COST C17 BUILT HERITAGE: FIRE LOSS TO HISTORIC BUILDINGS,
Note of Research Seminar: " The Application of Water Mist in Cultural Heritage Buildings " held in the Archbishop's Palace Trondheim, and Associated Scientific Programme, Melhus, Trondheim and Roros, Norway: 16 and 18 April 2004

Background

Riksantikvaren

The Directorate for Cultural Heritage, (Riksantikvaren) is an Executive Agency responsible to the Norwegian Ministry of the Environment, to which it provides management expertise and technical advice. The Directorate is responsible for all Norwegian protected cultural heritage objects, including 70,000 archaeological sites, extensive medieval deposits in eight cities, and 3200 buildings. (It is estimated that there are over 500,000 Norwegian buildings more than 100 years old).

It co-operates with a number of international organisations including UNESCO following the World Heritage Site status conferred on the mining town at Roros in 1980. The Norwegian Cultural Heritage Act requires the permanent protection of all sites and monuments older than at 1537; standing building older than 1650; submerged ships, and Sami cultural heritage older than a 100 years

Nidaros Cathedral and Archbishop's Palace, Trondheim

Nidaros Cathedral, Trondheim was built over the grave of St Olav with construction starting in 1070. The oldest part of the current building dates from the mid-12th century in Romanesque form. Hit by fire on several occasions, it was rebuilt at various times in the Gothic style.

The Archbishop's Palace is the oldest secular building in Scandinavia. Work started during the second half of the 12th century and it was the Archbishop's residence until the Reformation in 1537. Following the Reformation it became the Danish Governors residence and, from 1700, was occupied by the military.

It was the location of the COST C 17 meeting. The joint session was held in the Main Conference Room of a new building erected in the Palace courtyard after a major fire in 1983. Working Group meetings were held in the adjoining medieval Chapter House. The adjacent new museum was constructed after five years of archaeological excavations following the fire.

Research Seminar: "The Application of Water Mist in Cultural Heritage Buildings" 16 April 2004

Members and Norwegian Participants were welcomed by Sjur Helseth: Head of Department, Riksantikvaren, Norway and Ingval Maxwell: Director TCRE Historic Scotland, Chairman COST Action C17.

The following papers were presented:

Sjur Helseth, Riksantikvaren, Norway
<u>"Fire protection strategy and the application of water mist in stave churches"</u>

All historic buildings are constructed of wood in Norway. Concern on the level of fire loss started in Norway with the Bryggen incident in Bergen in 1955. From 1992 onwards there have been 40 arson church fires, with 20 totally destroyed. Related to these incidents, considerable emphasis was placed on determining appropriate fire protection measures.

Main goal is optimal protect with minimal damage accommodating -
- Physical damage, and wear and tear
- Water damage, whether unintended or intended
- Aesthetic disturbance
- Damage to archaeological remains.

Adopted Strategy considers:
- Probable cause of fire
- preventative measures
- Remaining risk
- Fire limiting measures
- Acceptable remaining risk.

Levels of Protection are incremental:
- "Volkswagen/Volvo/Rolls Royce" model equates to:
    - Building group/Listed building/Buildings of Special National value - resulting in an incremental approach of:
    - factors /factors +/factors ++ approach

Solutions focus on physical measure, organisational approaches and planning in a colour coded system:
- Green: Prevention
- Yellow: Reduce/Limit after file
- Red: Too late (but this is where the current concentration of effort centres)

A variety of technical solutions, including a 1:1 scale model of Stave Kirk that was used for testing were illustrated. Many sites have no water supplies therefore there was a need to create miniature fire stations nearby – but this created a negative aesthetic impact and required a rethink.

To ensure adequate management and maintenance there was a need to ensure that all equipment was operative and up-to-date, and experience showed a requirement to build-up local knowledge and awareness in a cycle that involved - Advising/Planning/Local Management/Central Management/Advising.

Different technical system had been implemented, including:
- 5 low and 7 high pressure water mist systems
- Sprinkler systems in copper/steel/fibreglass
- Deluge system
- Impulse water mists
- 7 aspiration systems

- Simple systems (4-5m throw fire buckets, with a handle on their base)

Stewart Kidd: Loss Prevention Consultancy, UK
'Water in Fire Extinction'

Over-riding Principles:
- Minimally invasive
- Reusable
- Essential
- Appropriate
- Compliant

Special Conditions:
- Understand the historic fabric and its authenticity
- Be sympathetic in design
- Arrange full coordination of the work team
- Produce a method statement
- Employ specialist support trades
- Ensure adequate supervision of work force.

Fire Triangle and Fire Plume:
- Evaporation
- Volume – increases surface area.

Accept that the building is liable to be destroyed if the fire cannot be controlled within the first 2 minutes. Choices involve fire fighting by staff, the Fire Brigade or through the use of suppression by sprinklers and water mist systems. A number of solutions that have been adopted in historic buildings were illustrated. The point was made that 30% of all Historic Building fires outside urban areas have a shortage of water supplies. Real benefits of active water systems were that water was applied direct. This assisted with smoke scrubbing, a reduction in water usage and run-off, and in providing safety for fire fighters.

Sprinkler effectiveness was good with 60% of incidents controlled by 4 sprinkler heads. Type of sprinklers included Wet, Dry, Wet & Dry and Pre action. Plastic piped systems should not be painted with oil based paints as this will damage the plastic.

Ragnar Wighus, Norwegian Fire Research Laboratory (SINTEF) Trondheim
"Fire Extinguishing Properties of Water Mist".

In water mist systems 90% droplets (by mass) have a diameter of less than 1000 microns (1mm) whilst sprinkler droplets are believed to be larger in size.

Noting the properties of water, 1 kg. water removes 400 kJ. of heat. Mist systems use the latent potential of water to increase heat removal by a factor of 6 (1700 x expansion by evaporation) Water mist becomes an inert gas (steam) when it evaporates, but water mist is not an inert gas in itself.

In considering the effect of different water droplet sizes on fire, and on time to evaporation, water mist use less water than sprinklers (at one-fifth to one-tenth the discharge rate) where larger amounts of water droplets reach lower down in the fire/interior.

The results of tests on flash-over prevention with water mist illustrated that 30% volume is inert steam ($100m^3$ - 30 m^3 steam required) (30 m^3 steam requires 1.8 litres of water). In practice a continuous supply is needed due to loss of steam through voids, but there are no common engineering correlations as each case is nozzle dependent.

In the Trondheim city block fire of 5 December 2002 there was a loss of 2 courtyard blocks. The Fire Brigade arrived 3 minutes after the alarm sounded (the fire was then estimated to be 8 minutes old at that time). It started in a kitchen deep-fat fryer and was initially extinguished by the installed sprinkler system – but was still burning un-noticed in the loft. 3 minutes later the sprinkler system was stopped but, by then, the roof was well alight.

Post fire analysis indicated that future strategies should:
- Try to get a better overview of the fire situation
- Better planning was required
- Flashover would have been prevented by a water mist system in the loft
- If an automatic fire-fighting system had been installed the fire spread might have been prevented
- Consider the benefits of relevant apparatus such as:
    - Portable water mist equipment
    - Integrated cutter and water mist equipment.

Geir Jansen, (Interconsult: Member of COWI Group)
<u>"Water Mist Installation in Cultural Heritage Buildings"</u>

The presentation investigated the experiences of water mist installations in a variety of historic buildings including:
- The Hermitage, St Peterburg
- Historic Churches in Finland
- 12 Stave Kirks & 4 Mediaeval Churches in Norway
- 2 Wooden Historic Buildings in Norway
- Historic Ships
- Baudshaug Hotel installation (to be visited by COSTC17)

The benefits of the system were considered to be:
- Safe and practical
- Harmless to people and internal decorations
- Suppression of fire with less smoke damage
- Small amounts of pipe work involved
- Effective with less thermal damage
- Smoke scrubbing
- Delicate pre-wetting of combustibles
- Low water density

Compared to gas installations (in leaky room situations) water mist systems:
- Do not run empty
- May be turned off and on
- Do not require equipment shut down
- Have no environmental issue
- Have an instant refill capability

Water mist systems are superb and robust if they are installed correctly. Nozzles are only 19.8 mm in diameter (finger thick) and protrude 35mm so can be sensitively positioned in a historic interior. The clear message is to avoid difficulties by applying current knowledge, make it simple, and ensure that it is maintained.

Pitfalls that have to be considered include:

- Small fires may continue to burn for a long time
- Burn-through can prevent the mist from reaching the fire source
- Deluge mist systems require nozzles to be open at all time, so more water is required
- Reliability is design sensitive.

Other related equipment and systems tested and considered for use included:

- Large water mist impact gun, located remote from the building (Visually intrusive)
- Snow generator (Did not work).
- Water canon (To provide upwards projecting cover for overhanging eaves)

Survey analysis of the installed schemes revealed that there was no known "heritage" application incident. There were concerns expressed about the reliability of the systems, although owners were generally content. There were 4 known incidents of unintentional release water mist systems. There were misconceptions about the system and this needed to be addressed.

It was reported that the European Standard CEN 191 (WG5) was being drafted and, when approved, the European Technical Approval (ETA) was no longer required. However, heritage was not yet being addressed. Considering that applying fire protection standards to heritage properties could be disastrous in their outcome, there was an ETA initiative being devised by *Interconsult* to apply for an ETA for water mist usage on heritage properties, listed residential buildings, attics in wooden historic towns and for other application not yet addressed by CEN 191 [NFPA 750].

In summarising the facts, it was indicated that:

- Fire spreads rapidly
- 20% fires start from outside the buildings
- Sprinklers don't control external fires
- Incorporating too many systems in one place can lead to water supply failures
- In the Roros scheme a combination of fire risk assessment, and the use of novel techniques, was adopted

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Anne Steen-Hanson, Norwegian Fire Research Laboratory (SINTEF) and Norwegian University of Science and Technology (NTNU).

"Presentation of the fire protection project for the World Heritage Town Røros"

The presentation opened with a brief background to the history of Roros which was added to the UNESCO World Heritage Site list in 1980. The fire protection scheme was financed by the Norwegian Ministry of Labour and Government Administration as a 'know how' project.

The project group involved SINTEF, Interconsult ASA, NTNU, SINTEF Safety and reliability, and the Roros Local Authority. The project started in February 2003, and ended on 31 December 2003.

The task was to guide and advise Roros Local Authority on implementing the existing fire safety plan whilst collecting knowledge about fire protection on historic wooden towns. The publish Report is available in Norwegian on web at <www.nblosintef.no>.

The main principles of the scheme focused on:

- Safety organisations
- Safety plans
- Community involvement
- Fire detection
- Passive fire protection.

During the assessment process a pilot block of 12 typical houses were analysed involving a 15 strong multi disciplinary survey team. Noting that 40% of Norwegian fires were the result of faulty electrical installations and equipment, and 25% were caused by open fires, survey information was sought on:

- How do fires spread:
  - within the building
  - from house to house
  - from one block to the other
- Existing fire safety levels
- What should be improved
- How well can the Fire Brigade act?

With the aim of stopping fire from getting outside any affected building the survey checked for gaps between buildings and used thermal imaging cameras to check the health of electrical distribution boards. Focus was given to the amount of rubbish stored in attics and how fire might spread by interconnections between the houses. It also established any existing fire protection measures, the adoption of façade sprinklers and the location of fire break walls which were plotted onto a key plan. The intention is to put this information into a Database for future reference.

The proposed technical solutions were tested by setting a house on fire where:

- water mist systems lowered the temperature to reduce the time to flashover
- heat detecting wires (run along the external building eaves) can give fast response times
- Fire protecting jelly can be effective if correctly applied

The question was whether or not a water mist system would work in temperatures of -40ºC so the system was tested in freezing room with pre-heated water to +40ºc to ensure that the nozzles would opened. This was adopted in the final scheme with a further recommendation that the water is not turned on until the hot smoke reached the mist protected areas.

Heat detecting wire were installed along the extremities of the buildings, under eaves and windows and at 1st floor levels, and radio transmitters were installed to relay monitored details directly to the fire brigade.

In a follow up to the project, building owners were encouraged to tidy up and remove the rubbish in their attics and improve the fire resistance of building elements. Installed water hose-reel stations were located around town for use by the community and its citizens were trained in their use for fire fighting and other purposes (car cleaning etc).

Daniel Rusch, ETH, Switzerland
"Simulations of Sprinkler performance by Computational fluid"

Aim of the project was to:
- Simulate the interaction of fire sprinkler systems
- Develop simple sprinkler models
- Validate the project intentions

The effect of a Sprinkler system is to:
- Remove energy from the fire
- Displace oxygen with vapour
- Absorb fire radiation by vapour

The test case was described as the equivalent of a (1mw) fire in office or hotel bedroom. Nine sprinklers were involved using simple and advanced models using "super droplets". The project was currently looking at the experimental data with a possibility of effecting modifications of the adopted system.

Steve Emery, English Heritage
"Fire Protection Project in Bath, England"

A brief presentation on the recent fire protection project in Bath, England was offered describing a brief history of the buildings and the original fire codes. Noting that the project solution did not comply with these codes, it was explained that lateral thought was required to accommodate the answers – for example the adoption of a domestic sprinkler system in lieu of creating 2 lobbies.

Various aspects of the project, with reference to series of floor plans, were explained and the range of solutions that had been devised and lessons learn discussed.

The underlying principle was one of "minimal intervention and reversibility wherever possible".

Scientific Programme

Fire-test focussing on flashover control using low-pressure water-mist, Melhus, Trondheim. 16 April 2004

The real-life scientific visit, which involved burning a complete traditionally built Norwegian timber farm-house at Melhus, near Trondheim, was carried out in conjunction with Riksantikvaren, the Trondheim Fire Brigade and Water Mist Engineering AS, <www.wme.no> (WME). WME is a Norwegian based company that has developed and produces water mist and gas systems for fire fighting. They also supply other active fire-fighting systems such as foam and deluge.

Water mist systems work through a combination of effecting heat absorption and oxygen depletion at the heart of fires. They can also help slow the spread of fire by absorbing radiant heat. The systems are non toxic, non corrosive, and safe for use in occupied areas.

The simple water mist system is normally connected to a secure water supply source, or to a fire or water ring main. In addition to the supplying pipe work, the system contains valves, a filter and discharging points. It can be activated by a solenoid or manual valve. It is cheap and simple to install, only requiring a safe, clean, water supply and reliable power source (which can also be a disadvantage). A small centrifugal pump system can be used where-ever insufficient water pressure exists.

Eye-witness Report on the Melhus fire test

A redundant farmhouse at Melhus was subjected to a water mist fire test where the house was ultimately tested to destruction.

The exercise was carried out by Water Mist Engineering Norway. The company had rigged heat sensing wires and installed a water mist system in the ground floor living room, and attic, of the house and members were invited to inspect this in detail. The two-storey stud walled timber structure was built on a masonry base, with vertical boarded walls and a black bituminous felt covered roof. It was filled with furniture, fittings and contents, typical of a normal domestic house.

At the start of the exercise, a wet-trial was carried out using a demonstration water mist system installed on the exterior wall of the building to illustrate, at close range, how it operated.

A preliminary fire was set in the living room. The water mist system activated within a few minutes and the fire was successfully extinguished. The group was then allowed to inspect the interior to witness how the system had operated and controlled the fire.

A second test was put into effect a few minutes later when a much more severe fire was encouraged to grow. Within a few minutes of being started, dense smoke filled the living room, and was emanating from the upper stories. By this time the water mist system was activated. The entire process was monitored by computer, checking and recording the internal temperatures through the installed sensor wires.

After some 6 minutes from the start of the fire a report of 300ºC was being registered in the ground floor, 100ºC at first floor level, with the water mist protected attic level being held at 50ºC. Four minutes later it was reported that the water mist system had been "too effective" in controlling the fire due to the original water mist test making the room to humid and additional fuel was required to make the fire restart so that the experiment could continue.

At 3.40 p.m. the fire was restarted with additional fuel being added in the living room. Temperatures rose rapidly to 300ºC. On reaching 800ºC in the ground floor, the second floor was reported at 400ºc with 260ºC registering in the Attic. 2 minutes later smoke filled the ground floor, and a build up of heat and pressure against the window glass causes distortion. At 3.50 p.m. and the fire was well underway, the ground floor window glass broke, and smoke was emanating from every opening, and from under the roof eaves. At 3.53 p.m. the fire was also well alight on the outside of the building.

The application of the water mist system was initiated at 3.56 p.m. as 520ºC was being registered on the first floor. Using 28 litres of water mist per minute at the first floor level the fire was contained. 30 seconds later at 3.56 p.m. the first floor temperature was brought down below 300ºC. At 3.58 p.m. with the water mist system operating the first floor temperature rose to 500ºC and that in the attic to 200ºC.

The fire was allowed to develop and at 4.13 p.m. it was reported to be registering 212ºC in the attic. With the rest of the house pretty much alight, at 4.15 p.m. WME decided to stop operating the water mist system in the Attic, retrieve the equipment from the external wall face, and let the fire burn through the building.

The entire exercise will be written up in detail and reported on to the Action in due course. It (and the latter part of the research seminar) was also video recorded by Norwegian Television. The footage was to be broadcast by the local TV station News programme, and a fuller report would be broadcast nationally in a science based programme series.

Bardshaug Manor-house: 16 April 2004

Architect, businessman and diplomat Christian Thams' home at Bardshaug Manor-house is a unique and intriguing mixture of architectural styles and detailing. Bringing together influences from France, Africa, Belgium, Germany, India and Japan the building now service as a hotel and conference suite facility.

Dating to the late 19th and early 20th century, the importance of the complex warranted it to being fully water sprinkler protected.

The Fire protection project, Roros World Heritage Site: 18 April 2004

The visit to Roros expanded upon the paper *"Presentation of the fire protection project for the World Heritage Town Røros"* given by Anne Steen-Hansen, SINTEF, Norway, during the Research Seminar on 17 April 2004.

Roros was founded in 1644 when a trial copper mine was dug. The first smelting works was completed in 1646 and the town grew quickly thereafter. Smelting continuing until 1953 when a fire resulted in the process being discontinued. Following a fire the current smelting works was reconstructed from 1888 drawings. It houses the museum, exhibitions and offices.

Typical of the period, the town is laid out with two parallel main streets in a rectangular grid. The inhabitants combined mining and farming for a living, with the last working mine being closed in 1986. The Olav mine is preserve along with several buildings of the smelting works and the logging canal. The church dates to 1784, is among the 10 most important churches in Norway, and is the 4th largest in the country.

The oldest and smallest housing in the town area at the top of Sleggveien. These originally accommodated casual labourers, gypsies, musicians, widows, and single women with children. They were in use from 1850 to 1950 and are currently being restored by craftsmen from the Roros museum.

Ingval Maxwell OBE
Chairman
COST Action C17
1 May 2004