THE SECRETS OF WATER MIST AS AN EXTINGUISHING AGENT

WATER MIST BRINGS GREAT ADVANTAGES IN FIRE PROTECTION, ALONG WITH A FEW DOWNSIDES. IN THIS WHITE PAPER, RISKONET PRESENTS AN OVERVIEW OF THE APPLICATION OF WATER MIST SYSTEMS

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THE RISE OF WATER MIST TECHNOLOGY

Water mist is hot, in a manner of speaking. The water mist extinguishing system, which was developed in the shipping industry, resembles a sprinkler system in which the water is sprayed into a mist.

This technology is on the rise in the Netherlands and other European countries. And for good reason too: it is effective, safe and accurate. Additionally, thanks to it being a natural extinguishing agent, water mist is also environmentally friendly. Using a mist as an extinguishing agent also helps to extend evacuation time and prevents flashovers and backdrafts. Water mist installations require less water than sprinklers to suppress a fire. Moreover, rooms do not have to be airtight to extinguish gases.

However, it is certainly not the one-size-fits-all solution that some providers might have you believe. There are also downsides, because water mist is only suited to a limited range of fire risks. While the somewhat complex technique involved in water mist is fine in stable environments, it certainly cannot be applied in all situations.

This white paper outlines the possibilities and limitations of water mist extinguishing systems, in a neutral manner and without commercial interest. Armed with the facts and insights that it provides, it will help you make a well-considered assessment of the possible application of these systems in your organisation.

I would like to thank the following persons for providing input for this white paper: Jean-Paul Lamers of Fire Technology, Dutch representative of Marioff (Hi-fog); Jerry Krijn of Dr. Richard Sthamer GmbH & Co. KG; and our colleague Frans Stoop.

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WATER MIST SYSTEMS, WHAT THEY DO AND HOW THEY DO IT

WHAT MAKES WATER MIST SO EFFECTIVE IN EXTINGUISHING A FIRE? HOW CAN WHAT IS EFFECTIVELY JUST MOIST AIR, IN THE FORM OF WATER MIST, DO THE SAME JOB OF MORE CONCENTRATED SPRINKLER AND DELUGE SYSTEMS? THE EFFECTIVENESS OF WATER MIST DEPENDS ON PRESSURE AND NOZZLE SYSTEMS, AS YOU WILL READ IN THIS CHAPTER. IN ADDITION TO ITS PROS AND CONS, WE WILL ALSO HIGHLIGHT THE TYPICAL APPLICATIONS OF WATER MIST SYSTEMS. AS YOU WILL COME TO APPRECIATE, WATER MIST SYSTEMS CAN BE VERY EFFECTIVE. HOWEVER, THERE ARE ALSO SITUATIONS IN WHICH THEY WILL NOT BE FIT FOR PURPOSE.

INTRODUCTION

The discharge of a water mist system is very different from that of a sprinkler or deluge system. A person can walk through the cloud discharged by a water mist system and experience just moist air and a somewhat obstructed visibility of just a few metres. And all without becoming drenched. This is in stark contrast with the discharge of a sprinkler or deluge system, which feels more like very heavy rain.

The discharge of a single water mist nozzle comprises a small cloud of micro drops of water. The shape of the cloud depends on the design of the nozzle in question. It can vary between the shape of a pear in front of the nozzle to the shape of a kidney around the nozzle. All active nozzles of a water mist system work in harmony to create a misty area.

There are several types of water mist systems. These can be roughly broken down into:

- low-pressure, open-nozzle systems;
- low-pressure, closed-nozzle systems;
- high-pressure, open-nozzle systems;
- high-pressure, closed-nozzle systems.

The size of the droplets depends mainly on the water pressure as it enters the nozzle and, to a lesser extent, on the design of the nozzle. Higher pressure creates smaller droplets, while lower pressure creates larger ones.

The throw range of a water mist nozzle depends on the water pressure and the size of the droplets. Larger droplets have a further throw, but less cooling effect (= worse fire-suppression performance).

On the other hand, smaller droplets have a shorter throw (smaller impulse because of the friction with the surrounding air), but also a better cooling effect (= better fire-suppression performance).

THE PROS AND CONS OF WATER MIST SYSTEMS

- *Pros*
  - They require less water than sprinkler systems to suppress a fire.
  - The room doesn’t need to be airtight, as is the case for extinguishing gases.
  - They can be used as object protection.
  - They cause limited “thermal shock” on the bearings in machines with parts rotating at high-speed, such as gas- and steam-turbines and generators.
- *Cons*
  - Unlike deluge and dry sprinklers, they are not suitable for use in windy environments, such as outside.
  - They are only suitable for a limited range of fire risks.

TYPICAL APPLICATIONS

Application	Limited room height (4 – 5 m)	High ceiling areas	Specific rooms, limited volumes
Hotel sleeping area	Yes		
Family dwelling / lodging	Yes		
Health care (nursery area)	Yes		
Large atria		No	
Office space	Yes	No	
Library or archive	No	No	
Low piled storage	No	No	
High piled storage	No	No	
Parking garage	Yes	No	
Data centers	Yes		
Machinery spaces			Yes
Turbine enclosure			Yes
Cable tunnel	Yes	No	

WHAT MAKES WATER MIST EFFECTIVE AND WHY THE SIZE OF THE DROPLETS MAKES A DIFFERENCE

WHAT IS THE PRINCIPLE ON WHICH WATER MIST EFFECTIVENESS IS BASED? IN THIS CHAPTER YOU WILL LEARN ABOUT THE ALL-IMPORTANT SIZE OF THE DROPLETS. ABOUT WHY MORE SURFACE AREA MEANS FASTER EVAPORATION IN A FIRE, RESULTING IN QUICKER EXTINGUISHING WITH THE SAME AMOUNT OF WATER.

The secret of what makes water mist an effective extinguishing agent lies in the size of the droplets.

The extinguishing effect of water is based on the fact that it absorbs a lot of heat when it evaporates from its liquid to its gaseous state (= becomes steam). Under normal ambient conditions (atmospheric pressure at sea level) this happens at approximately 100° Celsius. In a fire this heat absorption cools down the surface of the burning objects, stopping the evaporation of material from the object and thus stopping it burning. It is worth noting here that, general speaking, solids and liquids don't burn directly; it is the evaporated material that burns.

A secondary effect is that water in mist form takes up much more volume than water in its normal liquid state. This expansion replaces some of the air (oxygen) that would otherwise fuel a fire. The volume of steam at atmospheric pressure, for example, is typically 1,600 times more than the volume of the liquid water where it came from.

The water evaporation process happens at its surface (except when boiling water!). The larger the surface area of the water, the easier and faster evaporation will take place under equivalent circumstances. In the case of water droplets, this surface area will be increased by the spaces between the droplets themselves because more air will be surrounding the droplets on all sides.

For example
Assume a common droplet size of 0.05 g with a diameter of approximately 4 mm.

Imagine this droplet is then split into 1000 mini-droplets, each weighing 0.05 mg (milligram!). Note that the diameter of each mini-droplet will be 1/10 (0.4 mm) that of the original droplet, because the size of the original droplet will be reduced in three dimensions. The surface area of each mini-droplet is thus only 1/100 of the ordinary droplet, because the surface area is two-dimensional. Therefore, in summary, the properties of 1 mini-droplet are:

- the diameter is 1/10 that of the original droplet;
- the surface area is 1/100 that of the original droplet;
- the volume and weight are 1/1000 that of the original droplet.

Result
The combined surface area of the 1000 mini-droplets increases to: 1000 x 1/100 = 10 times the surface area of the original droplet.

It stands to reason, therefore, that more surface area means faster evaporation in a fire, resulting in faster extinguishment with the same quantity of water. In other words: if you use smaller droplets you can derive the same extinguishing power with less water.

However, the fact that 1000 mini-droplets have 10 times more surface area than the original droplet also has a disadvantage. When discharged at velocity into the air, a mini-droplet will experience much more friction from the surrounding air than the original droplet. Consequently, the mini-droplets will lose speed much faster than the original droplet. In case of an intense fire the mini-droplets are also less likely to penetrate the fire plume and reach the heart of the fire. The kinetic energy (physics: ½m.v2) and impulse (physics: m.v) of each droplet will be relatively small compared to their surface area. In reality, an intense fire will even drive the water mist upward with the fire plume.

Notes
The actual size of water mist droplets can be much smaller than 0.4 mm. The size can vary between 20 µm (0.02 mm) and 1000 µm (1 mm), depending on the system in question.

On the other hand, ESFR (Early Suppression Fast Response) and Large Drop systems produce much larger droplets than ordinary sprinkler systems. This enables them to penetrate through the fire plume, even from ceiling level at a height of 13.2 m down to floor level.

WHY DISCHARGE VELOCITY AND PRESSURE ARE IMPORTANT

IN ADDITION TO THE SIZE OF DROPLETS, TWO MORE FACTORS DEFINE THE LEVEL OF FIRE-EXTINGUISHING CAPACITY OF WATER MIST: THE DISCHARGE VELOCITY THROUGH THE NOZZLE AND THE WATER PRESSURE THAT IS APPLIED IN THIS PROCESS. IN A NUTSHELL: HIGHER PRESSURE IN THE PIPE SYSTEM CAUSES DROPLETS TO LEAVE THE NOZZLE AT A HIGHER VELOCITY, RESULTING IN SMALLER DROPLETS. IN ESSENCE THAT IS GOOD, BUT THERE IS A DOWNSIDE.

VELOCITY

Water under pressure in a pipe system contains potential energy. When this water discharges through a nozzle into open air, the potential energy converts into kinetic energy. In other words: when water under pressure is discharged through a nozzle, it leaves that nozzle at a much higher velocity than the velocity with which it flows through the pipe system. In the nozzle the potential energy (physics: Δp.m) converts into kinetic energy (physics: ½m.v2). Higher pressure in the pipe system causes higher velocity of the droplets that are discharged through the nozzle.

An ordinary droplet, free falling in open air without any start velocity, keeps its shape and size because of the surface tension and cohesion force of water. The surface tension of a moving droplet is in balance with the friction of air and water at the surface of the droplet. As the velocity increases, the friction with the surrounding air becomes higher than the cohesion and surface-tension forces will cause the droplet to break into smaller droplets until a new balance is reached that matches the higher velocity.

In summary

The higher pressure in the pipe system causes the droplets to leave the nozzle at a higher velocity, resulting in smaller droplets.

But smaller droplets also have a disadvantage. Because of their larger surface area (relative to their mass), they are subjected to more friction from the surrounding air. The result is that a mini-droplet, discharged from the nozzle at a high velocity, will rapidly lose its velocity until it is almost stationary in the air.

Their light weight, relative to the friction with the surrounding air, means that gravity has little effect on these mini-droplets. They fall very slowly and they can easily be blown away by the wind.

For example

A high-pressure system with a water pressure of 100 bar can have a throw of approx. 6 metres. A low-pressure system with a water pressure of 10 bar can have a throw of approx. 3 metres.

HIGH PRESSURE

The pump pressure of high-pressure water mist systems typically ranges between 60 and 200 bar. Due to frictional losses in the pipe system and valves and, depending on the manufacturer's design, the resulting pressure at the nozzles can vary between 40 and 160 bar.

- *Advantages of high-pressure water mist*
  - The size of the droplets is very small, which means less water is required to control a fire.
  - The velocity of the droplets at the point of discharge is high, enabling a relatively large throw range. Ceiling level can be higher than with low-pressure water mist and the spacing between nozzles can be larger.
- *Disadvantage of high-pressure water mist*
  Very small droplets are exposed to more friction from the surrounding air, causing them to lose velocity faster than droplets from a low-pressure system.

LOW PRESSURE

- *Advantage of low-pressure water mist*
  Sometimes an existing sprinkler pump can deliver enough pressure to feed a low-pressure water mist system.
- *Disadvantage of low-pressure water mist*
  The throw range of the nozzles is limited. Closed water mist nozzles installed at ceiling level can only be used to protect an area up to a certain ceiling height.

THE EFFECTS THAT NOZZLE DESIGN HAS ON THE EFFECTIVENESS OF THE MIST CLOUD

THE DESIGN OF A NOZZLE THROUGH WHICH WATER IS DISCHARGED HAS A HUGELY SIGNIFICANT INFLUENCE ON THE END RESULT. THE AIM OF GOOD NOZZLE DESIGN IS TO INCREASE THE VELOCITY OF SMALL DROPLETS AS MUCH AS POSSIBLE AND THUS ACHIEVE AN OPTIMUM THROW RANGE – IN SEVERAL DIRECTIONS, AND THUS FORMING A MIST CLOUD THAT IS FIT FOR PURPOSE. IN THIS CHAPTER WE EXPLAIN WHY, AND HOW, OPEN AND CLOSED NOZZLES AFFECT THE PROCESS AND THE END RESULT. WE ALSO HIGHLIGHT THE ADVANTAGES AND DISADVANTAGES OF OPEN AND CLOSED NOZZLES.

CLOUDS

Because water mist droplets are very small, they lose their velocity soon after leaving the nozzle. In fact, they fall to the floor so slowly that they tend to form a cloud in the air around or below the nozzle. Because of this, the intensity of water mist systems is expressed as density per protected volume: $dm^3/m^3/min$. This is in contrast to sprinkler systems, where the intensity is expressed in density per protected floor area: $dm^3/m^2/min$.

Water mist nozzles differ from sprinklers in several ways. They usually don't have a deflector, because when a droplet hits a deflector it loses much of its initial velocity. The aim of good nozzle design is to increase the velocity of small droplets as much as possible and thus achieve optimum throw range.

A water mist nozzle can have more than one orifice to "shoot" the droplets in several directions. It can have orifices all around, sideways, upwards, downwards, obliquely, straight down or even a combination of the above. Every nozzle model has its own typically shaped spray pattern. The shape of the resulting mist cloud can then be in the form of a sphere, a pear or a drop below the nozzle or a kidney shaped cloud around the nozzle.

The orifices in water mist nozzles are usually small, because it is easier to create smaller droplets with small orifices. Small orifices also mean a small K-value. Applying high pressure assures that the required quantity of water will still come out of the nozzle.

Notes

A water mist nozzle (or sprinkler) cannot convert all the potential energy in the water in the pipe system into kinetic energy. The efficiency of a nozzle varies between 50 and 90 per cent, depending on the nozzle design.

There are open and closed nozzles. Open nozzles are like open sprinklers or deluge sprayers. Closed nozzles are closed off by a small disc that is held in place by a temperature-sensitive element, such as a glass bulb. In this respect, they are very similar to ordinary sprinklers.

OPEN NOZZLES

Open nozzles are like open sprinklers or deluge sprayers. A water mist system that has open nozzles has a deluge valve at the base of the system. It requires a separate detection system or manual means of activating the discharge of the water mist. The detection system can be like the ones used for deluge or pre-action systems: electrical smoke, heat, rate-of-rise or flame detection, pneumatic detection, etc.

- *Advantages*
  - An object can be enveloped in a mist cloud created simultaneously by several nozzles from several different directions.
  - Nozzles can be placed everywhere in and around the protected space enclosing an object, irrespective of the presence or height of a ceiling.
- *Disadvantage*

  A separate detecting system is required to activate the system.

CLOSED NOZZLES

Closed nozzles usually have a temperature-sensitive glass bulb and disc that keeps the nozzle closed until the glass bulb is activated when the temperature reaches the chosen threshold. This is very much like an ordinary sprinkler.

- *Advantages*
  - No separate detection system is required.
  - One system can protect a large area. Only the nozzles above the fire will be activated.
  - By combining a closed nozzle system with a separate detection system it is possible, if preferred, to design a pre-action water mist system.
- *Disadvantage*

  The nozzles have to be located below a ceiling to allow the glass bulb to respond quickly enough to the rising temperature in the event of a fire.

THE IMPORTANCE OF USING CLEAN WATER AND STAINLESS-STEEL PIPING

NON-NEGOTIABLE REQUIREMENTS OF A WATER MIST SYSTEM ARE THAT IT MUST ITSELF BE ABSOLUTELY CLEAN AND FED WITH CLEAN WATER THAT CONTAINS NO PARTICLES OR SLUDGE WHATSOEVER. THIS IS WHY THE USE OF FILTERS AND STAINLESS-STEEL PIPES ARE ESSENTIAL PRE-REQUISITES FOR THE PROPER FUNCTIONING OF A WATER MIST SYSTEM.

Solid particles and sludge can easily block the small orifices in the nozzles. A water mist system comprises several filters to prevent that happening. And to avoid these filters becoming prematurely clogged, it is vital that the water used in a water mist system is very clean and free of particles that are larger than the diameter of the smallest orifice.

This typically means that the water source for a water mist system is drinking water, stored in a clean tank that is made from materials like corrosion-resistant metal, epoxy-coated concrete or plastic.

Generally speaking, only stainless-steel piping is clean enough for the long-term use of a water mist system. Fortunately, an advantage of high-pressure and low-flow systems is that the diameter of the piping can be much smaller than that for sprinkler systems. This reduces the cost of using stainless steel piping. For high-pressure water-mist systems in particular, the diameter of header piping usually doesn't exceed 50 mm and the diameter of branch piping can be as small as 15 mm.

HOW FILM- AND FOAM-FORMING AGENTS COULD MAKE WATER MIST SYSTEMS MORE EFFECTIVE

THE DEVELOPMENT OF WATER MIST SYSTEMS IS STILL ON-GOING. NEW FEATURES ARE BEING TESTED ALL THE TIME, LIKE THE ADDITION OF FILM- AND FOAM-FORMING AGENTS TO WATER MIST SYSTEMS, THAT MAY BE USEFUL FOR THE SUPPRESSION OF POOL FIRES OF COMBUSTIBLE LIQUIDS.

German manufacturer of foam fire-extinguishing products, Dr. Sthamer, is currently researching the addition of film- and foam-forming agents to water mist systems, particularly in the field of suppressing pool fires of combustible liquids. Foam-forming agents facilitate the creation of very small droplets by reducing the cohesion force of water. It also allows the droplets to assume random shapes with larger surface areas than the typical shape of a droplet. Film-forming agents enable droplets to assume flake-like shapes that can enclose air in their movement. A thin layer of foam on a liquid pool reduces the amount of radiated heat that the liquid can absorb. A foamy film on the surface of liquid fuel will also reduce its evaporation rate.

Currently, its most common applications are for the protection of ships' engine rooms and the roll-on roll-off areas of car ferries.

Note

The opposite is also true. ESFR systems are not suited to the addition of film- or foam-forming agents. Given that they would drastically reduce the cohesion of water droplets, agents like these would break down the large droplets discharged from the sprinklers into smaller mini-packages of water. These mini-packages might assume random shapes and have less impulse and kinetic energy because of the air friction. As a result, the water might not be able to penetrate the fire plume and might not even reach the floor. This would be at odds with the basic principle of operation of an ESFR or Large Drop system.

LITERATURE

NFPA 750 Standard on Water Mist Fire Protection Systems

FM 5560 Approval Standard for Water Mist Systems

NEN-EN 14972 Vaste brandblusinstallaties - Watermistinstallaties deel 1 t/m 16, 2017-2019

Mgr inż. Szymon Puzdrakiewiz (Riskonet): "Analysis of Requirements for the Design of Fixed Water Fog Extinguishing Equipment on the Basis of VdS and NFPA Guidelines" (Google translated!).

APPENDIX

Two early examples of low pressure.

EARLY EXAMPLE, WKC EINDHOVEN

In 1995 Siemens installed a combined heat and power plant in Eindhoven. At the time, Total Walther had recently developed its MicroDrop system, a low-pressure system that produced very small, almost mist-like droplets.
The classification was based on a VdS certificate for cable tunnels and on-going mutual tests for other risks and properties by VdS and Total Walther. Siemens was also involved and was convinced that, in contrast to sprinkler discharge, this wouldn't damage the bearings of the high speed rotating generators by thermo-shock and wouldn't impair the blades of the steam turbine. The densities were defined per volume of protected space. The required quantities of water were appreciable, totalling up to 2,600 dm^3/min for the simultaneous activation of three large adjacent sections.

	Density	total flow
Density indoor transformer	5 dm^3/m^3/min	1,262 dm^3/min
Generator	5 dm^3/m^3/min	973 dm^3/min
Steam turbine	5 dm^3/m^3/min	829 dm^3/min
Lubricant oil unit	4 dm^3/m^3/min	696 dm^3/min
Auxiliary oil set	4 dm^3/m^3/min	791 dm^3/min
Gas compressors	5 dm^3/m^3/min	756 dm^3/min
Cable tunnels	3 dm^3/m^3/min	not applied
Nozzle type	TWF MicroDrop FS7 and FS14	
Activation	Separate detection systems (smoke, temperature, flame etc.)	
Max. horiz. nozzle spacing	2.5 m max., in both directions	
Maximum area per nozzle	6.25 m^2	
K-value	7 and 14 dm^3/min/bar½	
Nozzle pressure	5 - 8 bar	
Area of operation	Deluge-type, not limited	

Today's MicroDrop systems are high-pressure systems.
See www.tyco.no/products/WaterMist/microdrop

EARLY EXAMPLE: LEVEL3 AMSTERDAM

In 1998 the then Level3 built a new data centre in Amsterdam. This centre was a facility where one of the transatlantic Internet backbones from the USA connected to the European distribution network. Level3 was very wary of having water in the data rooms and absolutely didn't want to use a sprinkler system. They agreed with the use of pre-action water mist. Because there was little choice at the time, they opted for low-pressure pre-action water mist with closed nozzles.

Classification	OH1
Nozzle type	Tyco Aquamist AM24
Activation temperature	68° C
Max. horiz. nozzle spacing	2.5 m in both directions
Maximum area per nozzle	6.25 m^2
K-value	9.2 dm^3/min/bar½
Minimum nozzle pressure	7 bar
Resulting minimum density	3.9 mm/min
Maximum area of operation	139 m^2

Additionally, a smoke-detection system provided the signal to activate the pre-action valve. The maximum water pressure in the system was 12.1 bar, delivered by an electrically driven fire pump. A second electrically driven fire pump was installed as a back-up. The water was stored in a coated concrete tank with a net capacity of 30.6 m^3, which was sufficient for 30 minutes.

To comply with the design criteria of the low-pressure water mist system, an engineering company lowered the ceilings to less than 3 m. Data cabinets and large cable trays were all kept below 2.3 m to maintain a minimum of 0.6 m free vertical space between the nozzles and these obstructions.

Today a broad range of Aquamist ULF AM open and closed nozzles are available from Tyco.
See https://www.tyco-fire.com/index.php?P=product&S=S22

IS IT TOO COMPLICATED AND COULD YOU USE SOME PROFESSIONAL HELP?

Do you need assistance in identifying your company's specific risks, or would you like advice regarding potential safety issues that you may have overlooked? Or do you, in your capacity as manager, director or entrepreneur, want to know more about your responsibility as a link in a sound and successful fire protection strategy? If it's a "yes" to any of these questions, feel free to contact Mark van Zeijl or Szymon Puzdrakiewicz, no strings attached. We will be more than happy to help you.

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