Riksantikvaren - The Norwegian Directorate for Cultural Heritage (RNDCH)

A White Paper on

Water Mist for Protection of Heritage

Submitted to COST C17 - Built Heritage: Fire Loss to Historic Buildings

by

COWI

on behalf of

RIKSANTIKVAREN

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in support of

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A report by Interconsult on behalf of the Directorate for Cultural Heritage, Norway.

Submitted to:

COST Action C17 - Built Heritage: Fire Loss to Historic Buildings

Interconsult
Member of the COWI Group

Project: **Directorate of Cultural Heritage, Norway**
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WATER MIST FOR PROTECTION OF HERITAGE

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Executive Summary

Water mist for fire protection is a relatively new technologly with specific advantages to the built heritage. Many fixed installations are commissioned throughout Europe and many research activities are ongoing or being considered. The standard making processes does not currently address heritage applications, but performance-based codes are favorable for introducing new water mist. The COST Action C17 WG here reports on the experience this far and presents basic knowledge about water mist for the heritage community. Challenges, implications and perspectives of the technology are outlined in order to ensure the best protection of the European heritage possible. A guide on how to accept or approve of mist systems in heritage is given.

Water mist application is the most subtle way of water extinguishing. It provides safe and practical environment for rescue work, it protects visitors and staff, it incur minimal secondary damage in valid or unintentional activations and substantially remove harmful particles from smoke.

Apart from the above and general extinguishing capabilities of water, mist applications add several advantages over standard sprinkler, which often justifies a moderate extra cost. Mist systems discharge less water and use small-diameter pipes. Water supply may not run empty, as does limited gas supplies or other extinguishing media. Water mist may be turned off and on again. Water mist can be used where water was not previously considered practical. Water mist is used in hand held extinguishers, fire hose nozzles, small stand-alone units, object protection systems, room filling systems, hand held impact guns and large water mist impact monitors. Applications include museum vaults, heritage buildings, hotels, churches and art galleries.

Water mist protects from fire by the mechanisms of primarily cooling, inerting and radiant heat blocking. But also vapor to air ratio, the enclosure effect and the kinetics and duration of sprays play important roles. Water mist systems consist of a water supply, valve, pipes and nozzles – and indeed, some are so similar to sprinkler systems nozzles are interchangeable. The droplets are smaller though, which makes the difference. Mist sprays are characterized by flux density, momentum, optional additives and spray density. Application methods are termed object, room filling or zoned.

Many features of water mist suits heritage: Some nozzles are deemed ‘sprinkler-equivalent’ by standard tests ensuring they are at least as effective as sprinkler and rated or listed for light or ordinary hazard areas where they can be safely used. An extremely water-efficient way of using water mist is fire-spread ‘braking’ by flashover suppression. Fine, soft, natural mist droplets and low-density offer optimum cooling performance. By preventing flashover the practical maximum size of fire that may persist in an heritage environment is then kept within the capability of the fire brigade. Subtly applied mist causes minimum of damage to artefacts and decorations. For even less water consumption dedicated smoke scrubbing systems are being evaluated for heritage and museum vaults. Although, the best way to avoid smoke damages from established fire is a fast knock-down to stop smoke production. Fast knock-down is accomplished by both high-pressure fine mist and low pressure coarse mist systems technologies, underlining the diversity of mist system designs.

Current development activities include water mains presssure driven systems, water mist in freezing temperatures, flashover suppression systems, stand alone systems, mist systems for listed multistorey townhouses, pipe-integrated and other ‘fitting’less nozzles. New technologies thay may compete or combine with fixed water mist systems are hypoxic air systems, manually operated self-penetrating nozzles and ‘unwet water’.

Water mist require attention to details. Proper design, installation, maintenance, and testing are important. Once the reliability issue is addressed and systems successfully commissioned, however, water mist may even offer improved operational reliability as well as performance reliability to conventional sprinklers.

Preface

Combustibles in a natural environment are controlled by water. Vegetation thrives in water and is consumed by fires when dry. Water in terms of wet vegetation, drizzle and rain suppress and limit extent of forest fires.

Water mist is a natural and environmentally sound method of fighting fires.

Humans tend to deduct that if small is good a lot is better. But just like a waterfall does nothing to halt forest fires, a thick stream of water is not an effective way of applying water to fight a room fire.

Man-made water mist for fire suppression is still a relatively new technology. Gaps in the current knowledgebase of water mist limit applications for heritage protection.

The potential of water mist for fire suppression in the built heritage is insignificant secondary damage in fire or non-fire failures, early extinguishing, low cost and unobtrusive installations.

Image by WME

1 BASICS OF WATER MIST

Water mist application is the most subtle way of water extinguishing. It provides safe and practical environment for rescue work, it protects visitors and staff, it incur minimal secondary damage in valid or unintentional activations and substantially remove harmful particles from smoke.

Apart from the above and general extinguishing capabilities of water, mist applications add several improved performances and advantages over standard systems. They discharge less water, use smaller-diameter piping, and have lower overall weight. Water mist can be used in applications where water was not previously considered practical.

Water mist supplies may not run empty, as does limited gas supplies and other extinguishing media. Water mist may be turned off and on again.

Water mist is used in hand held extinguishers, fire hose nozzles, small stand-alone units, object protection systems, room filling systems, hand held impact guns and large water mist impact monitors.

Water mist fire suppression systems are used in a wide variety of applications which include hotels, museum vaults, heritage buildings, churches and art galleries.

Proper design, installation, maintenance, and testing are required to ensure the effectiveness of water mist fire suppression systems.

1.1 Water Mist for Fire Protection

1.1.1 EXTINGUISHING MECHANISMS

Cooling (Heat Extraction)

As drops size decreases the overall surface area of drops to interact with the hot smoke layer in a room fire increases. The finer mist does the better cooling. Vaporizing water extract an enormous amount of heat.

Inerting (Oxygen Displacement)

Water mist is likely to act as gaseous extinguishing agent if the average compartment temperature is between 60 and 70°C. In a cooler compartment, the effectiveness of oxygen depletion is reduced. Flame and fuel cooling and wetting become the primary mechanisms of extinguishment. Oxygen displacement is described as "steam inerting" /31/ in water mist applications.

Radiant Heat Blocking

Water mist may effectively block heat radiation between flame and unburnt surfaces and between flame and burning surfaces as well. Blocking effect is linked to the number of droplets of less than 50 microns diameter – the more and smaller droplets the better.

Water mist creates a rather safe environment for fire fighting and rescue work.

Secondary extinguishing mechanisms:

For some applications water mist performance may be strongly effected by these secondary mechanisms:

Vapor/air Ratio of spray

Air and water vapour entrained in a water spray may dilute the vapour/air mixture to below the lean flammability limit. The actual effect of dilution is not clearly understood so cannot be quantified.

Kinetic properties of mist

It is a fact that water mist sprays sometimes extend the time to extinguishment and/or trigger increased flame intensity or 'flare-ups'. There are various theories. One suggest that the turbulence created by the spray cause more air to the combustion zone. Water mist for explosion suppression are unpredictable: Mist may either invigorate or quell the explosion.

Enclosure

Enclosure effects are, contrary to kinetic effects of spray, potentially extremely effective. Water mist easily extinguish large fires relative to room volume and just barely effect small fires. Shielded fires are more or less enclosed, and in some cases the enclosure effect extinguish them. The enclosure effect is linked to heat from the fire vaporizing water and the vapor being contained and filling the enclosure if not well ventilated.

Duration of spray

The water mist spray may operate continuous or in on-off cycles. The spray may be operating for a fixed period as in preengineered systems or for a minimum period such as 30 min by the NFPA 750 Standard /9/. Obviously the effects on control, suppression or extinguishing is largely dependent on spray duration and must be adequately considered in all applications. Too short duration may cause reignition.

Resource on water mist extinguishing mechanisms: See MawHinney /31/ for comprehensive descriptions.

1.1.2 SPRAY CHARACTERISTICS

Drop size distribution

For a comparison of various defined water *droplets* //:

Technical definition of 'mist':	*0.01-10*	*micron*
Technical definition of 'spray':	*10-4000*	*micron*
Smog:	*0.01-2*	*micron*
Clouds/fog:	*2-70*	*micron*
Mist:	*70-200*	*micron*
Mist for Fire Extinguishing, Suppression orSmoke Scrubbing	***50-200****	***micron***
Drizzle:	*200-500*	*micron*
Rain	*500-5000*	*micron*
Sprinkler for Fire Extinguishing and Suppression	*500-5000*	*micron*

** Above values are mean diameters. In fire protection mist droplets are defined as $D_v0.9$ or $D_v0.99$ <1000 micron. The latter means sprays for which 99 percent of the volume of the spray is contained in droplets less than 1000 microns in diameter.*

The above indicate relative drop sizes. However, mist is characterized by a rather wide drop size distribution, i.e. the number or volume of droplets for each given droplet diameter within a spray. See reference /31/.



mages:
Marioff (Hi-fog), GJ (Cobra), WME (FogTube)

Flux density

Flux density is measured by l/min m^3 or l/min m^2. Neither is good design specifics as spray performance relate more to momentum, cone configuration and subsequent influence by obstructions in spray paths. Most water mist sprays become very uneven or unpredictable, due to interaction with each other and cone shapes.

Momentum (kinetics)

Momentum of water mist is a very important characteristic. It is often decisive of performance in terms of time to extinguish, effective use of water and system reliability. Three factors constitute mist momentum: Velocity, direction and mass. Direction defined relative to fire plume. It has been proven that directionality may be more important than both drop size distribution and mass flow rate of nozzles. Drops size distribution of $D_v0.9$ 200 microns may apparently be equally as effective as 100 microns and vice versa.

Additives

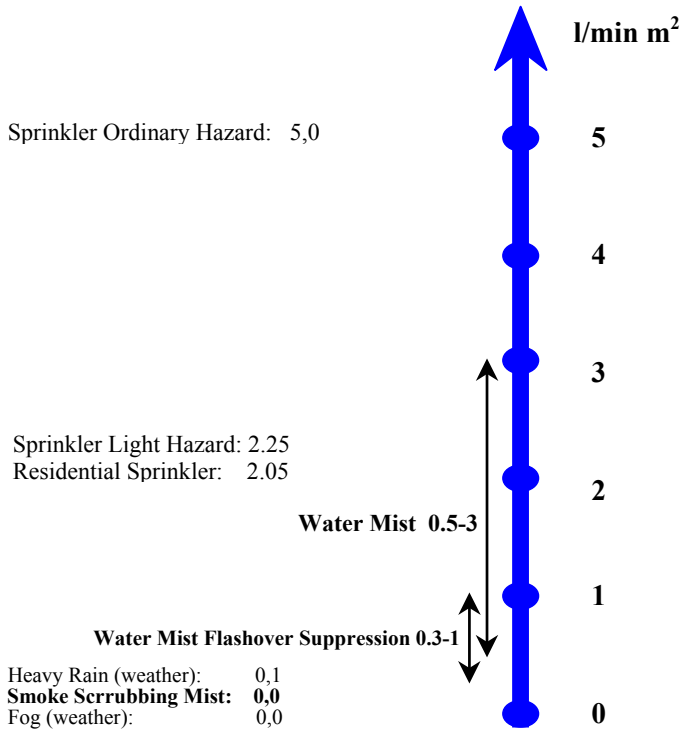
For heritage applications additives are generally not wanted and a potential hazard to artefacts, except anti-freeze protection in attics and in other rough areas of historic structures. But for the record, sea water mist extinguishes hydrocarbon fire up to 50 % faster than pure water, and substantial increase in performance is gained by just 0.3 % of AFFF additive (no longer readily available). Antifreeze additives may have adverse effects and currently most water mist systems employ the same type of antifreeze (Temper S) as optimum. The Temper-S additive /27/ is found not to add energy to fire and fits water mist applications especially well.

Toxicity

Water mist without additives, and even sea water, does not pose a health risk, according to reports by HARC and their conclusions adopted by EPA and US Federal regulation. The study was made on concerns about the small droplets entering deep into lungs.

Spray Density *(figure at right)*

See appendix A for a comprehensive comparison of water *densities*. Sample values illustrated in figure at right.



Resource on spray characteristics: See MawHinney /31/ for comprehensive descriptions.

1.1.3 NOZZLE CHARACTERISTICS

Nozzles are sometimes categorized by type of spray:

- Impingement
- Impinging Jets
- Pressure Jet
- Rotating
- Twin-Fluid
- Superheated Water

and sometimes by working pressure or arrangement, as by American practice:

- Low Pressure (<12 bar)
- Intermediate Pressure (12-34 bar)
- High Pressure (>34 bar)
- Deluge (open nozzles)
- Automatic (closed nozzles)
- Hybrid nozzles

Pressure jets are probably most common. Impinging jets are less common, based on two small jets of water colliding in air, but the new patented pipe-integrated nozzle FogTube, tested at the COST Action C17 seminar in Trondheim April 2004, belongs to this category /11, 12/.

1.1.4 APPLICATION MODES OF WATER MIST

Object Application (Local Application)

The water mist system is designed to discharge water on dedicated objects only, within a room.

Room Filling (Total Compartment Application)

The water mist system have nozzles uniformly spread throughout a room, protecting every objects and areas. Most systems are for fire extinguishing or suppression. Room filling is required for *flashover suppression*.

Zoned Application

As room filling systems, but zoned so that one valve serve a specific part of the protected room. The valve is operated from detection systems. Zoned application must be designed carefully and often becomes complex. Nozzles may be closed (automatic) or open (zoned deluge systems).

1.1.5 RELIABILITY

Water mist systems are generally, or at least they were in their early years of development, quite sensitive to design and engineering.

Conventional sprinklers are robust and conservative: Ample water is always applied and all along the line of design, testing, approvals and installation requirements there are substantial margins that makes conventional sprinkler systems less prone to failure, if not failure proof.

Water mist require somewhat more attention to details. Early experience have shown that lack of education and training of installers reduced reliability of water mist systems. The neccessity of pressure pumps for medium or high pressure systems add complexity which inherently reduce reliability. Preaction or deluge mist systems involve seperate detection systems which are prone to fail or to cause unintentional activations.

Once the reliability issue is addressed and systems successfully commissioned, however, water mist may even offer improved operational reliability as well as performance reliability to conventional sprinklers.

1.1.6 SUITABILITY OF WATER MIST FOR THE BUILT HERITAGE

Standard Water Mist Systems

Many water mist systems are deemed 'sprinkler-equivalent' by standard tests ensuring they are at least as effective as ordinary sprinklers. VdS (Germany) and FM (US) have rated or listed systems for light and ordinary hazards LH, OH1 and OH2.

The benefits with these are reliable performance and 'soft' sprays. But several sprinkler-equivalent water mist systems discharge as much water per square meter as do sprinklers or residential sprinklers, and some nozzles, fittings and even pipes may not neccessarily be smaller or less unobtrusive than sprinklers either.

The best of these systems, however, offer the smallest of pipe and nozzle dimensions and only 10-20 % of sprinkler water density. These are typically expensive too, and comes in high quality materials and parts for extended lifetime and high reliability.

Water Mist as a 'Fire Brake': Flashover Suppression

Fine, soft, natural and low-density water mist offer the the best cooling performance of water applications. This inherent benefit of water mist is used in flashover suppression systems. By preventing flashover the spread of fire is seriously slowed down, and the practical maximum size of fires that may persist in heritage environments is then kept well within the capabilities of any fire brigade.

Applying water mist this way require just 50 % or even less than 10 % of the density discharged by standard water mist systems. Pipe dimensions are similarly reduced, number of visible nozzles are decreased as are water supply and cost.

There are currently no test standard for flashover suppression, and the term may not exactly mean the same to all. Application tests have been successful /2, 28/, notably for the stave church applications, however. And the attic protection systems with water mist such as used in UNESCO World Heritage Listed Røros, Norway, are based on reports from ad hoc standard tests were reduced nozzle flows would suppress flashover but not fully extinguish as required.

Designing for flashover suppression with water mist is a much easier challenge than designing for extinguishing. One must be cautious where there are possibilities of open windows, open doors or early burn-through.

Flashover suppression water mist systems also - if kept on - wets surfaces, which prevent reignitions or slow down the speed of fire spread even after the systems are finally turned off or get emptied /12, 28/.

Fire engine high pressure pump connection (middle of dark wall) to flashover suppression system (Marioff, Hi-fog) in historic mining town Røros. Pic: G Jensen.

Church Naves, Large Halls, Large Room Volumes

Contrary to popular belief, fires within the large rooms of heritage buildings are seldom threatening. Fires seldom start there and typically they will not spread easily. Flashover in church naves is simply impossible. Local application water mist systems may be useful, and for the extreme event flashover systems in upper half of the rooms. Water mist at floor level only, protecting most combustibles, is another strategy - where room flashover is impossible and the middle and upper room surfaces are decorated and sensitive to water.

Concealed Spaces, Attics

Water mist is found beneficial for concealed spaces and attics in order to prevent the weight of water from sprinkler to break down decorated ceilings etc. Again, flashover suppression mode may be sufficent.

In one case, a water mist system in the attic of a church, with water soluble ceiling decorations beneath, was designed with limited water supply consistent with the mass of water that the attic insulation would absorb.

Prewetting of Combustibles

Porous combustibles are quickly wetted by water, by sprinkler as weel as mist sprays, and literally becomes non-combustible for a considerable time. This was demonstrated in the living room fire at the COST Action C17 seminar in Trondheim, April 2004. After discharging 1.21 l/min mm^2 for 60 s, i.e. 28 litres to extinguish the first fire - the humid room was almost impossible to ignite for an hour afterwards, despite bringing in dry combustibles and flammable liquid /12/.

This is to state and conclude that water mist may be used in application rates down to 0.3 l/min mm^2 only, to prevent flashover and to prevent reigniton for considerable time after shut off or emptied water supply, if proved in tests.

Just barely wet – but room fire was hard to reestablish. Pic: G Jensen.

Avoiding Damage to Decorations and Artefacts

Smaller droplets, less momentum and less flux density is generally accepted as ways mist reduces damage, compared to ordinary sprinkler. This seems obvious, but is not, to our knowledge, quantified by research.

The full scale tests made to prove performance of water mist systems in stave churches showed a remarkable effect of the mist to not cling to sample decorations on the walls. The floor became wet after a while, of course, but walls remained perfectly dry. The phenomena was not explained, however, and is still not /2,3/.

There are four reported cases of unintentional water mist discharges in heritage buildings: See 3.13. and appendix B. Only one caused any damage – due to extraordinary long time to shut off.

Smoke Scrubbing

Increasing number of/smaller water droplets and/or velocity, increases smoke scrubbing efficiency of mist. Water soluble gases and particles are removed and sediments with droplets to surfaces. The percentage of particles removed are not well documented, and stated figures varies from estimated 50 to 99 %. The Marioff Hi-fog system for smoke scrubbing in computer rooms is a special, high performance application. Such performance is not obtained by standard total flooding mist systems, although smoke scrubbing by any mist system are considered much more efficient than sprinkler.

Two potentially much more efficient ways to remove harmful gases and particles in heritage fires are (1) fast knock-down by the water mist systems to seize smoke production and (2) smoke venting. The latter may not be fast enough, and may require structural changes to accomodate inlets and outlets and extensive maintenance to provide sufficent performance and reliability.

To sum up, the best way to avoid smoke damages from established fires is fast knock-down to stop smoke production. The superior smoke scrubbing effect of water mist compared to sprinklers is a bonus that reduces damage from the smoke released prior to extinguishing and may slightly improve visibility and toxic conditions for rescue operations. In some cases, thermal damage from hot smoke is a greater threat to artefacts and decorations than particles and gases – and water mist is the most subtle and efficient way to cool the smoke and to lower or seize the rate of heat release /5, 15/.

Haukipudas Church, Pic: Martti Jokinen

Life Safety of Visitors and Staff

It follows from the above that mist improve conditions for evacuation and rescue compared to sprinklers, although fast response sprinklers generally is a quicker system to extinguish, hence stop the heat and smoke release. The soft spray, partly improved visibility and smoke scrubbing effect of mist systems are considered favourable to evacuation and rescue of people and artefacts – but again, research dodumentation is scarce.

Unobtrusive Installations

Most installations of water mist systems are less obtrusive than sprinkler, but some sprinkler systems are in some cases less obtrusive than mist systems so caution need to be taken.

One recent milestone example is the pipe-integrated nozzle demonstrated at the COST Action C17 meeting in Trondheim. FogTube offers copper tubing as a 'benign heritage' material and no nozzle or nozzle fittings protrude or are visibile on the tubes. Another recent milestone were demonstrated by Marioff in welding their Hi-fog nozzles into small diameter stainless pipes, creating a clean, slim look (not in production).

Below: FlexiFog nozzle to blend into white suspended ceilings
Left: FogTube in attic. Integrated nozzles invisible

Hi-fog nozzles, welded to pipe. To the right, painted white

Cost

All water mist systems hitherto are more expensive than standard, large production sprinkler systems. Some compete well by cost, while some nearly double costs. Water mist offer added benefits compared to sprinkler in heritage and in several other applications, which justify extra cost. Because most water mist systems are relatively new and frequently improved, bids on water mist tend to be rather unpredictable and vary a lot.

It is expected that cost will decrease towards the level of sprinklers as volume production increases. But also by systems now being developed by several manufactures to be driven by water mains pressure, thus not requiring pumps, vessels and related parts.

For an American view on water mist suitability for heritage: see Jack MawHinney /5/. His considerations and constructive warnings in this presentation are valid: they compare well to European experience.

1.2 Commercial Products

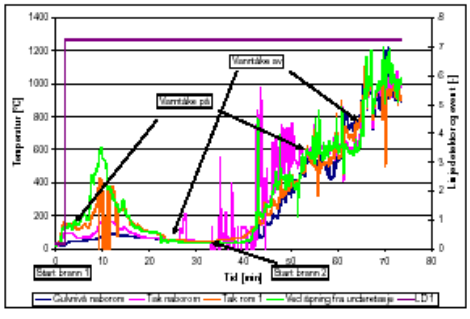
The table below /7/ lists water mist brands and manufacturers. Later, new products have emerged, such as FogTube by Water Mist Engineering, confirming that the market develops.

Produktnamn	Företag	Land	Hemsida
AquaMist	Grinnell Corporation	USA	www.grinnellfire.com
AQUASYS	AQUASYS	Österrike	-
Aquatec	LPG Fire Fighting Technology & Engineering	Spanien	www.lpg.es
Fire-Scope 2000	Securiplex	Kanada	www.securiplex.com
FlexiFOG	Heien-Larssen	Norge	www.heien-larssen.com
Fogmaker	Fogmaker International AB	Sverige	www.fogmaker.se
FOGTEC	FOGTEC Brandschutz GmbH & Co. KG	Tyskland	www.fogtec.com
Hi-Fog	Marioff Corporation Oy	Finland	www.hi-fog.com
LoFlow	GW Sprinkler A/S	Danmark	www.gwsprinkler.com
MicroDrop	Total Walther	Tyskland	www.totalwalther.com
Micromist	Fike Protection Systems	USA	www.fike.com
MisterySpray	Angus	England	www.angusfire.co.uk
Mistex	Tamar Designs Pty ltd	Australien	www.tamar.com
Minifog, etc	Minimax GmbH	Tyskland	www.minimax.com
SEM SAFE	SEMCO A/S	Danmark	www.semco.dk
SoftEx	Softonex Oy Ltd	Finland	www. softonex.com
Ultra Fog	Ultra Fog AB	Sverige	www.ultrafog.com

1.3 Non-commercial Applications

One can apply water mist non-commercially. Buckets of water for fire safety may be very effective, but are not subject of standardization like fire hoses and nozzles are.

At a recent ad hoc test during demolition burning of a house in Norway /28/, SINTEF and Interconsult installed a dry water mist flashover prevention system in the attic.



From ad oc test /28/: Readily available general water mist nozzles and pipes in attic (top left).

The graph (top right) demonstrate (indicate) flashover suppression effect as valve is shut off and on.

A non-protected room (arrow) adjacent to the protected attic remained intact to the end of the demolition fire.

It was made of simple hardware components that anyone may acquire, i.e. not a commercial water mist system. Consisting of 12 m coiled up copper pipe and 3 nozzles, costing less than EUR 100, it was easily installed in a couple of hours, and worked splendidly.

This is not to advocate use of none-approved water mist installations, but to put a perspective on the issue.

Further, in Norway, The Directorate for Cultural Heritage have purchased several installations, including water mist systems, which were accepted from specific full scale application tests and relevant documentation in lack of fully standard approved systems /1, 2/.

Realistic application tests in lieu of standard tests are an accepted alternative, and useful in heritage where specific conditions are quite apart from conditions of standards for industry, residential and commerce. It may add cost, but where the number of similar buildings are great developing and testing a tailored system could result in installations both more safe, less obtrusive and less expensive than standard ones.

Appendix B, slide 26 (‘Fully compliant - and useless’) and 27 (‘Fire safe, simple, reliable, inexpensive and unobtrusive - but not to any standard’) exemplifies this.

2 REGULATION AND STANDARDS

2.1 Regulation Bodies

An extensive listing of national regulation bodies in Europe is beyond the scope of this paper.

Many countries now has performance-based building codes. These make approval af water mist applications in heritage possible, despite the lack of national standards for water mist systems. Certified fire protection engineers may evaluate documentation of systems and if appropriate design water mist systems for specific objects to be protected.

2.1.1 EUROPEAN REGULATION / DIRECTIVES

A European standard for water mist is being prepared. According to a recent statement by Christian Lais of VdS Schadenverhütung, time to get it finished and adopted could take from 2 years up to 7 years.

2.2 Approval Standards and Installation Guidelines

2.2.1 APPROVAL STANDARDS

Various listings of approval standards are found in these documents:

- SINTEF Report, 2000 /6/
- SP Report, 2001 /7/
- NFPA Standard 750, 2003 /9/

The latter, and reference /31/, present fairly up-to-date overviews.

2.2.2 INSTALLATION GUIDELINES

- NFPA 750 (US / World-wide)
- CEN/TC 191 (WI 00191125:2004 draft, parts applied provisionally in Germany) (Europe)
- AS 4587 (Australia)
- IMO Res A800, IMO MSC Circular 668 (Maritime, Intern.)
- FM Various Standards and Drafts (Insurance, US)

3 EXPERIENCE AND CHALLENGES WITH WATER MIST IN HERITAGE

3.1. Applied Water Mist Installations

3.1.1 EUROPEAN (Nordic) EXPERIENCE

Water mist systems have been installed to protect remote heritage buildings in Norway and Finland. The 1000-year-old wood stave churches are located in remote areas with minimal or no water supply. For a few years in the 1990s, heightened concerns over arson led to demands for better protection. There was a need to provide an automatic detection and suppression system that could protect the structures with a minimum amount of water and without damaging the irreplaceable icons painted with water-soluble paint on the wood walls. A water mist system was developed using nozzles at ceiling height to achieve "flashover suppression" by delivering enough water to take the heat out of the hot gas layer but not to wet the walls. The open nozzles discharge as a deluge system to provide effective cooling. Supplementary nozzles with higher flow rates were mounted at floor level to extinguish the accelerant fires. Ad hoc testing was performed in Norway to validate the concept, and Norwegian authorities responsible for preservation of national treasures were pleased to have a means of protecting the structures. These systems utilize water stored in pressure-rated cylinders, connected to compressed gas cylinders to provide the driving force. The minimal electrical requirements are met by a fire alarm control panel with battery backup power. Fully non-electric monitoring and activation are provided for some installations by pneumatic systems /4/.

Norway

- 5 stave churches low pressure flashover prevention water mist systems (non-commercial, application approval)
- 7 stave churches high pressure flashover prevention/extinguishing water mist systems (commercial, standard and customer approvals)
- 2 medieval churches high pressure extinguishing water mist systems (commercial, approvals)
- 1 medieval church low pressure flashover prevention water mist systems (non-commercial, application approval)
- 1 medieval church medium pressure flashover prevention water mist systems (non-commercial, application approval)
- Polar Ship Fram (Amundsen and Nansen Pole Expeditions)
- 3-5 listed, or old wooden, hotels: Gyldenløve, Kong Carl, Baardshaug, Boeverdalen
- Domus Academica, University of Oslo
- City of Røros (UNESCO List of World Heritage): Water mist flashover prevention in all attics and all sheds in the mining town (one block of 20 houses completed, planned for complete listed area of town)

On the stave churches Arvidson and Hertzberg writes (Swedish, unfortunately not translated to English) /7/:

> *De norska stavkyrkorna är en av landets främsta kulturskatter och har tillsammans med vikingaskepp blivit en bland Norges främsta nationalsymboler. Kyrkorna är ofta belägna på landsbygden, i områden där både elnät och vattenledningsnät kan ha låg tillförlitlighet, om de överhuvudtaget finns. Under 1990-talet utsattes flera kyrkor för anlagd brand och runt femton kyrkor har brunnit helt eller delvis. I ett stort antal fall har det varit fråga om dåd från satanister.*
>
> *Sedan år 1982 har det norska riksantikvarieämbetet successivt förbättrat brandskyddet i de norska stavkyrkorna, genom riskanalyser, installation av brandlarm och genom att bilda lokala brandvärn. Sprinkler är också vanligt och före år 1990 var hälften av alla stavkyrkor försedda med någon typ av sprinklersystem. Men historiska byggnader ställer höga krav på att sekundärskadorna minimeras. I vissa fall är kyrkorna försedda med vägg- och takmålningar som är utförda med vattenlöslig färg. Estetiska hänsyn måste också tas vid installationen och så små ingrepp som möjligt göras. Därför blev riksantikvarieämbetet intresserade av att utvärdera andra alternativ, i första hand system med vattendimma.*
>
> *Vid försök i både småskala och i full skala med brand i stavkyrkor har det observerats att vattendimma inte väter vertikala ytor i någon större omfattning. Eftersom byggnadsmaterialen, dekor och väggmålningar tar skada av vatten är det en egenskap som är högt värderad vid släckning av brand. Vattnet bör vara fritt från tillsatsmedel såsom kemikalier, skumvätska och liknande för att undvika ytterligare påverkan. Försök har också visat att vattendimma .tvättar. ut rökpartiklar vilket bidrar till att rökskadorna blir mindre vid en brand.*
>
> *Ett flertal installationer av system är genomförda. Ett exempel är stavkyrkan i Haltdalen, Sør-Trøndelag som är en av de allra minsta och enklaste kyrkorna i Norge. Kyrkan är kvadratisk, 6 m x 6 m och har ett kor på 3 m x 3,5 m. Det system som installerats skyddar själva kyrkorummet, koret, det tomma utrymmet under golvet, ventilationsöpningar, etc. Eftersom kyrkan är så pass liten aktiveras alla munstycken samtidigt med en genomsnittlig vattentäthet på 0,6 L/min/m2. Systemet är anslutet till en trycktank med vatten som ger ett systemtryck på 10 bar. Systemet aktiveras av ett separat branddetektionssystem.*

Sweden, Finland, USA, Italy, UK, Russia:

Samples are shown in Appendices B and C.

3.1.2 US EXPERIENCE

According to MawHinney /4/: Similar stand-alone, high-pressure, cylinder-driven systems as in the stave churches have been installed by the US Parks Board in some remote heritage buildings in the United States. The National Gallery of Art has installed a preaction, high-pressure water mist system in two galleries in Washington, DC. The galleries chosen do not contain paintings or works of art— they are period rooms with decorative walls or ceilings. A fire in these galleries would threaten all other areas of the gallery with smoke and fire damage. The combustible walls and ceilings were not considered to be irreplaceable so that the woodwork could be recreated if damaged by water. The objective was to provide fire protection with minimal water use, so that other areas of the gallery would not be flooded or damaged. Water mist nozzles were selected to project spray horizontally along the underside of the ceiling in the concealed spaces above the ceiling and in wall cavities. The nozzles are thermally activated, although the fire pump unit does not start unless there is an alarm signal from at least two smoke detectors. A high-pressure pump unit was installed in the basement with capacity to handle numerous separate design areas if water mist is extended to other parts of the building.

The US National Fire Protection Association have adopted the Norwegian flashover suppression concept in their Fire Protection Handbook /4/. Extract:

> *Water mist systems for hotels and heritage buildings can be characterized as follows:*
>
> ***Safety Objective**. For hotels, the objective is life safety, although property protection is also important. For remote heritage churches, parks buildings, and galleries the objective is primarily property protection and heritage preservation.*
> ***Mechanisms.** Cooling of hot gases near the ceiling to minimize the occurrence of flashover and direct wetting of Class A combustibles on the floor.*
> ***System Features**. For hotels and galleries, high-pressure pump water supplies for a minimum 30-minute duration. For remote heritage buildings, compressed-gas–driven systems with 10 minutes' stored water. Use of open nozzles on deluge system for flashover suppression; thermally activated (automatic) nozzles on preaction system for gallery protection; automatic nozzles on wet-pipe systems for hotels. Preaction and deluge systems would also include the use of a supplemental fire or smoke detection system and interconnected alarm panel.*

Jack Mawhinney writes on the suitability of water mist for fire protection *in general* in /4/:

> *The choice of a fire performance objective requires an understanding of the levels of water mist performance, and an analysis of the protection needs of the hazard.*
>
> *For some hazards, fire control will be sufficient. With fire control, growth of the fire is limited or stopped upon activation of the water mist system, but manual intervention will be required to complete extinguishment. The heat and products of combustion released during the time prior to extinguishment must be considered, along with the effect they will have on exposed equipment and stock. Fire control will limit the ceiling gas temperature so that structural damage is prevented.*
>
> *If the potential for nonstructural damage is too great for the fire control option, fire suppression may be an acceptable performance objective. Fire suppression results in a sharp reduction in the heat released from the fire and prevention of its regrowth. Fire suppression also requires manual fire fighting to achieve extinguishment. Because the fire is less intense, the difficulty of manually extinguishing the fire is reduced, and is accomplished in less time, as opposed to a fire control performance objective. The results are less damage directly associated with the manual fire fighting effort and less overall damage, due to the reduced intensity of the fire.*
>
> *The highest level of water mist performance is obtained with a fire extinguishment performance objective. Fire extinguishment will completely and automatically suppress a fire until there are no burning combustibles. Fire extinguishment does not require manual fire fighting and results in the lowest potential for damage.*
>
> *Some factors to consider when analyzing fire loss potential and selecting the most beneficial water mist performance objective are presented below:*
>
> *(1) **Life safety**. What effect could this fire have on the occupants? The means of egress must be maintained to allow all occupants safe travel. Also consider the effect that loss of use of fire damaged equipment could have, such as with marine applications or public transportation exposures. A higher performance objective may be needed if life safety is an issue.*
>
> *(2) **Time required to achieve extinguishment**. This time frame can vary from seconds, if the system is designed for extinguishment, to many minutes, if the system depends on the response of public fire-fighting personnel.*
>
> *(3) **Susceptibility of equipment and contents to the effects of the fire**.Sensitive equipment, such as electronics, and susceptible products, such as pharmaceuticals, will benefit from reduced exposure to heat and products of combustion. Consideration should be given to the effect of radiant heat on nearby equipment. Fire suppression and fire extinguishment will result in a low potential for radiant heat damage, due to the reduced rate of heat release, compared to a fire control performance objective*

See /5/ for Jack MawHinneys presentation on water mist for *heritage* applications.

3.1.3 EXPERIENCE FROM UNINTENTIONAL SYSTEM ACTIVATIONS

Four cases of unintentional water mist discharges in heritage buildings are known to be reported (Norway):

1 *Bibsys Library Database*: Smoke scrubbing & extinguishing water mist system in computer room. Activated by welding. Computers were running, no damage. Similar systems considered for museum vaults.

2 *Kong Carl Historic hotel*: Medium pressure water mist. Broken bulb activated nozzle in guest room. "Never seen a room so perfectly wet; still, no water running or dripping. Dried quickly, no damage to interior", manager said. "Nice fitted and unobtrusive".

3 *Rollag Attic:* Mist system designed for flashover suppression. Limited volume of water designed to be absorbed by attic floor insulation, to avoid damage to decorated room below. Activated by lightning strike. Worked as designed - no decor damage.

4 *Tanum Church:* Faulty activation of deluge zone of high pressure water mist system. System was not yet commissioned by fire brigade. Therefore, 30 min to find shut off valve. Substantial water damage. High grade system, but detection algoritm questioned.

3.2 Full Scale Testing Experience

Most known European tests and studies on water mist related *to heritage* are done in Norway, listed below. There are some experience in Sweden and Finland too, but written reports are not available.

1. Statsbygg and Directorate of Cultural Heritage, Norway: Application Testing of Water Mist at Non-accredited Test Facility /30/. Ad hoc tests performed, recorded and reported on medium pressure water mist, on-off sprinkler and aerosol systems for heritage applications. Norwegian language. 1996.

2. Mock-up Pre-Tests of Flashover Prevention Water Mist in Stave Church. HSH/ResQ /2/. Norway 1992.

3. Full Scale Tests of Flashover Prevention Low Pressure Water Mist System Scale 1:1 Mock Up of Reinli Stave Church. SINTEF Accredited Lab. /2/. Norway 1993.

4. Commissioning Test of Flashover Prevention Low Pressure Water Mist System Reinli at Stave Church. Norway 1994. Propriatory evaluation report by NIKU/RA.

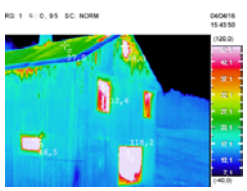
5. Commissioning Test of Flashover Prevention High Pressure Water Mist System at Torpo Stave Church. Norway 1996. Propriatory evaluation report by NIKU/RA.

6. Ad hoc test of flashover suppression system in attic at demolition fire. SINTEF and Interconsult. 2003. Preliminary report /28/.

7. Test of high pressure water mist in freezer, -30 down to –40 ºC. SINTEF and Interconsult. 2003. Preliminary report /28/.

8. Water mist hand held extinguishers: Extensive testing and evaluation by Interconsult on behalf of the Directorate for Cultural Heritage, NIKU and AB-utvikling proved that water mist extinguishers performed best overall from approximately 10 categories. Report later translated by US National Gallery of Art. Although limited to hand held extinguishers these tests involved 13 different 'artefact' materials, real smoke and actual application. One set of samples exposed to smoke+extinguishing media, while another set exposed to extinguishing media only /29/. Norway 1998.

9. Similar to 6 above, the Malvik 2004 Test - as witnessed by COST Action C17 delegates, of new patented water mist nozzle system FogTube in which nozzles are integrated part of pipe without either reducing inner nor increasing outer diameter of pipe /11/. Another realistic test of Fogtube is reported in /12/.



10. A unique piercing nozzle (Cobra) was evaluated at Røros by members of city fire brigade, Directorate for Cultural Heritage in Norway and Interconsult in June 2004 – for application in heritage.

11. Sweden: Tests done with high pressure mist and 12 samples of sensitive materials. Results not yet compared to the Norwegian test results referenced above. The report is not yet available (Marioff).

3.3 Technology: Current Development Activities

3.3.1 ACTIVITIES

New Performance Criteria of Water Mist

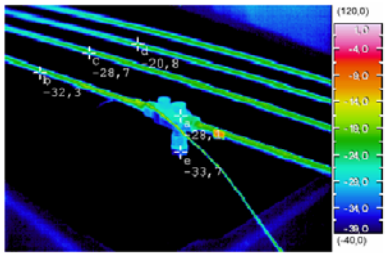
Surprisingly to many, the majority of water mist approvals relate to the performance of *sprinklers*, either by being tested as 'sprinkler-equivalent' or tested and evaluated on criteria set by the conventional sprinkler industry. Water mist offer unique properties, however, and in Sweden the VINNOVA project /16/ aims at new criteria based on the properties and merits of water mist itself, rather than sprinklers. They suggest that evaluation of sprinkler performance be made from 3 basic criteria: (1) *Hot layer cooling ability*, (2) *Ability to reduce rate of heat release from fire* and (3) *Ability to mix water droplets, vapour and fire effluents*. This may well be the key to even less expensive and better suited water mist systems for heritage applications.

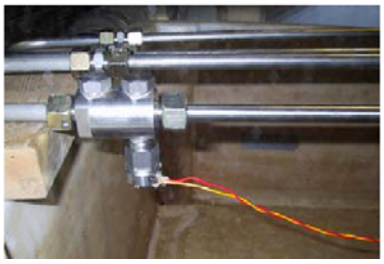
Flashover Suppression Systems (SINTEF, Interconsult and manufacturers)

Flashover suppression by water mist is especially interesting for heritage due to the low water consumption, small pipe dimensions, potentially reduced number of nozzles and potentially very gentle spray. Several manufacturers in Norway reports to be working on systems for this application, among them Lux brannteknologi, Water Mist Engineering and Prevent. The stave churches are the best known examples were flashover suppression by water mist are applied.

Water Mist in Freezing Temperatures (SINTEF, Marioff, Interconsult, City of Røros)

Ad hoc tests done in freezer room by SINTEF and Interconsult with Marioff. No formal report. Evaluations based on the tests were made for applications in the Røros mining town, and recommended precautions to avoid freezing are listed in /28/ (these to be published at Interflam 2004 – Hansen, Jensen, Wighus, Steiro).





Water Mains Pressure Mist Systems

A drawback of most water mist systems is the extra cost and reduced reliability associatied with pressure pumps and required accessories. Both clients and manufacturers strive for mains driven systems, such as sprinkler, but so far no systems offer acceptable performance (at least as per standards) without a pressure increasing arrangement.

It is known that at least two manufacturers (non-disclosed at this time) are are now developing nozzles with an aim to obtain standard test approvals with 3.5-5 bar valve pressure and densitiy within that of current high pressure systems. If such systems emerge, they may become competitive on cost, extinguishing properties of small fires and reliability.

For heritage, it is a matter of dimensions and aesthetics also, and one must expect larger pipes with these systems. Coarser droplets may not be as good as small to protect sensitive decorations etc.

Small Stand-alone Water Mist Systems (Lux brannteknologi)

Stand alone, small systems consisting of one pressurized cylinder and an automatic water mist nozzle - with or without intermediate piping - exists, Lux brannteknologi is refining systems for museums/heritage. Part of this were an ad hoc test at the demolition fire reported in appendices of /28/.

Dry Pipe Water Mist Systems Fire Engine Connection (SINTEF, Interconsult and manufacturers)

Dry pipes with automatic or open nozzles, and fire engine pump connection at street level, are installed in attics in wooden historic town centres of Fredrikstad and Røros - the former UL-listed atttic sprinklers, the latter high pressure water mist nozzles. The water mist installation have much smaller dimensions. Both installations are successful, though, as most attics and rooms in levels below are not very sensitive to damage.

Several variations of attic protection by water sprays are now being evaluated by Interconsult on behalf of the Directorate of Cultural Heritage in Norway in regards to Røros and similar sites. Objectives are safety performance, reliability, usability (fire engine personell), aestehtics and cost.

Water Mist for Listed Multistory Townhouses (Prevent, Oslo City)

Water mist systems are being considered for 4-6 level townhouses from the 1890-1930 period in Nordic countries. The critical way of fire spread in these buildings may be stopped by specially tailored water mist installations. The installations may potentially be quite inexpensive and they may allow for listed, original doors with and without glazing to be retained.

Adopting Water Mist Systems Approved for other Markets (Marine and Industry Applications)

Interconsult and SINTEF plans to clearify on which conditions water mist may be accepted in other markets than initally listed for, such as in heritage based on maritime listings, for various clients. Definitely, several maritime and industry *fire* protection performance requirements exceeds those of heritage buildings, but there are pitfalls (water mist is a design critical technology compared to, say, sprinklers) - and, of course, the system properties on aesthetics an uobtrusiveness are much more demanding in the heritage market.

FogTube for application in attics
(Water Mist Engineering)

The patented water mist system FogTube integrate the nozzles in the pipes, without any reduction of inner diameter and have no protrusions at the outer surface. It works by the 'impinging spray' principle and have good performance at water mains pressure only. The manufacturer are now exploring proprties by ad hoc tests for various applications, including heritage such as by test witnessed by Action C17 delegates in April 2004. The slender pipe installation, efficient water density an low pressure are promising for heritage.

Minifog for application in attics (Minimax GmbH / Lux brannteknologi)

Minifog is another low pressure water mist nozzle undergoing tests for application in attics: see 1, 5, 6 and 8.

'Fitting-less' nozzles welded to small diameter pipes (Marioff).

Marioff have demonstrated how high pressure nozzles can be welded to small bore pipes for slim appearence - see image. Not an option yet, but when documented such a method could be useful in heritage applications.

Water Mist Generator (PDX)

A recently announced patented "PDX Water Mist Generator" appears interesting to heritage: It apply supersonic steam for mist generation and produce long throw (up to 45 m) mist of very fine droplets (high percentage in sub 40 micron size range). It is claimed effctive at both A and B class fires (A being the most relevant to museums and historic buildings) and to scrub smoke and to decontaminate air. The high-momentum spray penetrates into flame sources. The nozzle orifice is coarse and accept brackish water. It is intended for spaces sensitive to water and the spray density is near theoretical minimum. One nozzle may cover a large volume.

3.3.2 HYBRID TECHNOLOGIES:

Below systems are recently introduced. Cobra and FirePass does not fit existing standards, but test reports are useful. (Note: The impulse water mist guns of IFEX offer valid performance, and should be considered for heritage. IFEX is a well established system, however, hence not listed as 'current development activity'.)

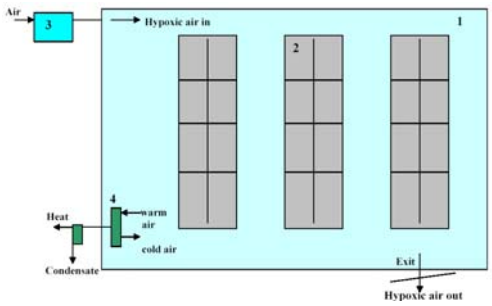
Cutting/piercing water mist nozzle (Cobra)

Self-penetrating high pressure water mist nozzle Cobra, introduced from 2000 and developed in Sweden are a novel technique of interest in heritage. If employed by local fire brigade, it may partly substitute dry water mist installations in attics.

Interconsult is currently evalutating the potential – see 5 above.

Hypoxic air + water mist (FirePass, Interconsult)

Hypoxic air has lowered oxygen concentration, still no less than comparable to air in aircrafts or settlements in 2000-3000 m heights above sea level. FirePass (US) recently patented a protection system for hypoxic air for 24 h (continuous) filling of protected spaces. Continuous inerting in this way makes it impossible for common fires to ignite, still occupiable for both long (working hours) and short term visits to the spaces.



FirePass and Interconsult are discussing the suitability for museum vaults and historic buildings. For full protection water mist in extinguising or flashover suppression mode could be added. A positive implication of this is the best of two worlds: Preventive protection, i.e. no fire ignitions in the first place plus effective 'fire braking' provided by the hypoxic air, and effective and subtle extinguishing by water mist if by any chance the inert atmosphere is jeopardized. Yet another benefit is provided: By lowered oxygen level, deterioration of artefacts is effectively retarded. The parties are looking for sponsorship or clients to explore this.

Total flooding by 'unwet water' (Novec)

The 3M invented 'Novec' extinguishing media is handled as a fluid in storage and pipes, but evaporates at 49.2 ºC and therefore behaves like a gas in fire. It has fairly good environmental and toxic properties and. The water mist industry will see this as a gas system, as it does not offer the cooling properties of water on solids and requires all common neccessary precautions to other gas systems to keep the room gastight to prevent reignitions and prevent the storage tank from emptying too early etc. In Appendix B is a comparison diagram of extinguishing systems for robustness, reliability and secondary damage. Novec may prove to be better than common extinguishing gas types, still not substantially and gas systems are at least as design-sensitive than water mist.

3.4 Challenges in need of Research, Development, Application Tests

Below are registered issues that calls for research. Explanations for the identified demands are given:

Water Mist in Freezing Temperature

Why: Non-heated areas typical in heritage. Protection of combustible facades.

Flashover Suppression Systems

Why: Inexpensive. Unobtrusive. Minimal secondary damage.

Small Stand-Alone Water Mist Systems

Why: Inexpensive. Unobtrusive.

Mobile water mist equipment (piercing nozzles, motorbike back-packs, hand helds, impulse guns)

Why: Fast intervention. Effective. Small amounts of water. No obtrusive installations. Reduced damage.

Dry Pipe Water Mist Systems With Fire Engine Connection (Attic Spaces)

Why: Inexpensive. Unobtrusive. Effective trade-off for otherwise expensive and obtrusive safety measures.

Water Mist for Listed Multistory Townhouses

Why: To retain building construction, and allow use as is.

Dripping

A problem in decorated environments are dripping from nozzles before and after activation at full pressure. No current research work known to address this.

Total Amount of Water Applied. How Beneficial is less Water? Time to Shut Off.

The amount of water applied, and potential for damage by water, increases with extended operation of water mist nozzles, by use of deluge mode and by specific nozzle efficency. It has been argued that once the water absorbing capacity of surfaces and artefacts are reached, residual run-off water may not add much to damage if it is drained or ducted away from water-sensitive valuables, thus the difference in water density by water mist and sprinklers is less pronounced after saturation. Saturation may be occur quite early. On-off and cycling systems are known, but not addressed for heritage. No current research is known to address these issues.

Adopting Water Mist Systems Approved for other Markets (Marine and Industry Applications)

Some standard approvals may be relevant if scrutineered - if so: Inexpensive and unobtrusive.

Less Obtrusive Nozzles and Fittings (WME, Marioff)

Water mist installations are less visible than sprinkler, still not acceptable to many. As explained in part 8 and 10 of chapter 3.3, some companies recently introduced very interesting improvements.

Reliability of Water Mist in Heritage

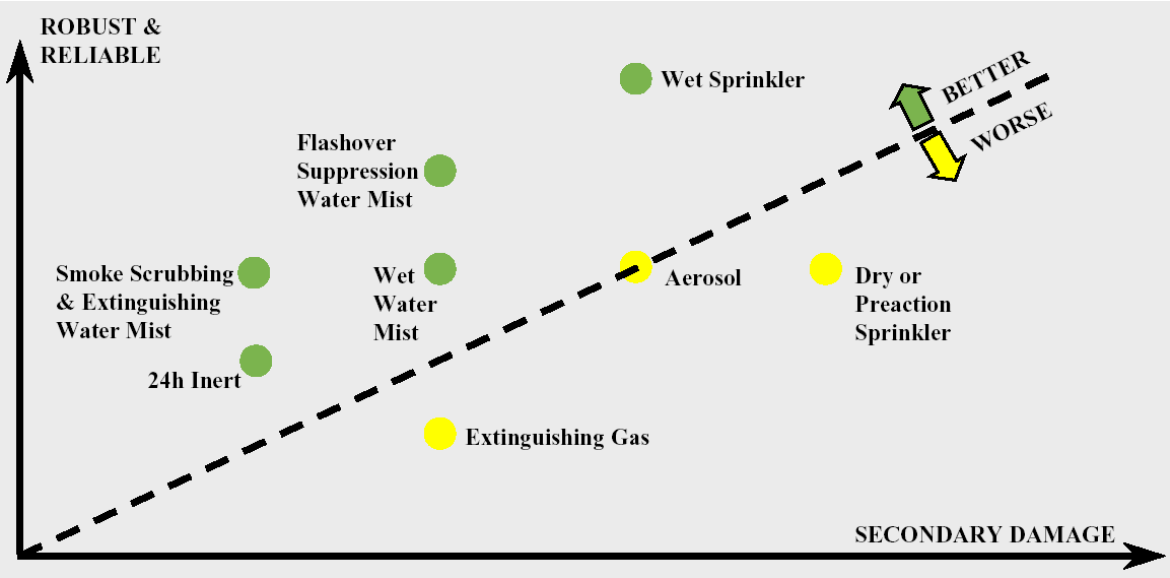
Water mist systems are considered less reliable than sprinkler in terms of performing on demand. It is a relatively new and design-critcial technology. Mains-operated systems can be a huge step forward, *but there are no known specific activities* on improving reliability other than that of development of low pressure systems.

Cost-Effectiveness

Water mist costs more than sprinkler except for rare cases. The reason for water mist i heritage buildings is its superior net performance. But how much extra cost is justified for the benefits? Manufacturers and vendors try to reduce cost by be more competitive. There is reason to be cautious: Simplifications must not lead to reduced performance or reliability. *There are no known activities on cost-effectiveness issues*.

Amidst Alternative Extinguishing Systems

Evaluating several optional extinguishing systems should be routinely performed before making decisions. Water mist offer many benefits to heritage. In the diagram below robustness and reliability is compared to risk of secondary damages for a number of extinguishing systems only, but aesthetics, cost, maintenance, space requirements etc must also be considered to complete comparison (diagram is strictly qualitative):



4 HOW TO APPROVE WATER MIST FOR PROTECTION OF HERITAGE

Performance-based codes are favorable for introducing new water mist applications.

This postulation is in the introduction of both prescriptive and performance-based standards of NFPA:

> *Nothing in this standard is intended to prevent the use of systems, methods,or devices of equivalent or superior quality, strength, fire resistance, effectiveness, durability, and safety over those prescribed by this standard. Technical documentation shall be submitted to the authority having jurisdiction to demonstrate equivalency. The system, method, or device shall be approved for the intended purpose by the authority having jurisdiction.*

It makes the point of the performance-based option well: i.e., if one provide technical documentation that demonstrate equivalency to a prescribed system, method or device it *shall* be approved. This principle apply to all known and enforced performance-based codes.

To obtain approval for a new water mist application for a unique heritage building challenge, one may:

1. Design a suitable system adhering to the special needs of the building(s)
2. Design a testing procedure (test protocol)
3. Make preliminary tests
4. Adjust system design and test procedure as appropriate
5. Make final tests
6. Report testing procedure, design and results
7. Apply to the respective body for acceptance

Bukowski /22/ is one good example on how to do performance-based designs to fire protection of historic buildings. The NFPA standard on water mist installations /9/ recommends this procedure when adopting test experience from one application to another (say, to heritage in our case):

> *One of the greatest challenges to engineering of water mist fire suppression systems lies in determining whether the conditions of a particular test protocol are representative of the actual conditions in a given application. An engineering analysis should be applied to evaluate the scale and significance of variations, based on an understanding of the dynamics of the interaction of water mist with fire.At least the following application parameters should be considered:*
>
> *(1) Is the fuel similar to the test protocol (liquid or solid fuel, flash point, combustibility, quantity, arrangement)?*
> *(2) Is the compartment volume equal to or less than the volume of the test room?*
> *(3) Is the compartment height equal to or less than the test protocol?*
> *(4) Is the compartment ventilation condition similar (area of openings, position of openings)?*
> *(5) Are there more obstructions to the distribution of mist than the test protocol?*
> *(6) Is the duration of protection provided by the listed system appropriate for the actual level of protection desired?*

The European Technical Approval Organization (ETAO) does not currently have any Guideline (ETAG) on water mist. Still, national organizations, some of them ETA-accredited, may on conditions issue national technical approvals for specific water mist systems and applications.

See the second section of '3.3.1 Activities' for promising new performance criteria of water mist to be used in fire safety engineering design /16/. See also slides 26-29 of Appendix B relating to this.

5 CONCLUSIONS

Water mist technology offer a high potential for effective and subtle fire protection of heritage. Several existing installations are proof of unique and successful experience in Europe. Water mist provides a safe and practical environment for rescue work, protects visitors and staff, incur minimal secondary damage in fire or by unintentional activations and may substantially remove harmful particles from smoke.

Applicable installation standards for heritage are lacking. Completion and adoption of the CEN standard for Europe are estimated within 2 and 7 years, but specific test procedures for heritage is so far not planned.

Performance-based regulation are now common in most of Europe, and fortunate in development of heritage installation guidelines for water mist or for case-by-case acceptance of applications. Several water mist systems are tested and approved as sprinkler-equivalents for museum and historical building hazards. There should be no great concern in accepting these for the fire protection performance in heritage applications, but one may find some of them overly expensive, advanced or obtrusive compared to refined mist systems which should be sought for the most delicate interiors.

Flashover suppression systems are being developed and should become ideal for heritage by using minimum of water and being unobtrusive and inexpensive. Low pressure systems connected to water mains do not require pumps and promise reduced cost and increased reliability - such systems are being prepared for market by several manufacturers. Low pressure systems for flashover suppression could be a good combination.

Pipe-integrated nozzles, mobile water mist systems, self-penetrating nozzles, hypoxic air combined with water mist for museum vaults and valuable interiors, and systems operated by water mains pressure are examples of other promising new water mist features for protection of the built heritage environment.

New criteria based on the properties and merits of water mist itself, rather than sprinklers, should be sought. Such are being developed for general applications, and may be a key to even less expensive and better suited systems for heritage application also. Alternatively, the heritage community may establish its own criteria.

Most challenges in research and development promise improved performance by water mist, while freezing and blocking of small openings are specific concerns with water mist systems that need to be carefully dealt with. The quantification of damages by surface saturation, condensation, dripping and water run-off for both sprinklers and water mist should be sought in order to appreciate benefits, limitations and properties of both. Full scale ad hoc fire tests have proven that water mist settles or subtly condense to floors rather than vertical surfaces, but the mechanisms are not fully understood. Experience from unintentional water mist releases in heritage environments is assuring - insignificant damage are recorded, except one case of late valve turn off.

Water mist require attention to details. Proper design, installation, maintenance, and testing are important. Once the reliability issue is addressed and systems successfully commissioned, however, water mist may even offer improved operational reliability as well as performance reliability to conventional sprinklers.

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26. Vaari, Jukka: "*Guidelines to Large-Scale Fire Testing of Water Mist systems*". Nordtest, TR 433. 1999.

27. Arvidson, Månsson: *"An evaluation of antifreeze for automatic sprinkler systems".* Brandforsk 631-961

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30. Jensen, Geir: "*Slokkealternativer for vitale rom i statens bygg*". Interconsult. 1996.

31. MawHinney J R, Back G G: "*Water Mist Fire Suppression Systems*". SFPE Handbook for Fire Protection Engineering, Chapter 14.

Resources on Water Mist for Fire Protection of Heritage:

The following organizations may be consulted when dealing with water mist fire protection in heritage:

- Directorate of Cultural Heritage (Norway)
- Interconsult, member of the COWI Group (fire protection engineers, Norway)
- SINTEF Norwegian Fire Research Laboratory (research and testing, Norway)
- Stord/Haugesund University College (education and research, Norway)
- VTT Building and Transport Fire Safety Research (research and testing, Finland)*
- SP Fire Technology (research and testing, Sweden)*
- Manufacturers: Refer to table in chapter 1.1.2
- Europe: International Water Mist Organization - IMWA*, in addition to those listed above
- US: NFPA, Hughes Associates, Inc., Smithsonian Institution, US National Gallery of Art

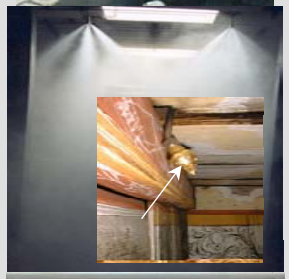
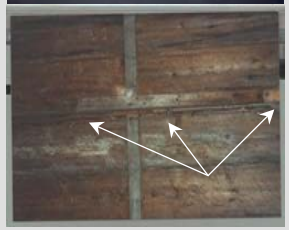
* *Those marked by asterix have not yet addressed heritage applications, but highly qualified on water mist technology in general.*

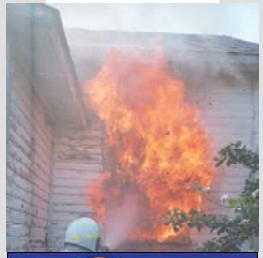
FIRE AND WATER

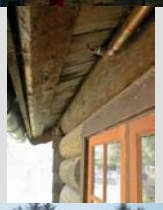
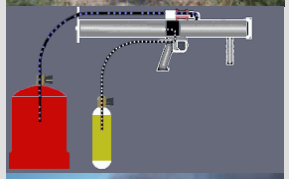
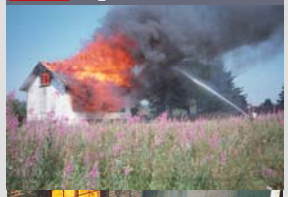
Water Densities of Application Techniques in Fires - Compared to other Water Densities

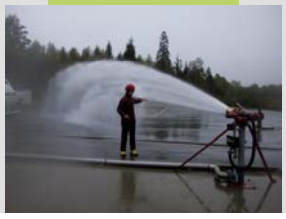
INCREASING DENSITY ↓

APPLICATONS IN HERITAGE

Fog	**0 l/min m²** Particle diameter size 10 micron. Fog does not settle on ground – particles are suspended in air.		The particle size compare to water mist for smoke scrubbing. This is an established fire protection system for computer rooms. Smoke scrubbing mist has been suggested for application in galleries or decorated historic buildings. So far no evaluation or realistic tests are reported.
Drizzle	**0.001 l/min m²** Particle diameter 100 micron com-pare to smallest diameter of water mist particles for fire extinguishing.		
Gypsym	**0.002 l/min m²** <1 liter per 10 m^2 partition area in 30 min of fire.		Gypsum ($CaSO_4 2H_20$) contain approx 50 % water by volume. By radiation from fire water is reformed, consistent with severity of exposure. Gypsum is suitable where protective concerns of original materials allows. Gypsum boards may be precut to size and hooked in front of windows or artifacts subject to fire exposure.
Fire Blanket	Released mass of water per unit area considered more than gypsum less than gel.		Fire blankets release water and/or have endothermic chemical reaction when subjected to heat from burns or heat from fire.
Gel	**0.01 l/min m²** 5 liter per 10 m^2 area in 30 min subjected to radition from fully developed fire.		Fire gels were introduced in Europe in the 80-ies and in USA in the 90-ies. Combustible surfaces may be covered by gel by way of fire hoses or garden hoses. Subject to radiation from fire the gel water content (99% of gel is water) vapourizes. Gel may protect sufaces from igniton for hou-rs. If neccessary gel layer is rebuilt by short duration clean water spray Gel hosed away to drains after use.
Rain	**0.05 l/min m²** 'Some rain' are typically 0.5-2 mm in 24 hours.		
Heavy Rain	**0.1 l/min m²** World records are even higher: 1 mm/min in 1 day (1.4 m in 24 hours). 4 mm/min in 5 min (20 mm in 5 min:compares to residential sprin-kler densities)		
Flashover Suppression by Water Mist	**0.3 l/min m²** Theoretical values are lower. Water mist or sprinkler syst-ems provide flashover suppression and are suitable where excessive water densities are accepted.		Water mist in very slight densities prevent flashover in encloures – if mixed into the hot smoke layer. To provide adequate protection were installations are potentially detri-mental to heritage, or the budget is low, water mist systems for flash-over suppression only are applied to romms like attics where accessibility for fire rescue personell is bad and/ or where fire may take hold. Especially effective in protecting historic wooden town districts.
High Pressure Water Mist	**1 l/min m²** (0,8-5 l/min m^2)		High pressure water mist systems are usually automatic and designed to extinguish or suppress fire to heat releases equal to or less than at time of activation. They do this even better than sprinklers, and with less water consumption. High pressure water mist is readily available and well proven. The fine droplets at moderate impulse seem to be kept away from walls by cold or moderately hot aircurrents - at a distance from the fire source, thus protects water-soluble decorations.
Low Pressure Water Mist	**2 l/min m²** (1.6-5 l/min m^2)		Low pressure water mist systems are usually automatic and designed to extinguish or suppress fire to heat releases equal to or less than at time of activation. They do this even better than sprinklers, and with less water consumption. New systems expected to work from water mains pressure, i.e. no presure pumps. Protect water-soluble decorations as described for high pressure systems (image: flashover suppress. version)

Irrigation sprinkler	**2 l/min m²** (nozzle 200 l/min on 100 m²)		
Residential Sprinkler	**>2.05 l/min m²**		Residential sprinkler sytems are designed for life safety, but offer cost-effective heritage protection, comparable to sprinkler,where building is of domestic character and if nozzles are provided in some areas not required by residential sprinkler standards.
Sprinkler Light Hazard (Wooden Houses, US)	**>2.25 l/min m²**		Ordinary sprinkler systems offer unsurpassed reliability and fire safety peformance. Does not require high water density in rooms of porous surfaces like wood (US), because water is prewetting the suface and prevent ignition or fire spreading. Even some water mist systems require higher water density rates. In other applications sprinkler demand high water densitiies. Sprinkler systems are readily available but require large pipes.
Water Mist Extinguisher Water Mist	**3 l/min m²** (nozzle 2-6 l/min m²)		Hand held water mist extinguishers turned out best overall in a study including realistic testing scheme of hand held extinguishers for use in heritage and museum environments. It provided early knock-down, fully extinguished fires and a minimum of secondary damage to 13 artifact materials by short and longterm effects. Not recommended to fight established or fully developed fires (image).
Small Stand Alone Water Mist Systems	**3 l/min m²** (1-5 l/min m²)		'Automatic hand held extinguishers' are positioned strategically in rooms. They have automatic thermally activated nozzles, or pneumatic detection plastic pipes that open valves when melting. Suggested for open air museums where the prime risk relates to one or a few rooms at the premises only, and budget or risk is low. Relibility is questioned though, and there are few referenced applications in heritage. Cost is EUR 100 up to EUR 1000 per room. For multiple building heritage sites this translates to a lot of safety at low cost.

Water Mist Impact Monitors	**3.6 l/min m²** (4 charges 30 liter each at 35 m² in 1 min)		Large water mist impact monitors are tested, evaluated and installed. They perform well in protecting sensitive exteriors of historic buildings from exterior fire exposure. The large units applied hitherto are expensive. Their complicated design require extensive maintenance.
Snow Generator	**4 l/min m²**		Realistic tests have proven futile.
Sprinkler Light Hazard (Wooden Houses, Europe)	**>5 l/min m²**		Ordinary sprinkler systems offer unsurpassed reliability and fire safety peformance. Does not require high water density in rooms of porous surfaces like wood, because water is prewetting the suface and prevent ignition or fire spreading. European sprinkler density requirements does not differentiate wood from other building constructions, however.
Water Mist Fire Fighting Nozzle, Small	**5 l/min m²** (nozzle 10 l/min at 2 m²)		Lightweight water hose mist nozzles have been evaluated. They perform well where water supply is limited, or when used by early intervention personell. They perform well where one is concerned about secondary damage and may apply them at an early stage. Larger nozzles are required if fire is likely to be larger.
Water Mist Impact Gun	**5 l/min m²** (5 charges 1 liter each at 1 m² in 1 min)		Water mist impact guns are tested and evaluated. They perform well where water supply is limited, or in use by early intervention personell. They perform well where one is concerned about secondary damage and one is able to apply them at an early stage. Larger nozzles are required if fire is likely to be larger.
Garden Hose, Small Fire Fighting Nozzle	**5 l/min m²** (nozzle 50 l/min at 10 m²)		Garden hoses and domestic fire hoses offer unlimited water supply and are very effective in extinguishing at an early stage, in prewetting exposed surfaces and to extinguish flying brands. Such simple means are useful in making neighbours and inhabitants protecting their heritage.
Piercing Water Mist Nozzle, Abrasive Cutting	**5 l/min m²** (nozzle 50 l/min at 10 m²) (200 bar)		Cobra is a piercing nozzle concept based on very high pressure. Sand is mixed into water to make a blasting - or rather active piercing effect to penetrate concrete, wood or steel. Once penetrated pure water is supplied to the nozzle to suppress or extinguish fire inside the enclosure. Specialized fire brigade equipment.

Piercing Water Mist Nozzle	**5 l/min m²** (nozzle 50 l/min at 10 m²) (5-10 bar)		Water mist piercing nozzles are availialble in many designs to penetrate walls or roofs by hammering, drilling or pushing manully or hydraulically. Simple and inexpensive. Used by many fire brigades. Especially useful for attacking fires that have taken hold in inaccessbile attics etc.
Pieercing Water Mist Nozzle on Hydraulic Arm	**7 l/min m²** (nozzle 70 l/min at 10 m²) (5-10 bar)		Hydraulically operated piercing nozzles are common at airports and in industry. Fire brigades protecting heritage may consider this for fast and safe safe nozzle access to attics etc with a minimum of damage.
Mobile Water Monitor	**8 l/min m²** (nozzle 800 l/min at 100 m²) (versions: 250-1500 l/min)		Portable water monitors are effective for use at heritage sites of multiple wooden buildings or combustible exteriors. Some will operate automatically in a cycle left-right or even in square cycles. They are common with all fire brigades, and relieves personell to do other rescue work.
Conflagration Fire Fighting Water Monitors	**8 l/min m²** (nozzle 40 000 l/min at 5000 m²). The smaller versions yield 20-30 000 l/min, the larger ones 70 000 l/min. Each ship usually carry several.		The huge water monitors of off shore supply ships may be applied to control or extinguish conflagrations in wooden building disticts. The fire safety plan of listed heritage site Old Stavanger require the fire chief to redirect supply ships to the harbour whenever a fire threathens to develop into conflagration. One monitor may reach alle houses from the harbour.
Fire Hose	**10 l/min m²** (nozzle 100 l/min at 10 m²)		Fire hoses offer unlimited water supply and are very effective in extinguishing at an early stage, to prewet exposed surfaces or to extinguish ignitions from flying brands. Fire hoses that are made available to the public, inhabitants or neighbours to heritage is costeffective safety.
Water Monitor	**10 l/min m²** (nozzle 1000 l/min at 100 m²) (versions: 750-5000 l/min)		Fixed water monitors are very simple to operate, even for the untrained. They are best suited for exteriors of heritage objects. They demand high water supply rates which limit their use.

Sprinkler Extra High Hazard	**>15 l/min m²**		
Fire Hose, Domestic Large	**30 l/min m²** (nozzle 300 l/min at 10 m²)		A special fire hose station have been developed for use in open air museums and for wooden exteriors. 50 mm diameter hose extends to 50 m. When fully extracted valve opens automatically. The hose station is less useful if one has to move around with the heavy nozzle and water-filled hose – or where water supply is limited.
Large Water Monitor	**75 l/min m²** (nozzle 7500 l/min at 100 m²)		Fixed water monitors are very simple to operate, even for the untrained. They are best suited for exteriors of heritage objects. They demand very high water supply rates which limits their use.
Vøringsfossen Water Fall	**84 l/min m²** (840 000 l/min at 10 mål) 840 000 l/min (13-14 m3/s)		
Niagara (Horseshoe Falls)	**35 000 l/min m²** (343 200 000 l/min at 10 000 m²) 343 200 000 l/min (5720 m³/s)		Preliminary study promises high fire extinguishing potential. Application challenges appear insurmountable.

Interconsult

All rates within this illustration are typical and for rough comparison only. For some items rate variations are huge, and for the same item different application techniques will result in wide variations in densitites.

For permission to reprint contact:

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1

Appendix B

Water Mist for Fire Protection of Heritage: Applications

COST Action C17 - Research Seminar
16th April 2004, Trondheim, Norway

Geir Jensen

Interconsult
Member of the COWI Group

2

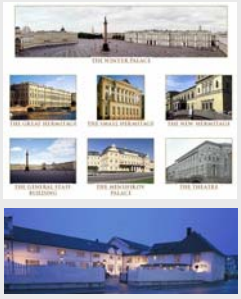
Water Mist in Heritage:

Where?
Why? Pros and Cons
How?
Challenges
New Solutions
Acceptance Criteria

3

Registered Installations in Heritage 1/9

The Russia State Hermitage, St Petersburg (right)
Historic Churches, Finland
12 Stave Churches, Norway
4 Medieval Churches, Norway
2 Wooden Historic Buildings, Norway
3 Historic Hotels, Norway (right: Kong Carl)
UNESCO World Heritage Site Røros, Norway
US National Gallery of Art, Washington DC



4

Registered Installations in Heritage 2/9

Historic Ship **Endeavour** (James Cook), UK

Historic Polar Ship **Fram**, Norway

5

Registered Installations in Heritage 3/9

Bårdshaug Historic Residence, Norway

Historic Hotel Elvestad, Norway

6

Registered Installations in Heritage 4/9

Haukipudas Church, 1762. North of Oulu, Finland.
Interior glue painting. Water mist by Marioff.

7

Water Mist for Fire Protection of Heritage: Applications

Registered Installations in Heritage 5/9

Vesilahti Church, 1802. Finland. Images prior to water mist installation by Softonex.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Water Mist for Fire Protection of Heritage: Applications

Registered Installations in Heritage 6/9

Nore Stave Church, Norway
(*One of 12 stave churches protected by water mist systems*)

Several heritage buildings in Venice, Italy


9

Water Mist for Fire Protection of Heritage: Applications

Registered Installations in Heritage 7/9

Kungsparken Casino, Sweden

Roosevelt Campobello Park, USA

10

Water Mist for Fire Protection of Heritage: Applications

Registered Installations in Heritage 8/9

Norwich Castle Museum, UK

Contemporary Art Museum (Marco), Spain

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Water Mist for Fire Protection of Heritage: Applications

Registered Installations in Heritage 9/9

47 Park Street Hotel, London, UK

Domus Academica, University of Oslo, Norway

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Water Mist for Fire Protection of Heritage: Applications

Benefits

Most subtle way of fire extinguishing
Safe and practical environment for rescue
Minimal impairment of building fabric
Minimal secondary damage to artifacts
Harmless to water-soluble decorations
Protects visitors and staff
Suppress fire - less smoke produced
Small size pipes and nozzles
Unobtrusive appearence
Effective cooling - less thermal damage
Cooling - less buoyancy reduce smoke spread
Special systems: Smoke scrubbing
Delicate prewetting of combustibles
Low water density

Water Mist versus Gas Extinguishing
Does not run empty
May be turned off, and on again
Room may be leaky/open door
Do not require shut downs, closing dampers
Prewets - prevent reignition
No environmental issues
Instant refill

(Comprehensive list in report on mist vs gas)

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Water Mist for Fire Protection of Heritage: Applications

Water Mist Superb and Robust - but you MUST do it Right!

There are pitfalls - if you don't know how:

- Small fires, both open or shielded, may continue to burn for a long time - neccessitating extended time of active misting. Result: Excessive smoke and water accumulated damage.
- Burn-through roofs, large windows breaking or large doors open - or combinations: Water mist deprived of reaching both the fire source and hot smoke layer - virtually non-effective!
- Deluge water mist in lieu of bulb sprinklers: Density (l/m2) less, but many times more water!
- Reliability suffers from design sensitivity, complexity, pumps, personell new to water mist

How to avoid: Apply current knowledge on water mist (*which is, by now, more comprehensive than that of sprinklers*)! Make it simple! Maintain!

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Water Mist for Fire Protection of Heritage: Applications

Water Densities in Comparison

Water mist systems, sprinkler-equivalent approved:

20-40 % density of sprinkler

Water mist systems for flashover suppression, prewetting, 'standby protection' or 'fire brake':

10+ % density of sprinkler

Sprinkler: 2.05 - 5.0 l/min m2

Water mist: 0.3 - 5,0 l/min m2

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Water Mist for Fire Protection of Heritage: Applications

Where and how?

- indoor, high pressure:

- indoor, low pressure:

Smaller than sprinklers:
Diameter: 19.8 mm
Protrusion: 35 mm
(typical sample - Marioff)

Sprinkler systems require large diameter pipes

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Water Mist for Fire Protection of Heritage: Applications

Where and how?

- outdoor, fixed:

- outdoor, manually:

17

Water Mist for Fire Protection of Heritage: Applications

Where and how?

- handheld water mist extinguishers:

18

Water Mist for Fire Protection of Heritage: Applications

Where and how?

- locally, by hand - water mist gun:

19

Water Mist for Fire Protection of Heritage: Applications

Where and how?

- outdoor, large water mist impact gun, remote from object:

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Water Mist for Fire Protection of Heritage: Applications

Where and how?

Water mist should NOT be applied to fight fire:

- by snow generator:

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Water Mist for Fire Protection of Heritage: Applications

Where and how?

Water mist should NOT be applied to fight fire:

- by undersized equipment, or wrongly applied:

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Water Mist for Fire Protection of Heritage: Applications

Where and how?

Water mist should NOT be applied to fight fire:

- when other solutions perform better:

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Water Mist for Fire Protection of Heritage: Applications

Does water mist installations fulfill expectations of owners?

Extinguish, control or suppress real fires:

- No known incident in heritage applications yet
- Concerns about reliability - if it is not seriously addressed

Unobtrusive installation, small dimensions, less water damage:

- Owners happy, no exception known.
- Next slide: Reported incidents of unintentional water mist activations

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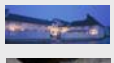
Water Mist for Fire Protection of Heritage: Applications

UNINTENTIONAL SYSTEM ACTIVATION: 4 INCIDENTS

1 + Bibsys Smoke scrubbing & extinguishing water mist system in **computer room**. Activated by welding. Computers were running, no damage. System considered for **museum vaults**.



2 + Kong Carl Historic **hotel**. Medium pressure water mist. Broken bulb activated nozzle in guest room. *"Never seen a room so perfectly wet; still, no water running or dripping. Dried quickly, no damage to interior"*, manager said. *" Nice fitted and unobtrusive"*.

3 + Rollag **Attic**. Mist system designed to flashover suppression. Limited volume of water designed to be absorbed by insulation of attic floor - to avoid damage to decorated room below. Activated by lightning strike. Worked as designed - no decor damage.

4 - Tanum **Church**. Faulty activation of deluge zone of high pressure water mist system. System was not yet commissioned by fire brigade. Therefore, 30 min to find shut off valve. Substantial water damage. High grade system, but detection algoritm questioned.

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Water Mist for Fire Protection of Heritage: Applications

Toughest Challenges: Misconceptions

Following the Windsor Castle fire, a statement goes:

"Good thing we didn't have sprinklers installed, imagine having water damage in addition to this fire damage …" *

A few other (out of many) **misconceptions:**

- "Water mist of no use if it's not equal or better than sprinkler"
- "All mist nozzles activates simultanously"
- "Water extinguishing system will damage historic buildings and artifacts"

* *Cited from unknown by Jack MawHinney at the NFPA 914 Workshop, September 2002, USA.*

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Water Mist for Fire Protection of Heritage: Applications

ACCEPTANCE CRITERIA

Yes, there ARE ways of obtaining approval of water mist in heritage buildings:

1 Application Specific Tests	Accepted in most countries, and by NFPA 750. Evaluation by certified professionals recommended.
2 Performance-based Evaluation from Owner/Authority Acceptance Criteria	Allowed by performance-based codes, and by NFPA 914. Require evaluation by certified professionals. Typically, test reports of non-specific standards are evaluated for *relevance* and *compensatory measures*.
3 European Technical Approval (ETA)	Initiative by Interconsult to apply for ETA's on water mist in Heritage, Listed Residential, Attics in Wooden Historic Towns and other applications not yet planned or adressed by CEN 191. (***Equivalent in US**: Application Specific Test Protocols as per NFPA 750)*
4 European standard CEN 191 (WG 5)	Being drafted. When standard approved, ETA's no longer required. Heritage not yet adressed.

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Water Mist for Fire Protection of Heritage: Applications

Water Mist: Approaches to Assess Suitability for Heritage

The performance-based design approach demonstrated in real projects:

Hughes Ass.: DiNenno and MawHinney in cooperation with the US National Gallery of Art carried out a project for the gallery. Hughes Ass. also reports on a project at a remote multiple building museum.

Their approach is strictly to US codes and legislation which differ from those of the Europeans, but points out important issues such as skilled vend-ors and installers, and useful tips of design.

Interconsult: On behalf of the Directorate of Cultural Heritage performance-based safety designs are developed to protect the stave churches. Objectives and performance require-ments were elaborated on behalf of the Directorate. A 1:1 full scale mockup testing scheme of one stave church were carried out. A flashover suppression water mist system were tai-lored and developed with manufacturer.

Later, Interconsult designed water mist applications to fit the polar ship 'Fram' and other heritage objects, from performance-based design.

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Water Mist for Fire Protection of Heritage: Applications

Fully Compliant..... and Useless

Applying a fire protection system strictly according to a universal standard, may be disatrous to heritage. ***Consider that*** you install standard sprinklers in all houses, to prevent conflagration of an historic town centre:

Apparently it would be OK:

- You get insurance premium savings
- You spend a lot of money on safety
- You adhere perfectly to the standard
- Your effort to protect from fire shows off

The facts are:

- Conflagrations spreads externally
- Excess of 20 % of fires start outdoor
- Sprinkler does not cope with external fires
- Too many systems operating: Water mains fail
- Interiors: Physical and aesthetical damage
- Expensive: Minitual safety per euro
- Low reliability: Dry systems, low headroom

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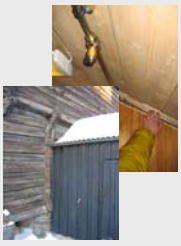
Water Mist for Fire Protection of Heritage: Applications

Fire safe, simple, reliable, inexpensive and unobtrusive.....But not to any standard

At UNESCO World Heritage Site Røros, our fire risk analysis led to water mist being applied in attics only, with external connectors to pumps of fire engines.

For external protection against spread, detection, manual intervention by inhabitants, fire hose stations accessible to all and fire protecting gel were carefully implemented.

Few of these safety measures, except for single items, comply with any standard!



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Water Mist for Fire Protection of Heritage: Applications

WAYS AHEAD

1 Water mains pressure systems (<50% of low pressure systems)

2 Pipe integrated nozzle: Patented *FogTube* nozzle - very sleek

3 Flashover suppression designs: Water mist as a "Fire brake"

4 Smoke scrubbing mist systems (museum storage vaults, galleries)

5 Hypoxic air + water mist* : 2 stages: 24h inert, water mist 'last resort'

* *An Interconsult and FirePASS elaborated concept for high challenge museum applications*

1

Appendix C

Sample Applications
- Water Mist in Heritage

An Extension of Presentation at the COST Action C17
Research Seminar 16th April 2004

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Water Mist for Fire Protection of Heritage: Applications

NOTE:

Registered installations of water mist fire protection in heritage are listed and illustrated on 7 slides (3-9) of the original paper presentation, Appendix B.

This series, Appendix C, show registered installations added later - and illustrations from various applications, equipment and tests.

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Water Mist for Fire Protection of Heritage: Applications

Water mist system of Historic Polar ship 'Fram'
(Performance-based design by Interconsult.
Manufactured by Mistex Ltd)

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Water Mist for Fire Protection of Heritage: Applications

Water mist smoke scrubbing and extinguishing system for protection of museum storage vaults or vital services

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Water Mist for Fire Protection of Heritage: Applications

Water mist installations in stave churches
(images from service rooms)

Control panel of pneumatic detection and activation system to the left.

The skid and equipment for large water mist impact guns to the right.

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Water Mist for Fire Protection of Heritage: Applications

Water mist extinguishing systems installed in service areas
(Marioff)

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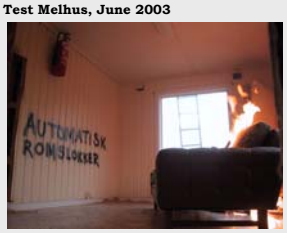
Water Mist for Fire Protection of Heritage: Applications

Water Mist Ad Hoc Test Melhus, June 2003





Mock up watermist system test. Deluge nozzles in attic in demolition fire. Attic remained well below ignition temperature and prevented flashover.

Left: Mist and sprinkler piping. Middle: Fire protecting gel evaporates, water vapor drawn into fire. Right: Automatic water spray room extinguisher on wall upper left - shortly before activation.

SINTEF and Interconsult for the The Directorate for Civil Protection and Emergency Planning, Norway.

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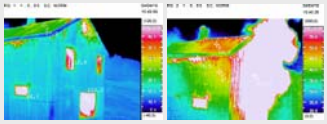
Water Mist for Fire Protection of Heritage: Applications

Water Mist Ad Hoc Test Malvik, April 2004



Pipe-integrated FogTube nozzle test. Deluge nozzles in attic in demolition fire.

Attic remained well below ignition temperature and prevented flashover.

WME and Interconsult for the The Directorate for Cultural Heritage, Norway.

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Water Mist for Fire Protection of Heritage: Applications

Water mist extinguishing by high pressure self-penetrating nozzle

(Cobra by Cold Cut system AB)



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Water Mist for Fire Protection of Heritage: Applications

Autonomous water mist units - for protection of voids, storage departments and single rooms

(Various manufacturers)




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Water Mist for Fire Protection of Heritage: Applications

Large Water Mist Impact Gun - Early test of Prototype

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Water Mist for Fire Protection of Heritage: Applications

Large Water Mist Impact Guns to Protect Ignitable Exteriors of Heritage Buildings

Specifications by
Interconsult

Designed and manufactured by
IFEX/LUX

Sponsored by
The Directorate of Cultural Heritage, Norway