NILS MARSTEIN:

Fire Protection of wooden historic Buildings

Wood has always been the main building material in Norway. Still more than 80% of all buildings in Norway are made of wood, although in a different construction than in the past centuries.

Wood has some great advantages that makes it a suitable building material, for instance, it is treatable and gives good thermal insulation.

It has, however, some disadvantages that often cause severe damage to wooden structures. It is not resistant to moisture and insect attacks, it weathers easy, and, last but not the least, it burns.

Norway tops the world list on fire loss per capita. There is no reason to believe that the historic wooden buildings should avoid this fire risk. During the last four years, three important listed churches and several other listed buildings have been destroyed by fires. Recently the wooden part of a palace complex was lost in a large fire.

We have for some years worked with a fire protection programme for the medieval wooden stave churches. The programme includes a fire prevention part and a fire suppression part.

The fire prevention programme deals with different fire precautions: For instance, grass is removed in a one meter zone along the church walls and is replaced by a flagged footpath; smoking or use open fire is prohibited inside the churchyard gate; an lightning conduction equipment is installed.

The fire suppression programme, which will be discussed here, is also divided into different levels. In the most simple form, the fire suppression programme deals with hand extinguishing outfit and water hoses.

The main goal with the fire suppression programme is to install an automatic fire extinguishing and alarm system in each of the 30 stave churches.

Fire Extinguishing systems

For the automatic fire extinguishing system we had different alternatives to evaluate

For outdoor:	Dry sprinkler
	Open sprinkler (deluge)
For indoor use:	Dry sprinkler
	Light foam
	Halon gas

1. Sprinkler test at Borgund stave church, May 1982. The deluge water flow is 1.3 cub.meter per second (16 cub. feet per second).
Essai de systéme d'aspersion á Borgund en mai 1983. (1,3 m³ par seconde).

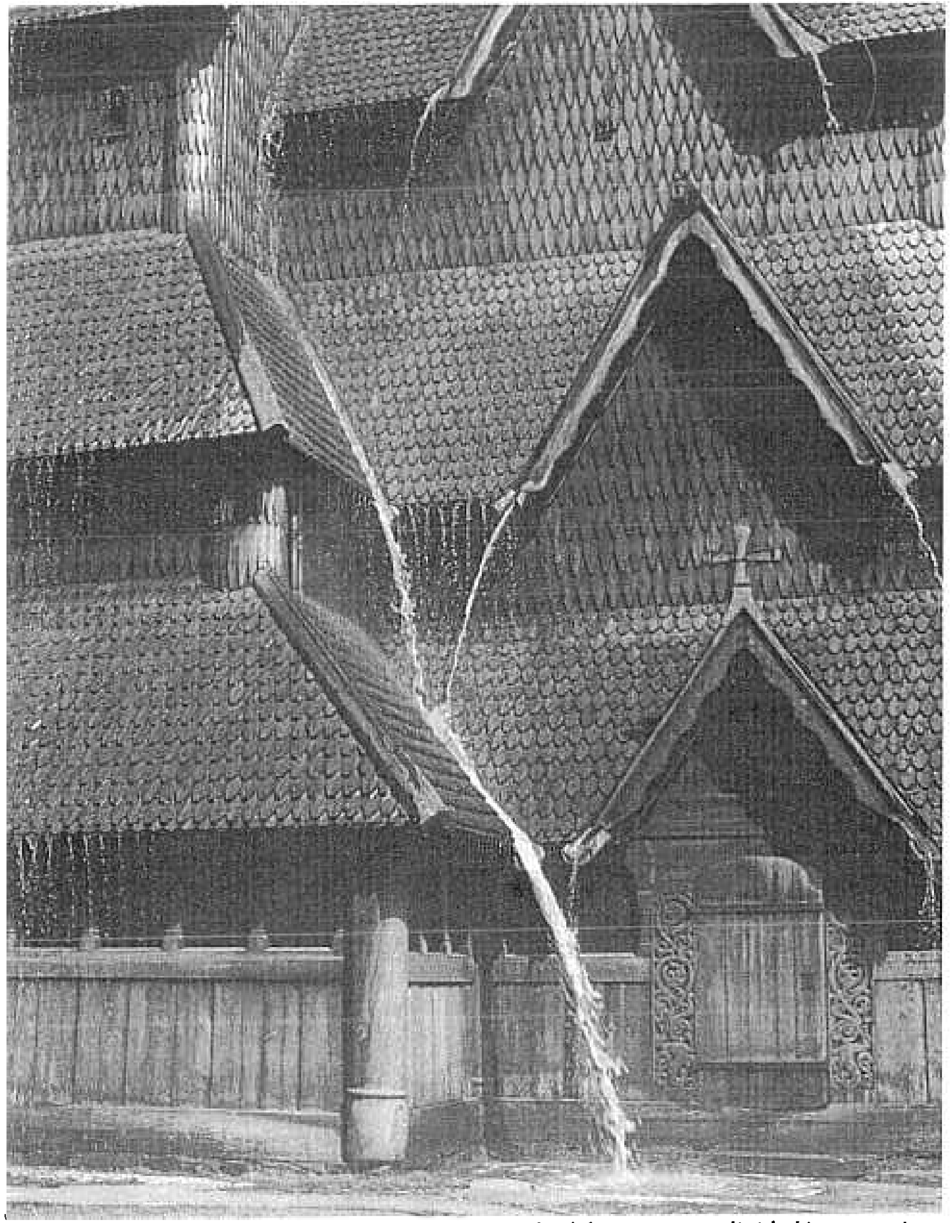
A sprinkler system consists of a water pipe layout with spray heads. The spray heads cover an area of 3×3 meters each, this way we need a spray head every third meter along, the church facade.

The dry sprinkler system is based on a conventional system. The spray heads in conventional system are closed. A membrane closes the end of the water pipe. A heat-sensitive bulb keeps the membrane in place. If the bulb is exposed to temperatures above 70°C, it is destroyed, the membrane falls of, and the pipe end is open to allow the water flowing.

The frost risk makes it difficult, and in most cases impossible, to use conventional sprinkler systems. The basic point for all kinds of water extinguishing systems used in our historice buildings, is that they remain dry until they are activated by a fire alarm. This way we avoid damage caused by frost inside or outside the buildings. By using a valve placed in a bunker in the ground outside the churchyard, we keep the pipes dry until on alarm activates the system.

An open sprinkler system (deluge system) lacks the membrane and the fuse. The water is, like in the dry conventional sprinkler system, held back by valves in the ground outside the churchyard. When it is activated, the water is flowing from all heads at the same time.

For the outdoor use we found after a period of testing, that a combination of a conventional dry sprinkler system (dry due to frost risk) and a deluge system (with open sprinkler heads) would give the best protection. The conventional system could work as



2. Sprinkler test at Heddal stave church, June 1983. The deluge system is divided into 5 sections to ensure necessary water in the top part 20 m (65 ffet) above ground level.

Essai du systéme d'aspersion á Heddal, Juin 1983. Il est divisé en 5 section pour assurer une quantité suffisante au sommet (20 m du sol).

a detection installation for the deluge system, and through this supplement the electronic detection system.

For indoor use, the choice was much more delicate. An installation of a sprinkler system would be rather complicated and would perhaps ruin the sensitive interior of the mediaeval church. The other possibilities, halon gas and light foam, were not so complicated, and would not harm the wood construction and the painted interior the way water would do.

However, the information on the halon's ability to extinguish a fire in wood was disappointing. Halon is 100% effective when it comes to put out a fire in machinery, oil drums and other kinds of surface fires. It is designed for that purpose. A fire in wood, however, must be put out immediately to ensure a proper result. If the fire has made its way into the wood, it will glow beneath the surface. The halon gas will have little or no effect. Tests made at the Fire Research Laboratory of Norway, indicated that the gas might be able to put out the fire, but only under certain, favourable circumstances.

We made a survey through the reports made on this subject around the world. We found no report that proved that halon was capable to put out fire in wood.

It is, however, possible that if we use enough halon gas, we are able to put out any fire in any material. The gas is effective when it makes more that 5% of the total air volume in a room. It is poisonous if it makes more that 12%. In buildings where the walls are as leaky as in the stave churches, it is impossible to keep a constant percentage of 7, which is the Norwegian standard on such gas installation.

As the gas does not put out glows deep inside the wood, the fire will blaze up as soon as the gas percentage is under 5. We know that glows can stay for days in the wood. The halon gas can, as we see it, only delay a fire in wood.

As a conclusion, we decided not to use halon gas as an indoor extinguishing system.

The light foam was more convincing. Water, with a 1-2% addition of a foam producing protein, is sent through a turbine where air is added. This way, 1 litre of water produces up ot 1000 liters of foam. As you see, this gives a dry extinguisher which does not harm wood or painting. In a series of test we made, the foam put out the fire quickly, leaving no trace on wood treated with glue painting.

In order to have the necessary quick effect, the foam had to fill the interior of the church within 5 minutes. In a church with 10-15 meters to the ceiling, this means that the foam ought to rise more that 2 meters per minute. This was alarming; we had to make sure that all people inside the building was evacuated before the foam system was activated. Otherwise, they might drown if they fainted in the foam; as long as we move around in the foam, bubbles will crush and give us enough oxygen for breathing.

As you understand, the risk that anyone might be killed if the foam was actuated by a malfuction, made it impossible to use light foam as an indoor fire extinguisher in the churches.

As the halon gas and the light foam could not solve our problems, we were left with the sprinkler system inside as well as outside the church.

As mentioned before, the sprinkler systems are dry, in order to avoid frost problems. Water is pressed into the pipes when the system is activated by an alarm. The pipe system is self draining, that is if water is put into the pipes, the water will run out of the pipes as soon as the system is out of action.

The detection installation made us face some interesting problems. No commercial detector was suitable for our door use, with rain, snow, wind, and frost. In two of the churches, where sprinkler systems were installed some years ago, the detector systems were out of order. As a smoke detector would react to all kinds of smoke from an area wide from the church, we decided to use a heat detector. After a series of experiments, we found that a wire detector, base on a serial connection of small (5×30 mm) heat detectors with 50 cm intervals, gave us an almost invisible but highly effective outdoor alarm system.

A wire detector based on several small heat detectors has certain advantages compared with a normal bimetal wire detector. Each detector has its own address. This makes it possible to identify the specific detector which is in alarm mode. The detectors also return to normal mode when the fire is put out.

This way we are able to divide the outdoor deluge system into several sections. The wire detectors control different sections of the deluge system. This reduces the water flow and ensures enough water for the upper part of the church.

The addressable detectors give the basic foundation for a new extinguishing system we are developing. In this system we use technology and information from the North Sea oil industry. We are working with a consept where the detectors controls 4-8 water spray cannons placed along the churchyard walls. Each water spray cannong covers one defined area of the church surface.

If we have a fire outside the church, one or more of the detectors elements on the wire detectors will be activated. They alarm the district fire departement, activate the church's fire alarm, and start the actual water spray cannon (s). If the fire is put out, the detectors return to normale mode. The water cannons stop, and the self draining pipe system evacuate the water from frost risk area.

The next step in the development of a extinguishing system like this, will be remote control of the water spray cannon. The detectors can easy inform the cannon that wind deflection has made the cannon miss the target. Then the cannon will turn in ordered direction until the feedback says that the fire area is hit.

A system like this, combined with a ITV monitor equipment, will enable the fire department to overrule the automatic extinguishing system; while the fire engine is on its way, the fireman in the fire department's control room will be able to use a joy stick to control the water spray cannons he is watching on the ITV monitor.

In most cases, the churches are situated in areas with little or no water supply. The lack of enough water under pressure, has made it necessary to install large concrete tanks containing approximately 100 cubic meters of water. The water is pressed into the pipe system by efficient electric or diesel pumps. This will give the sprinkler system enough water for about 50-100 minutes, depending on the size of the church.

The pumps, valves, and the 100 cubic meter water supply is usually placed in a concrete bunker situated in the ground outside the churchyard.

The bunker also contains all elctrical installations that possible can be kept out of the church.

The sprinkler pipes will function as a part of the lightning conductor installation. This demands a careful design of the pipe layout. It also means that we have to avoid all kinds of pipe joints with high electrical resistance. To manage this, the joints are solded together with a special electrical heated solding equipment. Open flame solding is, of course, out of the question.

The Norwegian Government has allocated money especially for fire protection of historic buildings. Each year we receive about 430.000 USD to protection equipment in the stave shurches, and 1.000.000 USD to other listed buildings. These funds makes it possible to protect 3 stave churches and 4-7 other buildings each year. Much time and effort are spent on tests, new designs, and the development of new detection and extinguishing systems. We are still working on the problems on how to fit these complicated structures into sensitive historic buildings. Much has been done, but we still have a long way to go.

Résumé:

Les mesures de protection contre l'incendie des monuments en bois.

Le bois a toujours été le matériau de construction dominant en Norvège. Même de nos jours 80% de la construction est en bois.

Le bois étant un matériau spécialement inflammable il n'est donc pas étonnant que la Norvège détienne le record mondial d'incendies par rapport au nombre d'habitants.

Ces dernières années nous avons établi un programme de protection contre l'incendie des Monuments Historiques en bois, en particulier les *stavkirker.*

1. Mesures de prévention: a) nettoyage d'une bande de 1 mètre autour du bâtiment, l'herbe étant remplacée par un dallage.
b) interdiction totale de fumer dans l'enceinte autor de bâtiment
c) installation de paratonnerres

2. Mesures d'extinction: Le but principal a été d'installer un système d'alarme et d'extinction automatique dans chacune des 30 stavkirker qui nous restent ainsi que dans les monuments profanes les plus importants.

Nous avons eu le choix entre les alternatives suivantes:
Pour l'exterieur système d'aspersion fermé (colonne sèche)
systeme d'aspersion ouvert (déluge)
Pour l'intérieur colonne sèche
mousse carbonique
gaz halon

Un système d'aspersion conventionel consiste en une canalisation d'eau munie de têtes d'arrosage placées à intervalles réguliers (tous les trois mètres pour ce qui est des *stavkirker).* Ce système d'aspersion est difficile à employer dans un climat froid à cause des risques de gel. Il est donc important que l'eau ne vienne qu'à partir du moment où

l'alarme est déclanchée. Dans les systèmes fermés l'eau est retenue dans une cuve enterrée dans le sol et l'arrivée de l'eau est déclanchée par les détecterus. Une combinaison des deux systèmes d'aspersion semble assurer la meilleure protection à l'extérieur d'un bâtiment.

Pour l'intérieur le choix a été plus difficile. Les systèmes à aspersion risquant fort de détériorer les décorations éventuelles et le mobilier, on a donc étudié les possibilités données par les autres systèmes. La mousse carbonique et le gaz halon utilisés à haute dose donnent bien sûr les meilleurs résultats quant au bâtiment. Mais ils comportent de tels risques d'asphixie pour le public que nous avons dû les éliminer et finalement revenir au systemme d'aspersion.

Il a fallu mettre au point un système de détection approprié, composé de plusieurs petites unités autonomes reliées chacune à 4 ou 8 jets d'arrosage placés autours du bâtiment, afin de limiter l'aspersion au stricte nécessaire en attendant l'arrivée des pompiers. Dans la plupart des cas les églises sont situées sans des endroits secs ou à mauvaise pression. Il a donc fallu prévoir des cuves d'eau d'environ 100 m. 3, ce qui nous donne une marge de 50 à 100 minutes avant l'arrivée des pompiers.

Le gouvernement a alloué des crédits annuels correspondant à 430.000 dollars réservés spécialement pour les installations dans les *stavkirker*, et 1 million de dollars pour les bâtiments civils importants. Ceci nous permet de prévoir des systèmes de protection à raison de 3 églises et 4 à 7 bâtiments civils par an.