Evaluation of water mist systems for fire protection in large occupancies

Carsten Palle, VID ApS, www.vidaps.com

IWMA Conference 2009, London.

Foreword:

Large occupancies are known from many different locations.
Common for large occupations are that they have very large room volumes with very high ceilings, lots of natural ventilations, and very often large occupancies have smoke ventilation to protect steel structures from heat of fire combustion gases, collecting around ceiling structures.
The tall ceiling heights set special requirements to activation of the water mist systems which can not be from overhead heat sensor release. Also the thermics from fires and the very large areas do not from a fire protection point of view allow activation of single nozzles.

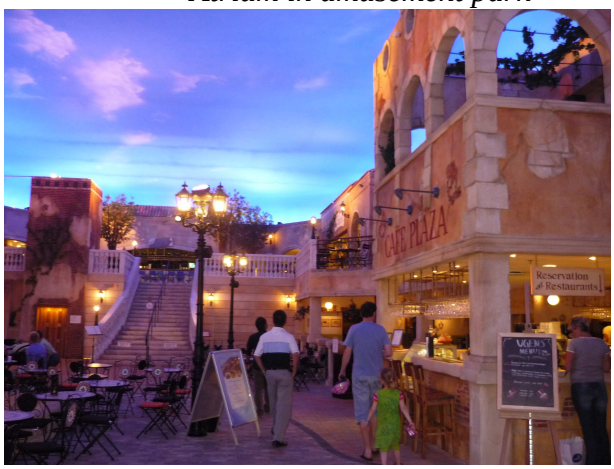
Examples on some large occupancies which are protected with VID fire Kill low pressure water mist systems for fire protection of large occupancies:

- Hangers, with water coverage from nozzles installed in floors.
- Atriums and other large occupancies from side wall installed nozzles
- Concert hall, with nozzles installed in furniture.

By applying water mist -with horizontal water mist sprays, VID Fire-Kill has to a large extend overcomed difficulties from the thermics of fires in large occupancies. Different systems have been tested in test setups, which in room heights, room volumes and fuel setup to a large degree matches the real occupancies. Danish Fire Lab (DFL) has developed a series of test procedures for different types of large occupancies which can be found on www.dafila.com

Concert Hall

Atrium in amusement park



Hangar

Atrium in shopping mall

The terms “Large occupancies” covers over many different locations and applications.
What is a large occupancy to one person might not be a large occupancy to another person. And what is a large occupancy for one water mist system might not be an occupancy causing fire fighting challenges to an other type of water mist systems.
Large occupancies is a relative thing. In the order to evaluate water mist systems for fire protection in large occupancies it is therefore necessary to try to understand what a fire is and how water mist systems fight fires, and the parameters being important for this process.

A simple model to under stand most fires is to see fires as being two chemical processes feeding each other. A pyrolysis process which requires energy (heat) and which generate flammable gasses, and an oxidation process which also requires a little energy itself, but which generates more heat than it selves require.

The pyrolysis process is well known from old city gasworks. Here the coal are heated in an oxygen free atmosphere. The coal then gasses a mixture of water vapour and flammable gasses, which were collected in large steel tanks flooding on water. When the tank was full the tank was high, and when the tank was empty the tank was low.
The same pyrolysis process takes place in a fire.

It all begins with a little heat, which heats the fuel surface. It makes the fuel surface gas a little.
The flammable gas comes in contact with the air which consists of 21% oxygen in a mixture with nitrogen. Some of the little heat heats the oxygen molecules and the gas molecules which break up.
The oxygen comes in contact with the free carbon atoms, and the hydrogen atoms, and forms water vapour H2O, carbon monoxide CO and carbon dioxide CO2.
When oxygen binds to hydrogen and carbon energy are released. The released energy are larger than what it takes to break up the gas molecules. The extra heat is heat. The heat heats the fuel, and the fuel surface becomes warmer and generates more flammable gases. Hydrogen and carbon from more gases binds to more oxygen, and more extra heat is being produced. A vicious circle has started. The vicious circle is called a fire.

To manage a fire the water mist systems have to manage the vicious circle.

To suppress a fire the water mist system must be able of slowing the vicious circle down. To control a fire the water mist systems must stop the vicious circle from accelerating, and finally to extinguish a fire the water mist systems must be able to stop the vicious circle.

Water mist systems have only a few main options when intervening with the vicious circle:

- **Blow fires out:** The thrust of the water mist spray (air with small droplets) can blow the pyrolysis gasses away from the fuel. Hereby the water mist spray removes the heat source away from the fuel. The radiant heating of the fuel surfaces disappears. The fuel surface cools and the pyrolysis gas production stops. With no flammable gasses to oxidate the vicious circle is broken. It does no longer exist. The water mist spray has extinguished the fire.
  However, if the fire was deep seated. If there ware gloves in the fuel. If the fuel was heated from an other source, or like for fat fryers, if the fuel is so hot, that the fuel it selves produces pyrolysis gasses, the fire will re-ignite, when the water mist spray stops blowing the pyrolysis gasses away from the fuel.

  It says it selves, that a Water mist systems abilities to blow fires our depends on a list of different factors, which are strongly limited to the particular occupation. Different occupation specific parameters become very important for successful fire protection results, a few parameters are:

  - The complexity of the fuel arrangement.
  - Obstructions to water mist spray
  - Distances from nozzles to fuels.
  - Location of nozzles to fires
  - Thermics from fire
  - Draft in the location
  - Fire size and Thermics
  - Pre-burn timers
  - Types of fuels
  - Etc.

  Blow out of fires makes fast fire extinguishing. It is also an unreliable method to transfer from one occupation to another occupation.

- **Cooling of the fuel surface**: If the fuel surfaces are cooled the pyrolysis process looses energy and the fuels produce less flammable pyrolysis gasses. The gas production may in many cases stop, and the fires are extinguished. In water mist sprays the water is distributed in many small droplets. Small droplets wet fuels well. It leaves only very few and small wetting vacancies, on the fuel surfaces, and the small water droplets finds its ways to many obstructed surfaces which would have been shielded from water jets and sprays of larger water droplets.

Compared with fire managements from blow out of fires, fire management from cooling of surfaces makes it much more safe to compare fire managing results from one occupancy to an other. Fire demonstrations becomes less spectacular and it takes longer time to achieve fire control and suppression, but the results are much more reproducible and reliable. Where cooling of the fuel is the most dominant parameter in fighting fires, more water, more water droplets in the water mist spray will improve the fire protection results.

However, the water droplets needs to get to the fuel surfaces. Therefore occupation parameters are important for water mist system where cooling of the fuel surfaces is a dominant fire management parameter: Here important parameters are:

- The complexity of the fuel arrangement.
- Obstructions to water mist spray
- Distances from nozzles to fuels.
- Location of nozzles to fires
- Thermics from fire.
- Draft in the location
- Fire size and thermics
- Pre-burn timers
- Types of fuels
- Types of fuels

- **Cooling the oxidation process:**

The reaction speed of a chemical process is very temperature depended. Most chemical processes cost energy. Is the energy removed from the oxidation process, less energy is available to the oxidation process of the pyrolysis gasses, and also the less extra energy in form of convection heat and radiant heat can the oxidation process deliver to the pyrolysis process and hereby to the generation of flammable gasses. The heat out put of the fire will reduce, and the fire is being suppressed.
For a water mist system to be able cool the oxidation process, the water mist system must be able to supply water droplets into the fire plume, and the water should evaporate in the flame plume. Evaporation of water costs a lot of energy. 40000J/mole. A side effect of evaporating water is steam, which is an invisible inert gas, which does not contribute to the oxidation of the pyrolysis gases.

However the difficulties in this way of fighting fires are that the spray of small water droplets shall be delivered inside the fire plume of the fire. This makes the water mist systems rather depending on parameters such as the already well known:

- Obstructions to water mist spray
- Distances from nozzles to fuels.
- Location of nozzles to fires
- Thermics from fire.
- Draft in the location
- Fire size and thermics

And again effects on fires from a water mist system will depend on the size of the enclosures and of cause of how the system is installed, and without taking the above parameters into consideration no comparisons between fire protection results should be made for water mist systems.

- **Smothering of fires**: by smothering of fires is mend that heat from fire evaporates water from the water mist stray of the water mist system. The evaporated water is steam. Steam is an invisible inert gas. The steam solutes the atmosphere surrounding the fire, or just the atmosphere of the entire occupancy. When the generated steam has reduced the oxygen level from 21% to about 15 – 13 % the oxidation process slows down and stops, and the fire is being smothered.
  In this case a water mist system behaves as a regular gas extinguishing system.

  This fire fighting effect is very dependable on a number of parameters and factures:
  - It depends on that the fire sizes and heat output is sufficient to evaporate sufficient with water.
  - It depends on the temperature in the occupancy. To low a temperature the seam condensates to small droplets known as fog, and fog does not inert the atmosphere surrounding the fire. This way it does also depend on the amount of water and water mist being distributed, and where, as the water mist spray cools the atmosphere, and hereby may cause steam to condensate.
  - It depends on the occupation size and especially the air volume and room height, and it depends on the insulation of the occupancy, and hereby the condensation of steam.
  - It very much depends on the natural ventilation, and forced ventilations in the occupancies. Fresh air supplied makes it much more difficult to obtain sufficient fire management results. Smoke ventilation is poison to this method of providing fire protection.
  - And of cause it depends on the systems abilities to supply the water mist spray to the fire and hot areas in the order to evaporate water. Hereby all the already known parameters become important for good fire management results.
  - Obstructions to water mist spray
  - Distances from nozzles to fuels.
  - Location of nozzles to fires
  - Thermics from fire.
  - Draft in the location
  - Fire size and thermics
  - Pre-burn time
  - Temperatures in the occupation when the water mist system is released.

  Fire protection from smothering of the fires is a time consuming mean of managing fires. It often requires high temperatures over long time to evaporate sufficient amounts of water, and the out come is very dependent on a long list of parameters which all must be right, to ensure a good fire protection result.
  The method is the less suitable for fire protection of large occupancies because of the nature of large occupancies. The method should only be used for smaller rooms with large fires, and where the occupancy are sealed and no people are inside the occupancy during a fire.

  Fire protection from smothering the fires are widely used for fire protection of maritime engine rooms. The international Maritime organisation has made a test standard MSC Circ. 1165 for tests of water mist systems for full protection of maritime engine rooms. Here one should remember that maritime engine rooms are sealed tin boxes and not large occupancies on land. No correspondences or similarities should be made.

IMO res. 913, local application fire tests:

The fire test scenarios concerns 1MW and 6 MW diesel spray fires 1m above the floor surfaces and with water mist nozzles installed above the test fires. The spray tests are conducted without flame stabilizer to the spray fire, and without fires in the ground below the diesel oil spray.
The fire is hanging in the oil spray. The fire exists for as long as the flame spread velocity is less or the same as the velocity of diesel oil flowing out of the nozzle. As soon as a water mist spray mixes with the diesel spray or in another way slows down the flame spread velocity of the diesel oil fire in the diesel oil spray, the oil spray pushes the fire away from the Oil spray and the fire is extinguished. The fire nor the extinguishing method is representative for fires or water mist extinguishing methods in large occupancies.

IMO Res 913, local Application fire test is therefore not suitable to describe fire performances of water mist systems to be installed in large occupancies.

.

Keeping all this in mind, water mist systems for large occupations should always be analysed for what is the systems dominant means of fire management to results from actual test fires, and particular comparisons between the test occupation and actual occupations should be made before a water mist system are chosen to be installed in large occupations.