High Pressure Water Mist:

How the Technology Works

As a process, fire involves chemical reaction between combustible fuel species and oxygen from the air. The prerequisites of sustained burning are:

- Combustible fuel, which can be solid (Class A), liquid (Class B) or gas-phase
- Oxygen
- Heat for ignition
- Uninterrupted chemical chain reactions

Fire size is characterised by its heat release rate, measured in Watts (W). The order of magnitude in small smouldering fires (no flames) is 100 kW, a flaming fire that can be approached by a hand-held extinguisher is under 1 MW, and the fire is extensive when it is above 5 MW. As a rule of thumb: 1 m3 of visible flame corresponds to 1 MW fire.

To extinguish a fire, at least one of the four prerequisites must be removed. Very seldom the fuel itself can be removed, but the three other parameters can be affected by different fire fighting agents:

- Oxygen concentration can be lowered, e.g. by adding inert (non-reactive) gas into the fire.
- Heat can be removed, e.g. by wetting the combustible surfaces.
- Chain reactions can be interrupted by adding a chemical that reacts with unstable sub-products of combustion.

Fires can be fought by fixed fire fighting systems and/or manually. Fixed systems are typically required to at least control the fire, manual intervention is often necessary to complete the extinguishment and prevent re-ignition. The three different fire-fighting terms used are extinguishment, suppression, and control. The meaning of these words is different and one should be careful in using them, so that the system performance would not be unintentionally under- or overestimated and that the client would not be provided with false expectations. The terms can be defined as:

Fire extinguishment	Complete elimination of any flaming or smouldering fire (preventing re-ignition).
Fire suppression	A sharp reduction in the heat release rate and prevention of re-growth of the fire.
Fire control	Limitation of fire growth and prevention of structural damages.

Manual intervention is always required to complete the extinguishment in case of applying suppression and/or control systems.

Fixed fire fighting systems may be *total flooding systems* that protect an entire enclosure by filling it up with the agent, or *local application systems* that protect objects locally.

Water mist as a fire fighting agent

Water is the oldest, the most widely used and the most widely available fire fighting agent in the world. It is non-toxic, environmentally friendly, and in addition: it has superior fire fighting capabilities in a wide range of applications as compared to any other agents.

Water has two major fire fighting mechanisms, both related to the evaporation of water:

- *Cooling*
  When turning into vapour water absorbs more heat that any other fire fighting agent.
- *Inerting*
  In evaporation the water volume expands over 1700 times displacing oxygen.

Evaporation rate of water depends on the free surface area: water in a bucket evaporates much more slowly than the same volume spread as a thin layer on the floor. The free surface area can be increased by splitting the bulk volume into droplets: the smaller the droplets are, the faster is the evaporation and the more efficient is the cooling and inerting.

Water in the form of mist can have an additional fire fighting mechanism that no other agent has:

- *Blocking of radiant heat*
  A dense cloud of small water droplets effectively absorbs and scatters heat radiation.

The droplet size has a considerable effect on the surface area and the number of droplets as illustrated in the following table describing the properties of one litre of water:

Droplet size (mm)	Number of droplets	Surface area (m^2)
10	1.9×10^3	0.6
1	1.9×10^6	6
0.1	1.9×10^9	60
0.01	1.9×10^{12}	600
0.1 x	1000 x	10 x

Decreasing the droplet size by a factor of ten increases the surface area (and evaporation rate) by a factor of ten and the number of droplets by a factor of thousand! Hence, a lot less water is needed for the same cooling and inerting efficiency than in conventional water spraying systems. And additionally, the surroundings are protected against radiant heat.

Small droplets as such do not guarantee efficient fire fighting capabilities: they also need to reach the flames, i.e. they need to *penetrate* the outward flows induced by the fire.

The fire fighting capabilities of a water mist system are hence defined by

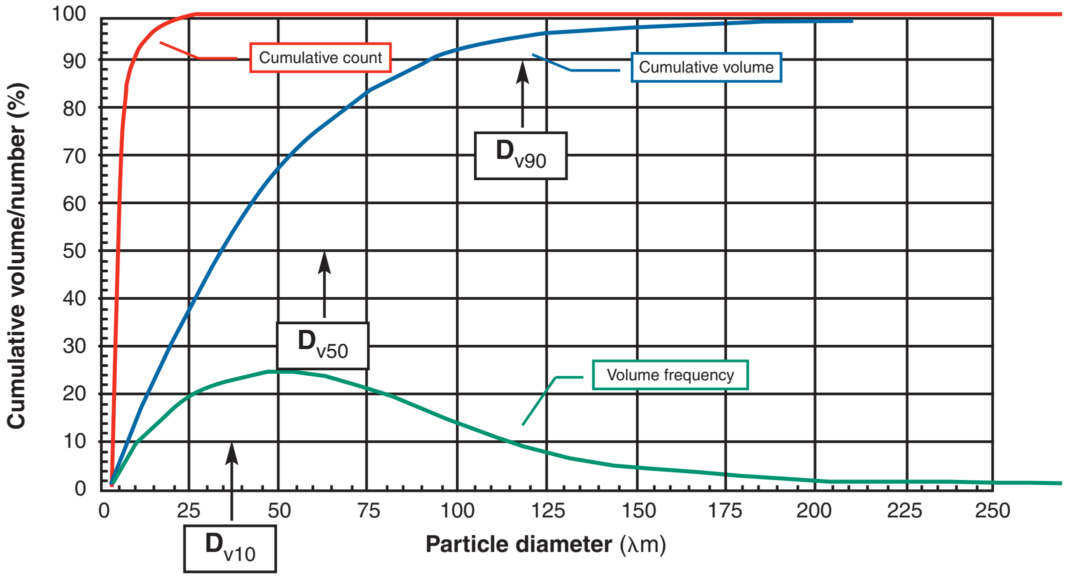
(i) drop size distribution,
(ii) number of droplets and
(iiii) penetration.

The combination of these properties is entirely system-specific.

Total flooding vs. local protection with water mist

Total flooding is possible only in enclosed spaces. In general, fires are always easier to extinguish in enclosed spaces than in open, and – for water mist specifically – in enclosed spaces larger fires are easier to extinguish than small fires. Less extinguishing agent per unit volume is also needed in enclosed spaces than in open for the following reasons:

- In enclosed spaces the extinguishing agent is contained inside the space around the fire. It



does not escape anywhere and, hence, no losses to the surroundings need to be covered.

- In enclosed spaces the fire itself consumes oxygen and helps in the extinguishing process. The larger the fire is, the more it consumes oxygen and the less additional extinguishing agent is needed.
- In enclosed spaces the fire heats up the enclosure. Large fires generate more heat, and the higher the ambient temperature is, the more water vapour is in the air (up to saturation). At around 60°C there is enough water vapour in the air to inert the atmosphere and extinguish the fire.

Local protection is applied in large or open spaces where a full simultaneous coverage of the complete area is not possible. In local protection applications enclosure effects cannot be accounted for. In large or open spaces smaller fires are easier to extinguish than large fires. More extinguishing agent per unit volume is also needed in open spaces than in enclosures for the following reasons:

- In open spaces the extinguishing agent is continuously lost into the surroundings and the losses need to be covered by increasing the discharge rate of the agent.
- In open spaces there is an unlimited supply of oxygen, the fire does not affect the oxygen concentration.
- In open spaces the fire does not affect the ambient temperature in the neighbourhood. At a close distance the temperatures are naturally high but the formed vapour is continuously lost into the surroundings. Vapour inerting is not possible in the open space.
- In open spaces there are strong, flame-induced flows outward from the seat of the fire. The larger the fire is the stronger are the flows and better penetration and higher concentration of water mist is needed to overcome the flows

System properties

All water mist systems are unique, and their capabilities cannot be generalised. There are even several different types of systems with characteristic properties and hence system-specific installation criteria.

High pressure water mist systems are powered by constant pressure electric or diesel pumps (pressures up to 140 bar) or by pressurised gas cylinders (pressures up to 200 bar). All the drop sizes usually fall in the range below 200 µm (see the Note below). The penetration length may be up to 7 – 8 m horizontally, and even longer distances may be reached vertically. The good penetration also contributes in spreading the mist throughout the space, even past obstacles. High pressure water mist behaves almost like a gas, which provides a superior property: it can replace not only conventional water spraying systems but also gaseous extinguishing systems.

High pressure water mist systems have a very high cooling, inerting and radiant heat blocking efficiency. Gas temperatures around the fire drop abruptly within seconds after discharge, and the fire is quickly surrounded by a dense cloud of small droplets. The radiant heat is blocked so effectively that at a few metres distance from the fire people do not feel any heat. The adjacent structures are well protected, even when the fire is still burning.

Depending on the application, the water mist systems are designed to extinguish (typically flammable liquids) or suppress and control (solid fuels) the fire.

High pressure water mist systems are a major development in water-based fire protection. The number of areas of application, test standards and performance criteria, type approvals, and market acceptance in form of customer references keep growing at an increasing rate.

Note: Drop size distribution

Drop sizes of a spray cannot be described with one single number. A spray always consists of a wide range of different drop sizes, and it can be described in many different ways. An example of a high pressure water mist spray is given below.

Three different curves of the same spray are shown: The most widely used curve is the *cumulative volume curve* which is characterised by three numbers: D_{v90} (90 µm), D_{v50} (33 µm) and D_{v10} (8 µm), i.e. the limiting droplet sizes in such a way that 90, 50 or 10% of the *volume* of water is in droplets smaller than that size. The *volume frequency curve* shows e.g. that the largest volume of water is in droplets of 50 µm of diameter. The *cumulative number curve*, on the other hand, shows that 90% of the total *number* of droplets are smaller than 10 µm! Already five different numbers are given to describe the same spray, and there are still several others. Comparing drop sizes needs careful evaluation. IFP