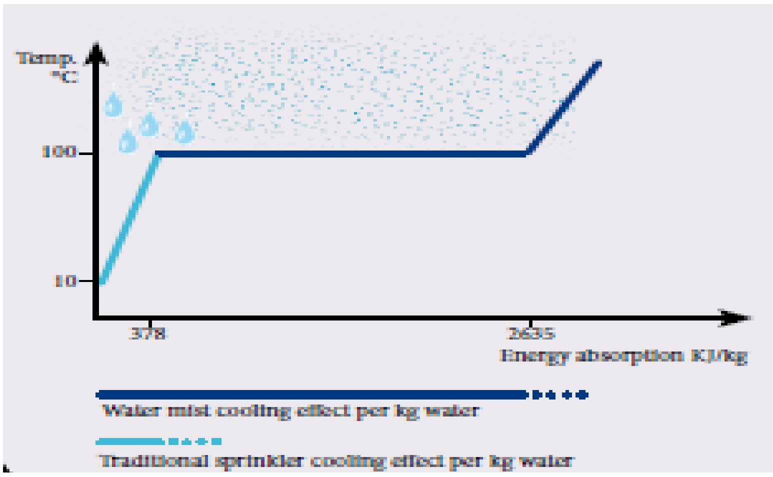

Figure COOLING EFFECTS GRAPH

That's why high pressure water mist cools efficiently per liter of water up to seven times better than can be obtained with one litre of water used in a traditional sprinker system.

The water mist with fine sprays was very efficient in controlling liquid and solid fuel fires, and suppressing hydrocarbon mist explosions.

This paper, as a first step, provides a review of the fundamental research in water mist fire suppression systems, including mechanisms of extinguishment, spray characteristics, methods of generating water mist and some factors that influence performance of water mist.

Water mist in fire suppression, however, does not behave like a "true" gaseous agent. When water is injected into a compartment, not all the sprays that are formed are directly involved in fire suppression. They are partitioned into a number of fractions as follows:

1. Droplets that are blown away before reaching the fire;
2. Droplets that penetrate the fire plume, or otherwise reach the burning surfaces under the fire plume, to inhibit pyrolysis by cooling, and the resultant steam that dilutes the available oxygen;
3. Droplets that impact on the walls, floor and ceiling of the compartment and cool them, if they are hot or otherwise run-off to waste;
4. Droplets that vaporize to steam while traversing the compartment and contribute to the cooling of the fire plume, hot gases, compartment and other surfaces;
5. Droplets that pre-wet adjacent combustibles to prevent fire s p r e a d .

WATER MIST EXTINGUISHING MECHANISM

There are two types of extinguishment was done by water mist, that as follows

PRIMARY MECHANISMS

1. HEAT EXTRACTION

- Cooling of fire plume
- Wetting/cooling of the fuel surface

2. DISPLACEMENT

- Displacement of oxygen
- Dilution of fuel vapor

SECONDARY MECHANISMS

1. Radiation attenuation

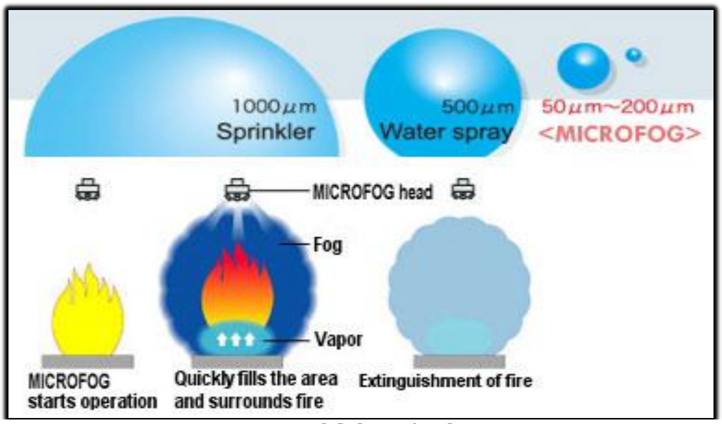

Figure FOG OPERATION

HEAT EXTRATION (COLLING)

The cooling mechanism of water mist for fire Suppression can be divided broadly into cooling of the fire plume and wetting of fuel surface. Flames cooling by water mist is attributed primarily to the conversion of water to steam that occurs when a high percentage of small water droplets enter a fire plume rapidly evaporate .A fire will be extinguished when the adiabatic flame temperature is reduced to the lower temperature limit , resulting in the termination of the combustion reaction of the fuel air mixture. For most hydrocarbon and organic vapors, this lower temperature limit is approximately 1600k

The rate of vaporization of a droplet depends on

- Surrounding temperatures;
- the surface area of the droplet;
- the heat transfer coefficient; and
- the relative velocity of the droplet in relation to the surrounding gas

A fire will also be extinguished when the fuel is cooled below its fire point by removing heat from the fuel surface, or when the concentration of the vapor/air mixture above the surface of the fuel falls below the lean flammability limit due to the cooling. In order to cool the fuel surface, a spray must penetrate the flame zone to reach the fuel surface and then remove a certain amount of heat from the fuel surface at a higher rate than the flame can supply it. It is recognized that heat is mainly transferred from the flame to the fuel by convection and radiation, while fuel cooling by water mist is primarily due to the conversion of water to steam.

For fuels whose low flash points are above normal ambient temperature, wore water sprays are needed to cool the fuel surface, because less heat is required to produce fuel vapor. Also, more water sprays are needed to prevent re-ignition of a hot, deep-seated fire. This is because higher water flow rates extinguish the fire faster, but the fuel remains hot and continues to pyrolize if the water is switched off immediately after extinction.

OXYGEN DISPLACEMENT

Oxygen displacement can occur on either a compartmental or localized scale. On a compartmental scale, the oxygen concentration in the compartment can be substantially reduced by the rapid evaporation and expansion of fine water droplets to steam, when water mist is injected into a hot compartment and absorbs heat from the fire, hot gases and surfaces.

The reduction of the oxygen concentration in a compartment by water mist is a function of the fire size, the length of pre-bum period, the volume of the compartment and the ventilation conditions in the compartment. As the fire size or the length of the pre-burn period of the fire increases, both the oxygen depletion due to the fire and the oxygen displacement due to the formation of more water vapor caused by high compartment temperatures are increased. This combined effect significantly reduces the oxygen concentration in the compartment and enhances the effectiveness of water mist for fire suppression.

On a localized scale, when the water sprays penetrate into the fire plume and are converted to vapor, the vaporizing water expands to 1700 times its liquid volume. The volumetric expansion of the vaporizing water disrupts the entrainment of air (oxygen) into the flame and dilutes the fuel vapor available for combustion of the fuel. As a result, when the fuel vapor is diluted below the lower flammable limit of the fuel-air mixture, or when the concentration of oxygen necessary to sustain combustion is reduced below a critical level, the fire will be extinguished.

The impact of oxygen dilution by water mist on fire suppression is sti'ongly dependent on the properties of the fuel. This is because the minimum amount of free oxygen required to support combustion varies with the type of fuel. For most hydrocarbon fuels, the critical oxygen concentration for maintaining combustion is approximately 13%. For solid fuels, the critical oxygen concentration required for combustion is even lower.

RADIANT HEAT ATTENUATION

When water mist envelops' or reaches the surface of the fuel, water can act as a thermal barrier to prevent further heating by radiation of the burning fuel surface as well as non-burning surfaces. Also, water vapor in the air above the fuel surface acts as a gray body radiator that absorbs radiant energy, and re-radiates it to the fuel surface at a reduced intensity. Blocking radiant heat by water mist stops the fire from spreading to un-ignited fuel surfaces and reduces the vaporization or pyrolysis rate at the fuel surface.

It has been shown that the attenuation of radiation depends very much on drop diameter and mass density of the droplets. A given volume of water will provide a more efficient barrier against radiation if it is made up of very small droplets in a dense spray, than a dilute spray with larger droplets.

IV. Proposed System

This paper proposes the IND-OCPA-P model to analyze the security of the proposed EOB and the encryption schemes supporting an efficient range query over encrypted data.

To demonstrate the fixed water fog system, a model is made with the use of following components.

1. A model compartment
2. Water misting Nozzles
3. Pipelines
4. Hand operated hydraulic line testing pump
5. Fire source

COMPARTMENT MODEL

- MI sheet of 1mm thickness is used to prepare a model compartment
- MI Sheet is made into a compartment of 1200mm X 600 mm X 600mm
- A frame is made for both ends of the compartment for strengthening purpose by using L-angle of size 600mm X 600mm
- By using Metal Arc welding, the frame is fixed to the compartment.
- Both longitudinal ends of the compartment is kept unclosed for demonstration and observing purpose.

WATER MISTING NOZZLES

- Single fluid, flat orifice nozzle
- Four misting nozzles were used. The nozzle specification is given below
- Nozzle tip diameter : 0.01mm
- Nozzle bore diameter : 0.8 mm
- Operating pressure : 12 bar
- Operation : Spring tensioned
- Nozzle tip material : Ceramic

- Number of tip : one

PIPELINES

- Stainless steel pipe of22.4mm for 5 ft were used.
- Material specification : S-202
- One end of the pipe is blocked, hence the water pressure will be developed inside the pipeline.
- Four nipples were TIG welded at unique interval for fixing the nozzle

HAND OPERATED HYDRAULIC LINE TESTING PUMP

- Maximum operating pressure : 70 bar
- Accessories : a pressure gauge; a drain valve; high pressure pipe of 1m

FOR HUGE INSTALLATION ONBOARD

- HYDRAULIC PUMP
    - The selection of pump is fully dependent on the requirement whether it is low load application or High load application
    - For low load application 20-30 bar of hydraulic pressure is required
    - For heavy load applications 70-80 bar of hydraulic pressure required
    - The pump should have the capacity to supply sufficient quantity of water to the misting nozzles
- MISTING NOZZLES
    - Selection of nozzle also depend on what load it is going to be used
    - For heavy load requirement HI FOG nozzles can be used which will operate at high pressure (approx. 72 bar)
    - The nozzles should be sufficient to mist the water droplets effectively
    - For heavy load applications pneumatic operated nozzles can be used for greater efficiency
- EXTINGUISHING MEDIUM USED
    - The most available fire extinguishing medium is sea water
    - The seawater can't be used alone
    - Some anti-scaling additives must be added in order to prevent scales at the nozzle.
- SAFETY DEVICES
    - A relief valve
    - A pressure gauge
    - A drain valve

HOLLOW CONE NOZZLE: START UP OF SPRAY

A series of pictures have been taken with the high-speed camera at the start-up of the hollow cone spray. The pictures are shown in figure 2b where the numbers indicate the distance below the spray nozzle in mm. The pictures show the development ofthe spray as the water is turned on. The pressure in the pipe is buildup within 100 ms as shown in figure 2a, however there is no significant spray after this time and therefore this pressure build up has little influence. Initially the throw length is limited as the momentum from the water dropsis transferred to the air and the droplets are decelerated. After 250 ms very little water is visible and after 300 ms the spray has only reached 300 mm. By now the momentum has been transferred and a downward air jet has been created. Therefore the water droplet can now move relatively fast down to 500 mm. 0 20 40 60 80 100 120 140 160 180 2000 spray, time for pressure build up

HOLLOW CONE NOZZLE: CONTINOUS SPRAY

Pictures were also taken with the high-speed camera of a continuous spray of water mist from the hollow cone as seen in figure 3. It is interesting for the understanding ofthe physics involved in the water spray to look at the shape of the spray and the level of instability. It can be seen that the water comes out in a cone. Up to 50 mm from the nozzle, the cone is stationary and the patterns shown in all the pictures are very similar. Around 100 mm there are slight variations and from 100 mm to 150 mm there are pronounced variations, the cone collapses and the spray continues down vertically. It can be seen that flow from 150 mm and downward is quite turbulent with large variations. An angle has been drawn to help the visual inspection of the cone shape. It is not the spray cone angle and closer inspection of the area around the nozzle shows that the cone starts to bend slightly inward already at 50 mm.

V. EXPERIMENTAL COMPUTATION

VISUAL INSPECTION

Visual inspection of the spray by characteristic droplets To provide a better overview ofthe data obtained in the PDA measurements a methodology has been developed for drawing the spray pattern of a water mist spray. Here characteristic droplets are illustrated as circles, with diameters to scale. Furthermore, velocities are illustrated with arrows that are also drawn to scale,

There are many different representative diameters that can be used to characterise a spray. They help to describe different phenomena, for example, for surface area cooling the surface mean diameter isused. In the case where the amount of water determines the extinguishing capabilities, volume-weighted. diameters are relevant. One problem in using a single value is that it doesn't describe the droplet distribution. A spray with a very wide distribution in droplet size may give the same volume weighted diameter as a spray where all droplets are of the same size. 56

THEORITICAL EXPLANATION

Droplet size distribution has therefore been characterized by using the three representative diameters.

D0.1 : is the drop diameter where 10% of the liquid volume is in drops of smaller diameter

D0.5: is the drop diameter where 50% of the liquid volume is in drops

Of smaller diameter, the mass median diameter (hereafter referred to as the mean droplet)

D0.9: is the drop diameter where 90% of the liquid volume is in drops of

Smaller diameter By using these diameters, both distribution as well as volume of drops, which for this application is the most important factor, are described.

Two other droplets are illustrated, the maximum measured droplet that varies in size from 33 to 70µm and the minimum droplet size from 3 to 8 µm. Droplet size of the largest droplet is illustrated whereas all the minimum droplets are all drawn with size 10 µm for practical purposes. The velocities are illustrated for the minimum, maximum and mean droplet. In most cases, they will describe the relevant velocity range. 57 the same, but the distribution is very different. The scan of the whole spray shows that there is a large spread in droplet size, whereas in the point measurement the majority of droplets have the same size.

The small droplets quickly transfer their momentum and adapt to the velocity of the surrounding air. It can be seen that a 10 µm droplet moving at 20 m/s in 10 m/s air flow decelerates to the air speed over a distance of only 10 mm. This means that the smaller droplets can be used to indicate the velocity of the air in the spray. The larger droplets of 70 µm will travel a distance of more than 200 mm before they have experienced the same slowdown. It is interesting to also look at this droplet and in particularly its velocity in comparison to the smaller droplets to see the spray pattern.

Hollow cone: Spray description

The characteristic patterns of the spray can be seen in figure 7. It has been found that the spray can be divided in 4 characteristic zones. These are described in broad terms here, witha more detailed analysis in the next section.

1) In the initial conical zone, the bulk of the water is in a stable cone around the nozzle. Here the largest droplets move at very high speeds. In the centre of the spray are very small droplets at slightly lower speed.
2) In the inflow zone, the large dropletsat the edge of the spray have lost their momentum due to drag and collisions and have slowed down and increased in size. Some mean size droplets have moved from the edge of the spray to the centre, where the small particles move at high speeds. This happens as air is being sucked into the low pressure zone in the centre of the spray through the water sheet.
3) Around the transient zone, the spray collapses dueto the low pressure zone in the centre of the spray. This results in a larger spread in particle sizes in the centre of the spray and a wider sheet with uniformly sized droplets moving at very slow speeds at the edges.
4) In the turbulent zone, there is considerable mixing and spray instabilitywhich eventually causes droplet distribution and velocity throughout the spray to be the same. There are large and small droplets throughout the spray moving at the same velocity.

Initial conical zone: 25 mm & 50 mm The initial conical zone is characterized by a stable shape, where the bulk of the spray is in a cone around the nozzle. The scans compared with the point measurements at 25 and 50 mm below nozzle indicates that the bulk of the water is in a cone, which consists of the largest droplets. The PIV measurements also indicates that the spray at 25 mm is wider than the PDA point measurement at 10 mm from centre. The same is the case for measurements 50 mm below the nozzle. Note that the velocity profile from the PIV measurements indicate that the spray pattern is not completely symmetrical. The larger drops in the cone have the highest speed as they are Decelerated slower than the smaller drops. In the centre of the cone are very fine drops moving at high speeds. A low pressure at the centre of the cone can be expected to be created by the fast moving water curtain. The mean droplet size for the entire plane increases from 28 µm to 35µm as the faster large droplets catch up with the smaller. The speed of the mean droplet reduces from 35 m/s to 23 m/s over this distance, due to drag and possibly energy lost in drop collisions.

Inflow zone: 100 mm. At the edge of the spray, droplets have now been decelerated and move much slower at only 8 m/s, whereas in the centre, the mean drops are moving at 26 m/s. At this stage a change happens so that the largest particles in the centre of the spray start moving slower than the smaller. Furthermore, the size distribution in the centre is changed and there are more larger droplets. It is likely that these drops have come from the edge of the spray. Due to the lower pressure created in the centre of the spray, air could be sucked in through the water sheet and this air will transport small to middle size droplets from the edge to the centre of the spray. The edge of the spray is now dominated by relatively evenly sized larger particles. Only smaller droplets have been sucked to the centre and the majority of the spray is still at the edge. Droplet size for this level has increased again so that the mean droplet is now 40 µm and moving at 7 m/s. Transition zone 150 mm:

Around 150 mm below the nozzle, the cone collapses, as was seen on the high speed pictures. At 40 mm and 60 mm from the centre, large drops around 50 μm appear. Drop sizes here are quite uniform, and the speed is very low, only a few m/s. The bulk of the water is no longer only in the edge of the spray. The scan shows that drops within dv0.1 and dv0.9 must originate from the centre as well as from the sides of the spray. In the middle of the spray, 0 mm and 30 mm from the centre, larger droplets now appear (dv0.9~45 μm) and there is a wide spread in drop diameters here. The larger drops move at slower speeds than the air velocity, which is around 19 m/s (the speed of minimum droplets).

VI. Conclusion

By this process, we are able to extinguish fire by eliminating two element of the fire triangle. We are able achieve the complete extinguishment of fire. And prevent any further life or property loss. Most of the fire spread is controlled to a certain confinement. One of the most effective ways of fighting fire is to provide quick and effective cooling at the source of the fire. To achieve cooling, suppression and extinguishing of a fire using water in a conventional way via a hose or standard sprinkler often requires many thousands of litres of water. The primary reason for this is that the vast majority of the water used is wasted; this can be seen by the amount of pools of water left on the floor, known as 'run off'. This is because only the surface area of the water drop or stream comes into contact with the energy from the fire (the heat) the rest is wasted.

The use of water mist in fire suppression, compared to the use of gaseous agents and conventional sprinkler systems, has demonstrated advantages including the following:

(1) No toxic and asphyxiation problems;

(2) No environmental problems;

(3) Low system cost;

(4) Limited or no water damage; and

(5) High efficiency in suppressing certain fires.

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