



- MASTER THE UNEXPECTED -

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 suppliers and representatives for providing input for this white paper.

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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 or with high thermal updraft.
- They are only suitable for a limited range of fire risks.

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: $1000 \times 1/100 = 10$ 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: $\frac{1}{2}m.v^2$) 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 sprinkler 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.

THE IMPORTANCE OF APPROVED SYSTEMS

WHY INDEPENDENT APPROVALS FROM AN REPUTABLE TESTING INSTITUTE ARE IMPORTANT

THE IMPORTANCE OF REPUTABLE EXPERIENCED TEST AGENCIES

The only way to ensure that a firefighting system will operated as expected is to perform full scale fire tests. The fire test must be repeated to ensure that the result is not depending on the odds of the day. Experience from test institutes has shown that results from small scale tests cannot always predict the fire growth in a full scale test.

ADHERING TO THE LIMITATIONS OF TEST RESULT

As building design becomes more challenging, the standard solutions are no longer fit. A designed solution, developed through Fire Safety Engineering, is the basis for acceptance. It is obvious that small deviations between the tested configuration and the actual application may not be a problem. This depends on the degree of deviation or modification of the system and conditions. A practical approach using system knowledge and common sense is required. Configurations that differ significantly from the tested configuration may fail in an actual fire situation. The authority or institute that approves such a special design should have in-depth knowledge of the parameters that have impact on success or failure of the selected watermist system.

Example

A watermist system has been tested and approved for a specific application with a room height of 4 meters. If the room is increased to 6 meters this means an increase of 50%. This may result in failure to control or extinguish the fire.

SYSTEM APPROVAL

Sprinkler systems have developed over the past 100+ years to such detail, that various makes and types of components can be applied in any one system. In watermist system there is a high interdependency of components, thus limiting flexibility in the design and installation of a system. Water mist heads and automatic valves can be very sensitive to the design and operating conditions.

Once a designer has selected a certain make and type of watermist system, it will be difficult or even impossible to change parameters that are related to the design of the system.

Example

A storage room of limited size can be protected with watermist nozzles, provided that the walls are fire rated. If the room is

enlarged, the watermist may not be able to achieve the firefighting goal in that room.

APPROVAL INSTITUTES

Below a list is given of the main approval institutes, with some specific information on these parties.

FM Approvals, the testing institute of Factory Mutual

FM originates as mutual insurance company. They have developed into a knowledge institute with their own design and testing standards. Water mist systems can be tested with their approval standard 5560.

International Marine Organisation IMO

As water mist was first developed for protection of ships, the IMO has in-depth knowledge and testing configurations for ship related systems.

Underwriters Laboratory (UL)

UL is a reputable test institute. Water mist nozzles are tested with UL test standard 2167. From this standard, reference is made to installation standard NFPA 750.

VdS

VdS is a German based standard and test institute. Tests are performed on the basis of the VdS 3188 standard.

There are also other research and testing institutions in the world.

The table on the next page shows the various watermist systems for which an approved test is available.

THE IMPORTANCE OF APPROVED SYSTEMS

Toeassing	Limited ceiling height ¹	High ceiling area	Specific rooms, limited volume
Hotel sleeping area	Yes		
Family dwelling / lodging			
health care (nursery area) ²	Yes		
Large atria		Limited use or special design only ³	
Office space	Yes		
Library reading area	Yes		
Library storage area or archive	Limited storage ⁴		
Low piled storage	No		
High piled storage	No		
Parking garage	Yes ⁵		
Data centers	Yes		
Machinery spaces			Yes
Turbine enclosure			Yes
Cable tunnel	Yes	Nee	

Notes

1. The actual height is depending on the specific system approval. This is depending on the make and type of system.
2. This application complies to the requirements for fire control and/or extinguishing. Parameters for 'life safety', like CO or other toxic gas concentration are not reviewed in the most tests.
3. Some system approval with closed head and ceiling height to 12 m are available, provided that fire load is limited. In general, special open or directional nozzles are applied. Fire detection and system testing make the design more complicated in comparison to closed head systems.
4. A limitation applies. For FM approvals storage is limited to 20 m², for VdS the room size is limited to 50 m² with fire rated walls.
5. Ceiling height is strictly limited.

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: $\Delta p \cdot m$) converts into kinetic energy (physics: $\frac{1}{2}m \cdot v^2$). 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, ventilation or the hot updraft of a fire.

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.

- 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. Very small droplets can be carried away by hot updraft.

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.

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 HUGE 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: $\text{dm}^3/\text{m}^3/\text{min}$. This is in contrast to sprinkler systems, where the intensity is expressed in density per protected floor area: $\text{dm}^3/\text{m}^2/\text{min}$.

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 SPECIAL PIPING MATERIALS

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 SPECIFIC PIPE MATERIALS 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. Especially high pressure systems are very sensitive, as the nozzle have very small openings. "Hard" water, containing high amounts of minerals, may have negative impact on proper operation. The minerals can build up in the valves or nozzles, thus hampering normal operation.

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. For low pressure water mist systems galvanized steel piping may also be applied. The material specification and production/installation requirements are very strict and can not be compared with standard design rules.

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 this special material piping. 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.

German manufacturer of foam fire-extinguishing products, Dr. Sthamer, is has performed research on 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

Currently, foam forming agents are being scrutinized in the PFAS discussion. The new generation Fluor free foams require aerated nozzles which will require yet new research. Water-based protection, hand-in-hand with quick removal of flammable liquids, is expected to be the economical solution.

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

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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