SP inaugurates new premises
**Editorial**/Björn Sundström

SP's CEO, Maria Khorsand, and the Chairman of Borås City Council, Per-Olof Höög, have just inaugurated SP's new fire research premises. The facility provides us with more space and a new laboratory - the 'spray' laboratory – where we are in the process of installing advanced equipment for laser measurement of flow fields in smoke and water mist. This enables us, for example, to measure droplet size distribution in water sprays from extinguishing systems, as described on Page 36 in this issue of Brandposten. When combined with calculations of water mist transport and firefighting properties, the technology can become an important component in the development of more efficient firefighting systems.

A particularly effective firefighting system has been verified in full-scale fire tests in a road tunnel in Runehamar, Norway. The system, which was stress-tested under extreme conditions on behalf of the National Road Administration, delivered its required performance and will be installed in road tunnels on the Stockholm Bypass route. The Administration's representatives were particularly pleased with the results, as this innovative solution costs only half that of a traditional firefighting system of the same capacity. The trials were spectacular, and were filmed by the Discovery Channel for a ten-minute long film which will be first shown on Canadian television.

Our largest and perhaps most exciting project is that of co-operation with Sintef NBL, the Norwegian Fire Research Laboratory. SP has now a majority shareholding, and the two organisations are already working together in a number of areas. We are both changing names to SP Fire Research. SP Fire Research is active in research, Fire Safety Engineering, support to national and international legislation, off-shore safety, risk analysis, testing, certification, inspection and so on. The group works globally. Both parts will be growing during 2014 and by the end of the year we plan to have a staff at the order of 130 people. Areas of activities are quite integrated using a research staff of about 50-60 people which includes about 20 PhDs. See http://www.sp.se/en/units/fire/Sidor/default.aspx and http://www.sintef.no/home/Building-and-Infrastructure/SINTEF-NBL-as/.

SP Fire Research now has a new PhD on its staff: we congratulate Robert for his success and an excellent thesis on the subject of spalling in concrete when exposed to fire. One of the working areas for which this is relevant is that of safety in underwater tunnels: a fire in such a tunnel must not create any risk of impairing the strength of the concrete.

Luleå University of Technology has announced a chair in Fire Technology, with the aim of improving the training of fire engineers and expanding research in the area in Luleå. The university has also seen presentations of two licentiate theses during the year.

Five new members of staff - Sven Karlsson, Anna Sandinge, Robert Svensson, Kim Olsson and Christina Nordström - have joined us since the summer: we wish them warmly welcome to SP Fire Research.

Björn Sundström
Manager, SP Fire Research
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New SP Reports

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Cover picture SP inaugurates new premises. Photo: Dick Gillberg
SP Fire Research inaugurates new premises

SP Fire Research has expanded its facilities by about 1000 m², in the form of about 30 office rooms and a fine new laboratory. Expansion at the rate of about 10 % per year has meant that we were growing out of our existing premises while at the same time establishing new services. In the new laboratory, which goes by the name of the ‘Spray laboratory’, we can perform such work as testing older sprinkler heads and checking the performance of fusible links for fire ventilators. These are important components which must work in the presence of a fire. In addition, we are installing advanced equipment for laser measurement of flow fields in smoke and water mist, known as Particle Image Velocimetry, PIV. Data from such tests can be used to verify calculations or to forecast the spread of smoke.

The formal opening was performed by SP’s CEO, Maria Khorsand, and the Chairman of Borås City Council, Per-Olof Höög, together triggering an impressive flame that burned away the inaugural tape. The event was attended by over a hundred invited guests from businesses and public services in Borås. It was followed by a tour of the new facilities, with presentations of the risks of bus fires, arson and our new working area in the offshore field, with the latter being supported by a special presentation of our working partner in this area, the Norwegian Fire Research Laboratory, NBL. NBL’s managing director, Paul Halle Zahl Pedersen, described its major resources at its laboratory in Trondheim, with particular reference to offshore and construction. We also presented a live demonstration of a fire in a sofa, caused by a candle, and of particular relevance at Christmas time, as fires of this type grow very rapidly.

The whole event was then concluded by an opportunity for those attending to mingle. This was particularly welcome for us at SP, providing an opportunity to describe some of our work and to show some of our research and experimental facilities. I look forward to further inaugurations of new facilities in the future.
New managing director at SINTEF NBL

Paul Halle Zahl Pedersen was appointed managing director at SINTEF NBL from 1st October 2013. Paul is 40 years old and has three children. He grew up in Sømna municipality in northern Norway, where he comes from a farm that has operated meat and milk production. Although being the holder of the allodial rights, Paul is not planning to pursue a career in farming. Paul has followed a somewhat untraditional educational path. His first education was at the vocational level, being trained as machinist. He then worked as a mechanic in the shipping industry for several years, and sailed as an engineer in both defence and offshore vessels – specifically standby-boats. After a few years of working, Paul started studying to be college engineer at Oslo College of Engineering and took a BSc degree in mechanical engineering, specializing in oil and gas constructions. Furthermore, he completed an MSc-degree in operational techniques at the Institute of Marine Technology at the Norwegian University of Science and Technology (NTNU) in Trondheim.

After completing the MSc-degree Paul Halle Zahl Pedersen was admitted as a PhD student at NTNU Marine Technology, where he studied economic models for optimal maintenance of technical installations. He ended his research fellowship after one year and went over to the private sector and to the consultancy firm Force Technology. At Force Technology Paul Halle Zahl Pedersen worked with many issues within the offshore industry; criticality analysis, risk-based inspections (RBI), reliability-based maintenance (RCM analysis), pipe calculations, strength calculations and minimum calculations for corrosion, technical risk assessment and failure mode-, effects- and criticality analysis (FMECA).

After several years as project manager at Force Technology, Paul Halle Zahl Pedersen joined Statoil in 2005. There, he worked with the daily operations of the Åsgard field in the North Sea, where oil, condensate and gas is produced. This is a field with three installations. Paul’s department had the responsibility for optimization of operations and ensuring maximum regularity. The tasks varied from planning turnarounds to helicopter planning. But most important was good HSE and good production. After four years in this position he had the opportunity to work offshore. This was a very instructive period of time, with many challenges. The operation of platforms is a complex area, with many factors that must work, both human, technical and organizational. In the North Sea it is both harsh and long distances to shore, and you are dependent on that everything is working, both with respect to personnel and to technical conditions.

After three years in the North Sea he returned to land and the path led to Statoil R&D in Trondheim. There, Paul Halle Zahl Pedersen was appointed Head of Technical Research Support (TRS), and with that responsible for the daily operation of Statoil's laboratories in Trondheim, Bergen and Porsgrunn. As the head of this unit the tasks were mainly aimed at follow-up of customers and partners, expertise and organizational development, and implementation of Statoil's strategy. In addition he was responsible for budget and investments, recruitment and development of the management team, as well as development of the department in line with Statoil’s ambitions and goals.

However, after eight years in Statoil, SINTEF NBL appeared with an exciting challenge, and at the same time, SP is on its way in as shareholder. “This job interested me greatly, and I feel very strongly that we shall succeed”, says Paul. “It is a very good match between SINTEF NBL and SP Fire Research, what is most important now is to draw the best out of these two organisations so that we become cost effective and competitive. We have a very good product and there are many unresolved fire technical issues still needing research. It is in this area we will strengthen through our partnership; the area of fire research.

I find both SINTEF NBL and SP Fire Research to be good work places. There are good professionals at all levels and I’ve got a very good impression of both organisations. What we need to work on, and which I have chosen to focus on, is health, safety, environment and quality (HSE +Q). If we are good in this field, we will be more attractive to our customers, which will give us a competitive advantage. Good HSE means good operation. Daily, we need to ask ourselves: What is our delivery? What is the task? Only then can we identify risk and thus be able to manage risk. This is central to my leadership.”

Paul concludes that he is positive about the future, and that he is convinced that the co-operation between SP Fire Research and SINTEF NBL will be very good. He looks forward to working with his new colleagues in Norway and Sweden.
SP, working in conjunction with prefabricated house manufacturer A-house, part of the Derome Group, has developed an energy-efficient detached house. The house, which was erected on SP’s site in Borås during the autumn, incorporates the latest technology in efficient use of energy and constructional features. The objective is that the overall cost should not be higher than that of an ‘ordinary’ newly-built detached house. The aim is to reduce energy use by at least 60 % in comparison with present-day standards. The house also provides a facility for testing and evaluating innovative technology and methods in a controlled and faithfully realistic environment. The house will also be seen by many, as it has been erected on the edge of the visitors’ parking area, as shown in Figure 1.

The house has been built as part of the joint NEED4B EU-financed project, the objective of which is to encourage the construction of low-energy buildings - residential buildings, offices and public buildings. The buildings will then be monitored for a period of two years in order to ensure that they are meeting their energy targets. In total, 27 000 m² of building area will be constructed between 2012 and 2018 in five European countries. Sweden’s contribution consists of two very low-energy houses. The second of these has been constructed in Varberg, and will differ from that in Borås in actually being used as a residence. Results and experience from the project will be published, hopefully assisting all new buildings to have better energy efficiency.

SPRINKLERS IN RESIDENTIAL BUILDINGS ARE RELATIVELY UNCOMMON IN DETACHED HOUSES, ALTHOUGH THEIR INSTALLATION IS RELATIVELY INEXPENSIVE AND STRAIGHTFORWARD IF CARRIED OUT USING THE VERY LATEST SPRINKLER TECHNOLOGY. THIS HAS BEEN DEMONSTRATED IN AN ENERGY-SMART DETACHED HOUSE ERECTED ON SP’S SITE DURING THE AUTUMN.

LATEST TECHNOLOGY OF RESIDENTIAL SPRINKLERS
Sprinklers in residential buildings are relatively uncommon in detached houses, although their installation is relatively inexpensive and straightforward if carried out using the very latest sprinkler technology. Working in conjunction with material suppliers and an installation contractor belonging to Sprinklerfrämjandet (The Swedish Fire Sprinkler Association), a residential sprinkler system has been installed in the house in order to demonstrate simple, aesthetically satisfying and cost-effective solutions.

The starting point for the installation is that the system is connected directly to the house’s cold water supply via a manifold in a manifold cubicle. A flow switch, upstream of the manifold, generates an alarm when a sprinkler has been activated. In turn, the house’s water meter and main shut-off valve are fitted upstream of the flow switch. This means that the sprinkler system itself has no main shut-off valve, thus reducing the risk of the system being accidentally turned off. The water meter is of the inductive type, having the high accuracy desirable in this particular house. In addition, it has a very low pressure drop at the flows normal for a sprinkler, and also incorporates an integral check valve.

INTEGRATED WITH THE COLD WATER SUPPLY SYSTEM
The sprinkler system manifold has four output connections, with two for each floor, as shown in Figure 2. The water circuits are arranged...
in two ring mains, with one for the ground floor level and one for the upper floor. Each sprinkler can therefore receive water from two directions, thus reducing the pressure drop in the system and allowing small-bore pipes to be used. The pipes themselves consist of an internal and an external PE-RT pipe, separated by an aluminium pipe. This arrangement makes optimum use of the properties of both plastic and aluminium. The pipe dimension is 25 mm by 2.5 mm, i.e. an external diameter of 25 mm and a wall thickness of 2.5 mm. The pipes are supplied in rolls, and can be bent, which facilitates the work of installation. The small pipe diameter was necessary in order to allow the pipes to be run between the ceiling battens and the gypsum plasterboard ceiling panels. The secondary battens are of standard 28 mm by 70 mm size, with c-c distance of 300 mm, which means that very little space is available for the sprinkler pipes. For this reason, the pipes have not been run in an outer leak telltale pipe, known as 'pipe-in-pipe' construction. However, any leak from a sprinkler pipe would require only the pipe between two adjacent sprinklers to be replaced. Apart from the connections to the actual sprinklers, there are no joints in the pipes except at a few positions in which joints were essential for reasons of space.

On each floor, the system is connected to the lavatory on that floor, which means that the system is partly integrated with the main cold water system in the house. Every time the lavatory is flushed, it is re-filled via the water in the sprinkler system. This serves the dual purpose of preventing water from stagnating in the system and also providing an indication that there is a supply of water to the system. There are therefore no special requirements for reverse flow protection to the public water system, apart from those applicable to any normal cold water system.

Concealed sprinklers with low water flow rates

One of the aspects to be considered, important for many house-owners, is the purely aesthetic. The sprinkler system must not, in other words, be visible, and so it uses ‘concealed sprinklers. The sprinklers are therefore recessed into the ceiling structure, covered by a 70 mm diameter white circular cover, which drops away when the temperature reaches 57 °C, and the sprinklers activate when their fusible links reach a temperature of 74 °C. Figure 3 shows a sprinkler after installation in the ceiling space.

The sprinklers have a K-factor of 43.2 (liter/min)/bar, with a design flow rate of 30.3 liter/min from a supply pressure of 0.5 bar. At this pressure, the maximum coverage area per sprinkler is somewhat over 13 m². The system is designed for simultaneous operation of two activated sprinklers, which means that the total water flow is a little over 60 liter/min. This is equivalent to a delivery rate of 2.05 mm/min, which is the lowest permissible delivery density in accordance with the requirements of Swedish standard SS 883001 and with the recommendations in NFPA 13D.

Sprinklers are installed in all rooms of the house, apart from its ‘climate lock’ and the ‘winter garden’, where above-zero temperatures cannot be guaranteed. The house therefore has a total of 22 sprinklers, with 13 on the ground floor and nine on the upper floor.

Even though residential sprinklers are installed, a fire alarm provides an important element of fire protection. In a normal case, local (in-house) fire alarms would be installed: in this particular case, however, the fire alarm is connected to SP’s area protection system and to the fire and rescue services. Alarms from the sprinkler system’s flow switches are connected to SP’s area protection system.

A seminar on residential sprinklers is planned for the spring of 2014, with demonstration of the sprinkler installation.
SP Fire Research arranges a seminar and courses on fires in vehicles

Responding to the high level of interest in fire safety in vehicles, SP arranged a seminar on the subject in November. The seminar was supported by several courses. Almost 220 persons attended the seminar, and a total of 130 attended the courses.

Seminar on fires in vehicles
November 5th almost 220 persons gathered at First Hotel Grand in Borås for a Nordic seminar on fires in vehicles. The seminar was opened by Tore Björkman from TS Utredartjänst, who described examples of contributory factors that can result in a vehicle fire. In many cases, fires are the result of a combination of vehicle design, general wear and tear, and inadequate maintenance. He was followed by Arnt Ivar Holmstad, from Norska Tryg, who described the causes of fires in cars and the method of investigating vehicle fires. Alexander Johansson, of Anker AB, presented examples of bus fires, and described how bus operators can help to prevent fires. Kristian Lindström from Lokaltapiola in Finland, presented the results of a Finnish investigation in 2013 that analysed the causes of 186 bus fires.

SP’s Jan-Olof Nilsson described the requirements for inspection and approval of fire protection measures, and presented statistics from the results of tests. Lars Nilsson from Trygg Hansa described the work of the Swedish insurance sector in reducing the number of vehicle fires which, in addition to requiring integrated firefighting systems, also include annual fire safety inspections of heavy vehicles. This work has drastically reduced the costs of fire damage claims. Per Björnberg, Volvo CE, described examples of Volvo’s work on vehicle design in order to achieve high fire safety. Oskar Bialas, of SP Fire Research, described the operation of various types of firefighting systems and their ability to control engine compartment fires in buses.

Ronnie Hansson, from LKAB, described the problems presented by vehicle fires in mines, which risk area was further emphasised by the examples of spread of fire between vehicles underground presented by SP Fire Research’s Haukur Ingasson. Anna Brand, from the Helsingborg fire service, discussed the fire in two gas-powered buses that occurred in Helsingborg in 2012, and showed what happens when gas tanks evacuates the fuel. The jet flame from such a vent is significant, making it difficult for fire and rescue services to decide on the best way of tackling such fires. Reidar Skrunes from Norska If described tests of fires in electric vehicles, while Lars Hoffman, of SP Electronics, described electrical safety risks, both in general terms and in particular for electric/hybrid vehicles.

Courses in investigation of vehicle fires
To complement the seminar, SP Fire Research held one-day courses in the methodology of fire investigation on 4th, 6th and 7th November, led by Tore Björkman and Stefan Skoglund from TS Utredartjänst. Both have a background in the police service, specialising in vehicle-related crime, and followed by investigation of vehicle damage. Those attending the classes could inspect vehicles that had been involved in fires in order to find the cause of the fires. The vehicles included some which had been deliberately set alight, and others that had suffered various types of electrical fires.
Work starts in ISO on safe handling and storage of wood pellets

How can wood pellets be safely stored? How can a fire in a silo be extinguished? What is the best way of testing and analysing any particular type of pellets in order to assess their tendency for spontaneous combustion or gasification? These are some of the most important questions that the new ISO Safety Group will hopefully be able to answer.

Essentially all organic materials are prone to self-heating, although to different extents. Whether or not this is a problem depends on the type of material, how it is stored, how much is stored, and on various ambient conditions. There are still a number of gaps in our knowledge, and areas in which more research is required, but it has become increasingly clear that there is a need to develop standardised methods of testing and clear guidelines based on existing knowledge. New and larger storage facilities are being built, and experience from fires that have occurred shows that there is a substantial need for guidance on how to prevent fires and explosions, and how to minimise the consequences of any incidents.

Anders Lönnermark chairman of safety standard working group

At a meeting of ISO/TC 238 in Bangkok in the spring, the Swedish delegation put forward a proposal to establish a group to draw up safety standards. The proposal was accepted, with Sweden being appointed to manage the work. The group held its first meeting at the beginning of October, inviting international experts to participate. The meeting attracted about 15 persons from seven different countries: in addition to them, several other experts, from Canada, the USA and elsewhere, had notified their interest in participating in the work. Anders Lönnermark was appointed chairman of the safety group. The main result from the meeting was the establishment of five sub-groups to prepare drafts of various documents, including guidelines for safe handling and storage of pellets in various sizes of stores, as well as of standards for methods of determining the tendency of materials to undergo spontaneous self-heating and/or gas generation. SP Fire Research’s Henry Persson and Per Blomqvist are also active members of these sub-groups.

A formal decision of which ‘work items’ are to be included in the group’s work will be made at the next meeting of ISO/TC 238 in Stockholm in June 2014.
The Swedish Transport Administration chooses a newly-developed firefighting system for road tunnels in the Stockholm bypass project

Full-scale tests have been carried out on a new fixed fire-fighting system in a road tunnel in Norway. On behalf of the Swedish Transport Administration, SP Fire Research has performed a series of six tests in which the system has been stress-tested under various fire conditions. The tests were so spectacular that both the Discovery Channel and Norwegian TV2 filmed them.

The objective of the tests, which were carried out in the Runehamar tunnel in Åndalsnes in Norway, was to measure the maximum acceptable time delay from the start of the fire until the fixed fire-fighting system must be activated in order to control a fire in a postulated goods vehicle trailer. On detection of a fire by fire monitoring cameras or the fire detection system, a 50 m long section of the fixed fire-fighting system in the area of the fire is activated, discharging water at a rate of 10 mm/min. The system consists of a single pipe along the centre of the tunnel ceiling, to which two spray nozzles are connected with a T-pipe downwards every five metres, each nozzle discharging 375 l/min of water horizontally in the sideway direction towards the tunnel walls. The result is that the entire tunnel cross-section is filled with large water droplets, preventing the fire from continuing to grow. Each nozzle discharges as much water as a fire-fighter with an ordinary hose. The unique feature of the system is its simplicity, together with the fact that large water droplets are sprayed sideways, thus filling the entire tunnel cross-section. Capital and maintenance costs have been calculated as approximately half those of a traditional system.

**The Runehamar test tunnel**

The tunnel in which the system was tested is an abandoned road tunnel which is no longer used. The Norwegian Road Administration has therefore used the tunnel for test purposes. The average size of the tunnel is 9 m wide and 6 m high, i.e. somewhat smaller than the Stockholm bypass tunnels in which the fixed fire-fighting system is to be installed. Its length is about 1650 m, and various carefully selected lengths have been protected by application of sprayed concrete in...
order to withstand fires. SP's tests were performed about 600 m from one end of the tunnel. Ventilation in the tunnel is controlled by fans, capable of maintaining an air velocity of 3 m/s in the postulated vehicle's direction of travel, i.e. the same air velocity as that for which the Stockholm tunnels are designed.

The fire source
The fire source consisted of wooden pallets, representing the load on a goods vehicle, and delivering a heat release rate of 80 MW. The load was protected by steel sheets in front and behind, as well as over the top of the pallets. This arrangement makes it difficult for the water to penetrate directly down onto the pallets, thus making it more difficult for the system to fight the fire. The pallets were ignited, and temperatures, air and water flows, pressures etc. were recorded. The actual heat release rate was calculated from measured data of oxygen content and air flow further away from the fire.

Performing the tests
In order to simulate a real situation as closely as possible, it was assumed that a certain gas temperature against the roof of the tunnel represented detection of the fire. Having been detected, a few minutes were added in order to locate the fire and manually start the fixed fire-fighting system. This length of time was the main variable parameter for the tests.

The detection temperature was set at 141 °C. The time from detection until activation was set initially at two minutes, with this time being increased for successive tests until the system was no longer capable of keeping the fire under control.

In addition to these tests, two further tests were carried out in which the physical arrangements and conditions were changed. One test involved a tarpaulin along each side of the trailer fire source in order to represent a covered load. In the other test, the steel plate in front of the load was removed so that the wind could help the fire to spread forward into the pallets. In both these tests, the fire was allowed to grow until the gas temperature below the tunnel roof reached 141 °C, followed by a further four minutes for ‘manual work’ before the water flow was started.

As the test series was carried out primarily in order to stress-test the fixed fire-fighting system under extreme conditions, the order of the tests was changed from that originally planned as the system performed better than expected. Table 1 shows the sequence of tests as performed.

Results
Even if activation should be delayed, the system has sufficient marginal capacity to fight major fires. It prevents further spread of a fire, and reduces the gas temperature in the tunnel; factors of considerable importance for design safety and for those escaping from a fire. This is also relevant in connection with the design of the fan system for the Stockholm Bypass project. It has been possible to reduce the design fire rating of 100 MW that was originally assumed, to 50 MW in combination with this fixed fire-fighting system, giving substantial savings in the capital costs of the ventilation system. A ventilation system capable of handling the smoke and heat from 100 MW requires considerably more drive power than one rated for 50 MW. The tests have shown that, if the system is activated too late, there is a significant increase in the quantities of toxic substances and smoke: this can be prevented by activating the system at an early stage.

In the tests with the fixed fire-fighting system activated, a heat release rate higher than 40 MW was never observed. The Swedish Transport Administration wanted a system capable of controlling fires and keeping the heat release below 50 MW. Gas temperatures below the tunnel roof never exceeded 400 - 800 °C after activation. Each of the tests controlled the fire during the period immediately after activation, and then continued until the fire was effectively extinguished.

To investigate the risk of further spread of the fire, a pile of pallets was positioned 5 m downstream of the end of the fire load. This pile was not ignited in any of the cases in which the fire-fighting system was activated, showing that vehicles in the vicinity of the burning object are effectively cooled by the water spray.

The heat release rate from the ‘almost free burning’ test was measured as approximately 80 MW, with a gas temperature in excess of 1300 °C. This particular test provides a good indication of the potential fire that the system is capable of handling.

Table 1  Order of tests

<table>
<thead>
<tr>
<th>Test nummer</th>
<th>Förutsättningar</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>141 °C tunnel ceiling temperature + 2 minutes</td>
</tr>
<tr>
<td>2</td>
<td>141 °C tunnel ceiling temperature + 4 minutes</td>
</tr>
<tr>
<td>3</td>
<td>141 °C tunnel ceiling temperature + 8 minutes</td>
</tr>
<tr>
<td>4</td>
<td>141 °C tunnel ceiling temperature + 4 minutes + load covered with tarpaulin</td>
</tr>
<tr>
<td>5</td>
<td>141 °C tunnel ceiling temperature + 4 minutes + front plate removed</td>
</tr>
<tr>
<td>6</td>
<td>Almost free burning (due to a failed bolt in the fixed fire-fighting system)</td>
</tr>
</tbody>
</table>
Arson – a societal problem

Arson is a serious problem, which costs Sweden over SEK 1000 million per year. In total, over 10 000 cases of arson occur per year in Sweden. Arson accounts for at least 25% (according to some sources, up to 40%) of all fires each year. This proportion rises to 50% for arson in schools. A five-year programme investigating the phenomenon, with particular concentration on arson in schools, has recently been concluded. The programme has been managed by the Swedish Fire Research Board, with SP Fire Research as the technical programme manager.

The problem
The programme has applied a cross-disciplinary approach, with a total of 16 different sub-projects covering both technical systems and human behaviour. This report presents only a selection of projects. Presentation of all the sub-projects can be found on www.anlagdbrand.se.

Available statistics show that:
- Each year, the Swedish Fire and Rescue Services respond to about 10 000 fires in buildings and about 15 000 outdoor fires. Of these, about 1 400 (12%) and 5 000 (30%) respectively are stated to have been deliberately started.
- The cause of fires in buildings is stated as Unknown in 25% of the cases, indicating a large margin of uncertainty.
- About 300-400 fires per year are reported in schools, of which about 200 have been started deliberately.
- Arson fires in schools are generally started at lunchtime or in the later evening; in infant schools, generally in the evening.
- Serious fires in schools are generally started in the evenings and at weekends.

Design fires and technical systems
Table 1 summarises the main parameters of four design fires, typical of deliberately started fires in schools and infant schools. The project has also studied the technical systems employed in schools and infant schools in Sweden, with the data being used for a cost-benefit analysis of a number of systems. The results of the analysis show that it is cost-effective to employ certain technical design features in exposed areas, but not to introduce the requirements on a country-wide basis.

<table>
<thead>
<tr>
<th>Fire</th>
<th>Description</th>
<th>Maximum heat release rate (kW)</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Outdoor fire</td>
<td>100-500</td>
<td>Rubbish</td>
</tr>
<tr>
<td>2</td>
<td>Smaller vehicle</td>
<td>1 000-1 300</td>
<td>Motorcycle with plastic cover</td>
</tr>
<tr>
<td>3</td>
<td>Flammable liquid. Molotov cocktail</td>
<td>50-800 300-1 300</td>
<td>Petrol on flammable floor materials.</td>
</tr>
<tr>
<td>4</td>
<td>Fireworks</td>
<td>20-100</td>
<td>Based on experiments</td>
</tr>
</tbody>
</table>

Typology of arsonists
Only about 5% of juveniles ever start a fire. Of them, only a few (about 0.3‰ [three per thousand]) do not also commit other crimes. A typology of young arsonists has been produced, based on analysis of data from BRÅ (the Swedish National Council for Crime Prevention), and from a number of court cases.

The commonest arsonist is a 16-year-old boy, also engaged in other criminal activities, such as vandalism. It is also clear that this group presents extensive individual and social problems. Figure 4 illustrates the typology that has been identified.
Arson in schools on the decline

Even over the period of the programme, a downward trend has been observed in terms of arson in schools. The project has not specifically analysed this decline in the short term, and we can only speculate on what actually lies behind it. One reasonable explanation is that the decline is part of a larger downward trend concerning juvenile crime, which can be clearly seen in the reduction of criminal and problematic behaviour in BRA’s school surveys. This change is usually explained by changes in recreational habits (more time is spent in front of computers), by more socialisation and better communication between young persons and their parents, by a change in attitudes towards, and performance of, schools etc. Based on the results from the project, it can be hoped that there will be a further reduction in arson in schools as a result of implementation of the various recommendations from the project.

Taken together, the results of the analysis show that arson is part of a larger social problem. Preventative work therefore needs to be defined and applied in conjunction between relevant stakeholders such as the fire and rescue service, schools, social services, police, voluntary organisations etc. The recommendations listed below are aimed variously at specific groups and sometimes at several groups, but a similar approach and improved communication between different parties would in all cases have a beneficial effect on arson as a phenomenon.

Recommendations

The programme has drawn up a number of clear recommendations, e.g.:

- Identify and counter all ‘playing with fire’.
- Teach children and juveniles about fire and its consequences.
- Improve the work environment and social relationships in schools.
- Create a pleasant and open school environment, with a high presence of teaching staff.
- Reduce the opportunities for setting fire to objects.
- Install technical systems to prevent or reduce arson.
- Implement the design fires defined in the project.
Nowadays buildings are fitted with numerous technical installation services for power supply, computer networks and transportation of water and sewage. In many cases these services penetrate fire separations in places that are mostly hidden away above ceilings and in alcoves. Since they are usually hidden from plain view it is especially important that these penetrations are fitted with suitable protection that fulfil the fire safety requirements.

What are penetration seals?
Generally, a penetration seal is a system to maintain the fire resistance of a separating element at the position where technical services pass through. More specifically, these services are pipes and electrical cables (including bus bars and coaxial cables), but not ventilation systems. One condition is that the services actually pass through the separating element, thus an electrical socket is not a penetration but is part of the partition.

Determining the fire resistance
The European Committee for Standardisation (CEN) has developed standard fire resistance tests for service installations, for penetration seals in standard EN 1366-3. The edition currently in use was published in 2009. This standard describes a method of test for assessing the contribution of a penetration seal to the fire resistance of separating elements. The technical installation services that are currently covered, represent services that can commonly be found on building sites in Europe, such as cables and pipes in various configurations.

During the fire resistance test, assessments are performed to determine the integrity and insulation performance of the separating element, the sealing system and the penetrating services. The worst result obtained determines the result of the sealing system. The integrity criterion is determined by using cotton pads to capture hot gases escaping through cracks and by visual observations of sustained flaming, which is defined as continuous flames on one location for a minimum duration of 10 seconds. The insulation criterion is determined by measuring the surface temperatures on the non-exposed face of the separating element, where a temperature rise of 180 K generally constitutes a failure.

As part of CEN’s revision cycle, this particular test standard is undergoing extensive changes to make it more user friendly and better suited to products that are currently in the market. Through continuous testing and new insights, some of the current rules will change and new rules will be added for more widely used services such as conduits containing cables.

If all goes well the revised test standard will be published late 2015.

European regulations
With the full implementation of the Construction Products Regulation (CPR) on July 1, 2013 manufacturers of constructions products have the obligation to CE-mark their products when they bring them into the market in European member states. But this is only applicable if that specific product is covered by a Harmonized European Product Standard (hEN); penetration seals are not covered by a hEN at the moment. However, it is still possible to obtain a CE-mark for such products, but the products characteristics must be based upon a European Assessment Document (EAD). For penetration seals the European Organisation for Technical Assessment (EOTA) has developed European Technical Approval Guideline N° 026 (ETAG N° 026), which serves as an EAD. In addition to the fire resistance of the product or system, other product characteristics such as durability and serviceability, airborne sound insulation or reaction to fire class can, and sometimes have to, be determined. An obtained CE-mark is a way for the manufacturer to declare the material properties, it is not a quality mark.

Some key players in the European market have already obtained European Technical Assessments (ETAs) for their penetration seal systems, which makes it easier to sell their products on the European market. Without these ETAs they would have had to obtain national approvals in separate European member states.

SP Technical Research Institute of Sweden
SP has testing facilities to determine the fire resistance of penetration seals in all possible configurations, in both vertical and horizon-
Susanne Andersson demonstrates the furnace temperature sensor in the EN ISO 1182 method for some of those attending this year’s EGOLF training courses.

SP is training fire laboratories in the European system for classification of construction products

On behalf of EGOLF, SP has been training European fire testing laboratories in the harmonised European standards used for CE-marking of the fire resistance properties of construction products. EGOLF is the European Association of Accredited Fire Testing Laboratories in the EU and EEA areas, and has over 60 members.

During a week in October, SP held courses in all the test methods included in the European EN 13501-1 classification system for construction products. The courses covered EN ISO 1182, non-combustibility, EN ISO 1716, determination of calorific value, EN 13823, the SBI method, EN ISO 9239-1, floor coverings, and EN ISO 11925-2, the small flame test.

The purpose of the course material, which is sanctioned by EGOLF, is to ensure a high and consistent level of testing technology competence on the part of EGOLF’s members. The courses involve a mix of theoretical explanation of the methods with practical exercises such as calibration procedures, setting up materials for tests, and materials themselves.

The courses are aimed primarily at fire testing laboratory personnel, but those attending this year’s courses also included personnel from manufacturing companies having their own laboratories.

In addition to the testing methods specified in EN 13501-1, we also provide courses in resistance to fire in accordance with EN 1363-1, General requirements, 1364-1 Non-load-bearing walls, EN 1366-3 Penetration, and EN 1366-4 Linear joint seals.

Working in conjunction with a fire testing laboratory in Belgium, we are also preparing new course materials for training in CEN/TS 1187, Test 2, External fire exposure to roof coverings, for the Nordic market. This course will be held at SP in Borås during the autumn of 2014.

Stefan van de Wetering is a project manager at SP and is mainly involved in fire resistance testing for technical installations such as penetration seals and fire dampers. He is SP’s representative in EGOLF and CEN TC 127 WG2.
Reaction-to-fire requirements for textile membranes in temporary buildings

SP Fire Research and Brandskyddslaget have now concluded a research project investigating the fire risk of textile membranes when used in temporary building structures. The work has evaluated small-scale test methods and validated the results against large-scale tests. The main result is a proposal for revised test methods and requirements ensuring closer harmonisation with those applicable to textile membranes in permanent buildings.

Using textile membrane products as building materials
Textile membranes are increasingly used in various types of building structures, both in permanent and in particular in temporary buildings. The traditional use of textile membranes for larger structures has been for tents, however, applications for textile membranes have become wider and have come to include new application areas such as event buildings erected for sport contests or other major events. The use of textile membranes for weather protection during the construction or renovation of multi-storey buildings for flats and offices is another new growing application.

This project has investigated the existing fire protection requirements in Sweden for public tents and other large temporary textile structures. The regulations for public tent buildings were under revision by MSB (the Swedish Civil Contingency Agency) at the time of the project. A goal of the project was to ensure that the fire safety for textile membranes in large tents was maintained, and further to define requirements for the new applications.

The work in the project has focused on the requirements and reaction-to-fire behaviour of textile membranes. The issues regarding fire resistance of the load carrying structure and evacuation from a textile building structure during a fire have not been addressed.

Regulatory structure and applications
The Swedish fire safety regulations for public tent buildings are governed by the Public Order Act and are regulated by requirements and guidelines from MSB. These rules are designed specifically for larger tents (> 150 persons) and the fire safety requirements are based on tests with a small flame (SIS 650082) or alternatively a large-scale test.

It has been seen that these regulations most often are applied properly for traditional public tents, where there are requirements on inspection and a type approved textile membranes. Regarding the new types of textile buildings, it seems that requirements from authorities have been unclear and have varied from case to case. The reason for the unclear requirements is that authorities seem often to require “material difficult to ignite” instead of referring to a specific test or regulation.

There has recently been a change in the regulations concerning the fire safety in permanent buildings. EN 13501-1 classification of textile building materials in permanent buildings is now included in the present Building Regulations from Boverket, BBR 19 (2012). The basic requirement is Euroclass E for single layer textile membranes. There are thus different test requirements on textile membranes depending on if they are going to be used in a temporary or permanent building.

With regard to fire safety requirements for textile membranes in weather protection applications, there appears to be no clear regulation. In some cases, there are requirements from the local rescue service or from the builder for test approval according to EN 13501-1. In other cases, there are probably no fire requirements requested whatsoever. It is clear that Arbetsmiljöverket (the Swedish Work Environment Authority), which is the responsible authority in this case, should provide clear requirements to raise the safety level.

The fire performance requirements generally referred to in Europe today, for textile membranes in permanent buildings, temporary buildings and weather protection, is EN 13501-1. Requirements for particular Euroclass ratings for different applications vary from one country to another. It can be noted that most of the Nordic countries have based their requirements on the Euroclass system.

Evaluation of methods for classification testing
Classification tests with typical textile membranes for some selected applications were conducted. The products investigated included a range of PVC coated polyester fabrics (PVC/PES), textile membranes that are used for large tents and event building. One of these PVC/PES products was for use as weather protection. Additionally a polyethylene membrane for weather protection applications on scaffoldings was included in the test programme.

All products were tested with the current Swedish classification tests, SIS 650082, and EN ISO 11925-2, which is a small flame test required in EN 13501-1. The conclusion from these tests was that EN ISO 11925-2 with 15 s edge application was equivalent, or harder to pass, compared to the present application of SIS 650082 for textile membranes. This test procedure with EN ISO 11925-2 corresponds to

Figure 1. Fire test of a PVC/PES fabric. The ignition source, a propane burner, was positioned inside the corner.
Euroclass E.

A few of the PVC/PES membranes and the polyethylene membrane were selected for tests with EN 13823, the SBI-method. This is a medium scale test method for determination of heat release rate, smoke production and flame spread. This test method, together with 30 s flame application with EN ISO 11925-2, is required for Euroclasses superior to E.

The results of the EN 13823 tests showed that the mounting of the textile membrane is important for the outcome of the test. A metal support for mounting the corner of the test specimen resulted in a more accurate test. Generally, this mounting procedure results in a lower Euroclass but gives more repeatable results compared to the standard installation without a corner support. Another observation was that EN ISO 11925-2 tests with 30 s flame application against the specimen surface give better correlation with EN 13823, compared to edge application of the flame. It was thus found that that there is a need to formalise the test procedures better for applications with textile membranes for building applications.

**Full-scale reference tests**

Reference tests were conducted with two PVC/PES membranes with different thicknesses and with the polyethylene membrane. Different test scenarios were built up, that tried to simulate applications in event buildings for the PVC/PES membranes, and a weather protection application in the case of the polyethylene membrane.

The main results of the tests with the PVC/PES membranes were that they showed good fire properties with limited fire spread, and they were basically self-extinguishing when the fire spread away from the flames of the ignition source. The problems found were smoke production and burning droplets. It has previously been assumed that smoke will be ventilated out by a rapid formation of a hole in the membrane caused by the fire. But the tests showed, however, that there will be no hole formed in the ceiling when the ceiling height is large compared to the size of the ignition source, and a hole in the corner of the building is not effective for venting out smoke.

Experiments with the polyethylene fabric showed self-sustaining fire spread and falling flaming droplets / particles. The fire spread was less severe as it was rather slow, but the flaming droplets formed pool fires on the ground, which must be considered as a severe hazard. Such pool fires may contribute to the spread of fire to adjacent materials and buildings.

**Draft proposal for revised test requirements**

Based on the fire tests conducted within the project and the study of fire safety requirements for textile membranes in other European countries, the report provides a proposal for revised testing requirements for textile membranes in temporary buildings. The proposal is to set requirements by the classification standard EN 13501-1 and put Euroclass E (with edge ignition) as a minimum requirement.

The justification for the proposal is that this gives the requirements under the same classification standards that now apply to textile membranes in permanent buildings in Sweden and are applied in most other European countries. The proposal also includes that a differentiation of the requirements depending on the type and use of the temporary building. The requirement is proposed to be higher (Euroclass C-s2, d0) when the building has more than one floor or where there is a raised platform or similar that is higher than half the maximum ceiling height of a single-storey building. These higher requirements are proposed for reducing the risk from smoke in an evacuation situation. For textile membranes used in weather protection applications is proposed a minimum requirement of Euroclass E (with edge ignition).

**Reporting**

The following report describes the work and the results from the project, and can be downloaded from www.sp.se: SP Report 2013:30, ‘Fire safety requirements on textile membranes in temporary building structures’.

**Contact persons**

- Reaction-to-fire: Per Blomqvist (SP)
- Building design applications: Staffan Bengtson (Brandstryddslaget).
Fire suppression systems for buses can be certified by P-marking

Despite many reported bus fires, no international standards have been developed for testing and evaluating the performance of fire suppression systems in the engine compartments of buses. Working with international parties, SP has now developed a new fire test method - SP Method 4912. For additional quality assurance, SP has also developed a voluntary certification and quality labelling system - P-marking - in the form of SPCR 183 (SP Certification Rules).

- Several other companies are now performing tests with us here in Borås in order to have their fire suppression systems P-marked, says Fredrik Rosén of SP’s Fire Research department.

  In addition to meeting the fire testing requirements of SP Method 4912, a P-marked fire suppression system also demonstrates a high degree of robustness, as its testing includes resistance to severe environments as specified in internationally accepted automotive standards. P-marking also includes quality assurance and annual manufacturing inspection.

  - An innovative and important part of the P-marking process is that risk assessments, based on the results from the fire tests, must be performed in order to optimise system capacity and performance when installed in actual engine compartments of buses, says Fredrik Rosén.

  P-marking facilitates procurement procedures for both purchasers and sellers. By using P-marking in the sector, purchasers can be sure that systems deliver an approvable level of quality and safety.

  Further details of the P-marking certificate can be found at: http://www.sp.se/safebus/certified.

Photo: Jonas Brandt, SP

Fire-testing a fire suppression system in a bus engine compartment in accordance with SP Method 4912.
With effect from 1st July 2013, or as soon as an applicable product standard is available, construction products must be CE-marked in accordance with the Construction Products Regulation (CPR). Up until now, there has been no available product standard for cables, but work is now in progress by CENELEC (European Committee for Electrotechnical Standardisation) on producing such a standard.

CENELEC TC20 has issued the following timetable for planned publication of CE-marking documents:

- prhEN 50575: This product standard for power, control and communication cables is planned for publication during Q2 2014. CE-marking of cables can start when this document is published.
- EN 13501-6: This classification standard is planned for publication in Q1 2014, and will enable cables to be classified. An EN 13501-6 report will provide the basis for CE-marking of cables in accordance with prhEN 50575.
- prCLC/TS 50576: EXAP, planned for publication in Q4 2013. Application of this document will minimise the number of tests.

SP has already accreditation for all the test standards mentioned in prhEN 50575, which means that SP can perform these tests today. Manufacturers can therefore already obtain information on how their products will relate to the requirements in the new classification system for cables under CPR.

SP can also help to minimise the number of fire tests that must be performed, by grouping cables in product families in accordance with the EXAP document (EXAP = Extended Application).

Please do not hesitate to contact us for assistance in working out an optimum path to CE-marking.
The seminar was held at the Petroleum Safety Authority Norway’s premises in Stavanger.

The participants find their seats after lunch.

Seminar on robust fire safety for offshore platforms

Thursday 24th October a seminar on fire safety was held by the Norwegian Petroleum Safety Authorities (PSA) in Stavanger, Norway. SINTEF NBL arranged the seminar in cooperation with PSA, and wanted to set focus on challenges connected to assessment of fire risk. Risk analysts, fire researchers and authorities were discussing both challenges and possible solutions from different point of views. The 130 attendees were given many good answers, however, the answers may lead to even more new questions.

CFD and automatized analysis
Tommy Jørstad from Lloyd’s Register Consulting talked about automatizing parts of the risk analysis and performing thousands of fire simulations to determine if loss of safety functions may occur more often than acceptable. Conducting this part automatically will improve the repeatability of the results from the analysis by avoiding too many assessments, “eyeballing” and “engineering judgements”. Available computing resources are increasing and make it possible to perform a much larger selection of fire simulations than earlier. Together with the automatization of the analysis process this leads to a wider selection of design fires in the risk analysis. However, many choices that the analysis is based on have still to be taken by a skilled risk analyst.

Heat fluxes in fires
How hot should fires be regarded? NORSOK has a very simple table for heat flux that was used as a reference several times during the seminar. These values are used as the correct answer for dimensioning fires in different areas. The Fire and Blast Information Group, FAB-IG, has another and more detailed table. Tests of fires in different sizes also show that the heat flux levels may be even higher than the values given in the referenced tables.

Ten to minus the fourth
$10^{-4}$ has been a magic number within risk analysis. Small changes in the risk analysis may determine if the results are within or outside acceptable limits. In many frequency plots over incidents the curves are very steep around this magic number. Incidents in this area may be very thoroughly analyzed to decide if the result is inside or outside the acceptable risk level. Chief scientist Ragnar Wighus remembered a seminar at Hankø in Norway many years ago where this magic number was determined. Since then the number has remained unchanged. Maybe it’s about time to revise the number? Head of process integrity section at PSA, Torleif Husebø, wish for a continuous improvement. “Cronic unease” is a well-known rule in this business sector. It shall remind everyone that one shall not relax even if everything usually turns out all right. We have to stay alert. Maybe the safety level should be increased by 5% every year to ensure that we do not stagnate.

Minimum requirements
Is it possible to analyze away from fire safety requirements? This may sound as a far-fetched question, but the requirements for a safety level may be interpreted in different ways. If a large effort is made on the probability of leakages, it is possible to perform the analysis in a way that leads to a probability of leakages in a certain area below $10^{-4}$. This does not mean that the analysis can be ended and that the fire resistant partition can be avoided in this area. Several seminar participants from PSA emphasized that there in any case will be minimum requirements that shall be maintained. This could be that the structure should resist a fire with all the contents between two ESD-valves (ESD = emergency shutdown). This requirement is independent of all probability calculations.

Is the human being the weakest link?
Barry Davies from Lloyd’s Register Consulting had the last presentation on the seminar and had interesting views from a bit surprising angle. Most errors are caused by so-called “human factors”. Is
Robert Jansson – new PhD

Friday 20th September 2013 Robert Jansson was presenting his doctoral thesis ‘Fire Spalling of Concrete – Theoretical and Experimental Studies’ at the Royal Institute of Technology in Stockholm. His faculty opponent was Professor Ulrich Diedrichs from the University of Rostock in Germany.

Robert Jansson joined SP Fire Research in Borås from the University College of Mälardalen and Eskilstuna in 2001, having performed his graduation project with us, becoming a project manager in the field of fire resistance. Shortly thereafter, in 2002, he began working with concrete for a minor project testing the fire resistance of self-compacting concrete. The results from this study showed that self-compacting concrete spalls severely when exposed to fire, i.e. the surface of the concrete is progressively and forcibly fragmented away. Since then, many different research projects have been carried out, with Robert’s close involvement, concentrating on the fire resistance of concrete.

Robert also presented parts of his thesis as a ‘keynote lecture’ at the third International Workshop on Concrete Spalling Due to Fire in Paris, immediately after his disputation. His work has made a number of very important - and, to some extent, controversial - discoveries. Primarily, it has been found that spalling caused by fire does not represent a property of the material, but depends on a number of external conditions such as the geometry of the concrete element, the load to which it is subjected and the way in which the fire develops. In addition, Robert’s work has found that water in the concrete (whether as free water or as chemically bound water that is released by heating) plays an important part in fire spalling, although not as important a part as previously claimed. One of the current theories of the fire spalling mechanism in concrete is that water in the concrete is converted into steam by the temperature rise, generating high internal pressures that can result in spalling. Together with other scientists elsewhere in the world, Robert has now repeatedly shown that this is not always the case. On the other hand, the water can affect other properties of the material, such as strength and stiffness, thus weakening the material and enabling spalling to occur more easily.

With his work on research into concrete far from concluded, Robert will continue to work in this field, including revision of the fire section of the Eurocode for concrete. In addition, he has been appointed secretary of a newly established RILEM (Réunion Internationale des Laboratoires et Experts des Matériaux, systèmes de construction et ouvrages) committee, working to develop suitable methods of testing in order to investigate those properties of concrete that are significant in relation to fire spalling.
The UN Headquarters Building Complex in New York, completed in 1952, has been under renovation since 2008. After over 50 years’ use, the buildings were badly in need of renovation by the beginning of the current century. The Capital Master Plan for the Renovation of the United Nations (CMP) faces a difficult and enormous task – particularly as the work and activities of the UN must not be hindered. Two buildings have been completed by 2013: the Secretariat Building (the actual ‘UN skyscraper’) and the Conference Building. However, this does not complete the work: the General Assembly Building is next in line for renovation.

Nordic design
The UN headquarters buildings were designed by Wallace Harrison, assisted by a group of world-leading architects, including Le Corbusier, Oscar Niemeyer and Swede Sven Markelius. When the Conference Chambers in the Conference Building were to be fitted out, the Secretary-General at the time, Tryggve Lie, suggested that the Nordic countries should perform the design work and provide the interior fittings as a gift to the UN. Norway’s Arnstein Arneberg designed the Security Council Chamber, and Dane Finn Juhl designed the UN Trusteeship Council Chamber.

The largest chamber, that of the Economic and Social Council (generally referred to as ECOSOC) was designed by Sven Markelius and provided with furniture, carpets, the marble floor and wood panels from Sweden. However, the largest and the most striking element was the large curtain in warm red, orange and violet tones hanging in front of the large window on to the East River. Designed by Marianne Richter, the work of weaving it involved ten weavers at Måås-Fjetterström AB in Båstad for a year. At that time, it was the largest and most expensive textile work of art that had been created in Sweden.

In the same way as with other items in the UN Headquarters, and in accordance with the City of New York’s fire protection regulations, Marianne Richter’s curtain was fireproofed when it was hung in 1952. However, after only a few years, complaints started to arise concerning the appearance of the curtain, as its fireproofing treatment had caused it to shrink and it was now showing signs of falling apart. It was sent back to Sweden for conservation. Statens Provningssanstalt - SP’s original body - found that the particular fire retardant (Flamex) that had been used, consisting of ammonium sulphamate...
and other substances, was a contributory cause to the poor condition of the curtain. Together with the effects of heat and strong light from the window, the flame retardant’s salts were breaking down the textile material. Washing the curtain with water in Sweden failed to cure the problem, and the curtain remained a constant worry until it was finally taken down for good in 1988.

In 2008, the UN asked Sweden for help in dealing with ECOSOC when it was finally due for renovation. The work was handled by the Swedish National Heritage Board, working in conjunction with the Public Art Agency, Moderna Museet, and the Ministry for Foreign Affairs. It was decided to replace the curtain with a completely new textile work of art. Four artists were invited to compete for the design of the curtain, which would be Sweden’s gift to the UN.

Fire resistance requirements
But how would the problem of the UN’s very stringent requirements in respect of safety, which include requirements in respect of flame retardant treatment, be dealt with? The Swedish National Heritage Board had previous experience of other textile works of art that had been destroyed by fire retardants. Sweden wanted the new curtain to have a good expectation of life, capable of being hung for at least 60 years - i.e. until the next renovation would be due. This could not be reconciled with experience of the life of textile works of art that had been treated with flame retardants: retardants were still being used, of essentially the same type that had damaged Marianne Richter’s curtain, i.e. using nitrogen or phosphor-based salts. The Board’s Conservation Science Department started an investigation that has now resulted in a report ‘Sustainable textile art?’ and general advice (www.raa.se/vardaval) as well as a Preventive Management Plan for the artwork and furniture in the ECOSOC.

SP Fire Research was brought in to discuss technical aspects and to assist in communicating with CMP and the fire authorities in New York. In parallel with the Board’s investigations, SP Fire Research’s Per Thureson discussed the conditions in ECOSOC with colleagues in the USA. What were the rules? How should the rigorous safety requirements be dealt with? Was there any way in which flame retardant treatment could be avoided?

Fire testing
The artists invited to compete for the design were given suggestions as to which materials would be the safest to work with. Natural materials, such as wool and silk, have good fire resistance properties, and the winning artist, Ann Edholm, submitted a design for a 100 % wool curtain, lined with Trevira CS (a polyester material with an inherent flame-retardant property). In order to provide a further demonstration of the resistance of the curtain’s materials to easy ignition, it was decided to submit it to a full-scale fire test in the form of the Steiner Tunnel test, ASTM E 84-12. The test was performed by the South West Research Institute in San Antonio in Texas. When the 7 x 1.5 m large test piece passed the test with relatively good results, the UN decided that the curtain would not need to be treated with flame retardant.

After several years’ work - and not least with considerable challenges in transporting and hanging the curtain in New York - it was finally time for the now fully restored ECOSOC Chamber to be re-inaugurated, supported by the unveiling of ‘Dialogos’ - Dialogos, to encourage conversation.

Margareta Bergstrand
Consultant (previously with the Swedish National Heritage Board)

Michael Strömgren appointed new chairman of SIS TK 181 Fire Safety

The latest meeting of SIS TK 181 Fire Safety saw Michael Strömgren elected to the post of new chairman of the committee. SIS TK 181 is responsible for developing standards for the assessment of fire risks, for ensuring the fire safety of buildings, and for evaluation of the fire resistance properties of construction materials.

The Fire Safety Committee plays an active part in influencing the content and guidelines of future standards. The ultimate objective of the work is that manufactured construction products and design methods used for fire protection purposes should contribute to the intended level of fire safety in new and existing buildings and other physical environments, both in Sweden and in other countries, and that the products concerned should have optimum fire resistance properties in terms of safety, cost and environmental impact. The Swedish Fire Safety Committee plays an active part in the work of drafting the European standards that provide a basis for CE-marking of construction products, as well as in the development of new methods of testing and analytical design of the fire safety of buildings. The committee is also closely involved in corresponding ISO work, in order to ensure that Swedish knowledge and interests will be included in tomorrow’s standards.

In addition to acting as chairman, Michael will also be involved in European standardisation through his participation in the recently started CEN TC 127/TG 1 Fire Safety Engineering group.

Michael Strömgren

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Infrared camera – a promising tool in fire testing and fire research

Infrared cameras detect energy in the form of infrared radiation from hot bodies and create a thermal image of the temperature differences. The technology is currently used for many different applications and has in recent years increasingly been used in fire prevention measures. Among other things, infrared cameras contribute to improving fire safety in tunnels, including the Mont Blanc tunnel and the Bjørvika tunnel in Oslo, in that they can detect a fire much earlier than ordinary surveillance cameras.

SINTEF NBL has an infrared camera of type FLIR GF-309. The camera measures temperatures from -40 °C til 1500 °C, it “sees” through smoke and flames and provides useful supplemental information in fire tests and to fire research. The infrared camera provides visualization of temperature distribution on the surface of a specimen, and thermal video sequences show the temperature distribution changes with time. The sensitive optics of FLIR GF-309 can detect temperature differences of less than 25mK.

Applications for the infrared camera in fire testing and fire research

Finding the “hot spots”
Our infrared camera can be used to visualize and detect so called “hot spots”, i.e. areas of a specimen that reaches substantially higher temperatures than the rest of the specimen, during exposure to a fire. Figure 1 is a good illustration of this. Here, the fire resistance of a non load-bearing wall with steel beams and two layers of ordinary plaster on each side is tested in a vertical furnace. The infrared image clearly shows areas where the surface of the wall has elevated temperatures.

The temperature of the “hot spots” can be extracted by analysing the infrared pictures, either directly during the test or afterwards. This way it is possible to ensure that the hottest areas actually are the ones that are analysed, as opposed to using thermocouples, where the measuring points are predefined before the test.

Detecting the local temperature growth is useful for anyone who develops products and structures that are meant to resist fire. Areas that are particularly exposed to heat can be detected and thus improved in further product development. This is useful information for most product types, for example for passive fire protection, pipes, panels, fire doors, walls, windows, and especially for products with potential weaknesses such as joints and connections.

Advanced analysis
Another advantage of the infrared camera compared to conventional thermocouples is the large amount of measurements possible. The number of measurement points is limited when using thermocouples due to time and cost aspects. In addition, the thermocouples are, as previously mentioned, placed in assumed strategic positions. However there is no guarantee that it is exactly at these positions that the most interesting and critical temperatures will appear.

There are no limits to the number of measurement points when using the infrared camera and its software. In addition, it is possible to measure maximum, minimum and average temperatures of specific lines or areas, and also see how these change over time. Furthermore, a set-up can be applied where all points above or below a certain temperature is marked with a specified colour. To date, the use of in-
Heat dissipation in steel structures

In a previous project conducted at SINTEF NBL, the load carrying capacity of a fired exposed steel structure was tested in a furnace for downwards heat transfer, built by SINTEF NBL (ref. Brandposten no. 48, 2013). The test simulated a fire on the deck of an oil platform, and the effect of the fire on the underlying steel structure was examined.

During the project the infrared camera was used to analyse and visualize how heat was dissipated within the steel. Figure 2 clearly illustrates how different areas in the structure differ in temperature. Such a test is suited for revealing how a structure is affected by a severe fire, and how quickly heat is dissipated to other parts of the structure that is not directly exposed to fire. This may, for example, indicate whether it is necessary to apply passive fire protection on all or part of the construction.

Tunnel fire

The use of infrared cameras can provide valuable information during tunnel fire tests. Experiments in tunnels often involve very heavy smoke production, and it is challenging to get good pictures and videos. The infrared camera can “see” through smoke, thus providing valuable information about the fire development and the changes in temperature in the tunnel over time.

Modelling

For those involved in mathematical modelling of fires, the infrared camera can be used to map surface temperatures over complete geometries, providing a basis for validation of calculations.

Please contact us for more information about our infrared camera, FLIR GF-309, or if you would like to use it during fire testing.

Contact

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Michael Strömgren elected to the SFPE International ‘s Board of Directors

Michael Strömgren has been elected as a board member of the international organization, the Society of Fire Protection Engineers (SFPE), from January 2014. SFPE has more than 5000 members worldwide and works to promote research and application of fire safety engineering. SFPE has recently created European Chapters Coordination Group (EGCG), and with this group, more activities will soon start. In Europe there are now seven parts of SFPE; the student sections of Benelux, France, Italy, Poland, Spain/Ibero, Sweden and Edinburgh.

In October, the EGCG, held a workshop in Basel in Switzerland on the quality of fire engineer work. With the foundation in a status report on fire safety engineering in Europe SFPE is now working for consensus. SFPE will also organize webinars, seminars and courses in Europe. As the European representative in the board Michael is responsive for requests and suggestions for activites. Several countries are about to start national SFPE departments, please contact Michael Strömgren for more information.
SP is currently involved in a project led by the Department of Fire Safety Engineering and Systems Safety at Lund University investigating fire safety in multifunctional buildings. Sponsored by the Swedish civil contingencies agency, MSB (Myn­digheten för Säkerhet och Beredskap), the project is 3 years long and is approaching the end of its 3rd year. The aim of the project is to support accident prevention activities within multi-functional buildings to meet the public’s need for a safe and secure environment. The objective and means to achieving this is to develop a methodology to identify and analyse risks associated with this particular type of building. Because of the complexity of activities on-going there is a lack of clear guidance for planning, control and design of such buildings for antagonistic and accidental actions.

The project has focussed on the consequences of antagonistic threats or major accidents such as fires and the research has been limited to aspects such as life safety in the event of a fire, spread of combustion gases, explosions, the building’s structural fire resistance, escape in case of accidents and the possibility of rescue operation.

What is a multifunctional building?
Multifunctional buildings are becoming increasingly common in modern society, where many functions may be brought together under one roof. For example, bus or train stations may be associated with shopping malls which may even contain offices serving some kind of administrative function. This means that the administrative functions and the transport hubs are at risk from the activities of store owners, and vice versa. Different businesses may place a different degree of importance on fire safety, meaning that a business which places a high importance on fire safety may be exposed by a business which places little importance on fire safety. Because of the complex management and letting conditions in this type of building this exposure can be difficult to quantify and to limit since it is not always clear who has responsibility for what in the building. Often this can result in an assumption that an asset is protected when in fact it is critically exposed.

Multifunctional buildings may contain large shopping centres, homes, hotels, offices, schools, data storage and communication centres, parks, theatres and other entertainment activities. Examples of existing buildings include the Central station building in Stockholm and adjacent buildings, Scandinavium / Swedish Exhibition Centre in Gothenburg, “Knutpunkten” in Helsingborg, and even the Ideon gateway in Lund. These last two examples have served as case studies throughout the project. In Malmö, the new central station may also be cited as an example of a multifunctional building.

What is most important though is that a fire or an incident resulting from an antagonistic threat in one of these buildings could have a significant knock on impact for other businesses or even to society!

Structure of the project
The project is structured as a number of work packages, with the scientific objective of the project being to develop a methodology for evaluating any heightened risk to businesses or occupants resulting in the use of multifunctional buildings. Different research methods are being used to achieve the projects objectives:

- Critical review of available literature and application to multifunctional buildings
- Field studies of current buildings, in particular the case study objects (Knutpunkten in Helsingborg and the Ideon gateway in Lund)
- Semi-structured interviews of occupants and owners in the case study objects
- Fire resistance and fire dynamics calculations with models for smoke and heat transport, fire resistance of construction and escape
- Evacuation experiments

Figure 1  First framework for Analysis of fire scenarios in multifunctional buildings.
Interviews and methodology

A first framework for a methodology has been developed for analysing scenarios in order to attain an acceptable safety level for multifunctional buildings. This structured method is based on the SFPE Engineering guides Fire Risk Assessment and Performance-Based Fire Protection. The method provides guidance on how to determine critical assets which should be preserved, protection objectives, exposures and finally the fire scenarios for multifunctional buildings.

Semi-structured interviews with stakeholders have been undertaken at the first of the locations which were chosen for the case study, Knutpunkten and are currently on-going at the second case study object. Interviews at Knutpunkten focussed on getting the information required to implement the methodology and to identify representative scenarios for analysis. Once the representative scenarios were identified it was possible to identify research questions for the physical phenomena required for the study of these scenarios. The first framework which was used in the Knutpunkten case study has been elaborated following input from the interviews and prior to implementation in the second case study. The completed framework, along with research questions arising with regards to life safety, smoke spread and continuity of functionality will be part of a licentiate thesis of Martin Nilsson on December the 11th, 2013, at 1315 in Lund.

Research questions

A number of research questions were identified in order to use the methodology which has been developed on the first case study. These research questions also give us the opportunity to look at specific aspects of fire safety in multifunctional buildings.

Research questions studied within the project have addressed questions including functional behaviour of electrical components exposed to fire, i.e. at what exposure is the function lost, and evaluating suitable protection options such as reduced oxygen environment.

Another aspect in these complex buildings is areas lacking extinguishing systems (e.g. sprinkler) adjacent to protected areas. A fire starting in the unprotected area might spread to the protected area and it is important to determine how effective the extinguishing system is in preventing further fire spread. Also quite common in infrastructural buildings is the presence of vehicles in a tunnel or under a canopy that is protected by a sprinkler system. There is a need to quantify the effectiveness of the sprinkler system when the water cannot reach the base of the fire.

It has also been found that buildings with socially important functions might be more exposed to antagonistic attacks. This could result in a more severe initiating event such as an arson fire using flammable liquids. The building might not be designed to handle such an intense scenario and some time has been spent investigating the impact of larger ignition sources as well as the fire growth rate when an accelerant is used.

Evacuation research has focussed on aspects which are typical for large multifunctional buildings. Examples are disorientation of building occupants, large crowds, an unknown environment for users of the building, possible malfunctions of evacuation system due to antagonistic attacks and queue formations due to inefficient use of exit routes.

For structural systems, we have carried out a short review of blast in and adjacent to buildings, comparing current trends in blast and explosion research and application with the current trends in fire. Surprisingly, a number of the recent advances in fire are mirrored in blast loading, as well as a current research trends.

We have also considered modelling approaches for hollow core floor slabs; looking at their robustness and performance in fire. As part of this we have also spent some time evaluating the material model which is provided in Eurocode 2 for concrete in fire. We have also been studying the response of steel columns to non-uniform fires. This research has resulted in the postulation of an analytical formula which describes the response of steel elements to non-uniform fires.
Fire testing of Profile Plank for transformer pit fire protection

The traditional way of improving the fire safety of transformer stations is to fill the transformer pit with stones. The purpose of these stones is that, in the event of an incident involving leaking and burning transformer oil, the oil should be cooled as it comes into contact with the stones and that the limited amount of oxygen would help to avoid a long-lasting fire when the oil runs into the transformer pit. An alternative to filling the pit with stones is to cover it with a Profile Plank. This has the advantage of allowing the entire volume of the pit to be available for rainwater and for any oil, instead of having much of the volume filled with stone. Another advantage is that it is easier to perform service work on the transformer station with a smooth Profile Plank as the base instead of stones. It is also easier to clean and restore the transformer pit after an oil leak.

No technologically neutral description is available today of the requirements for extinguishing burning oil in a transformer pit. Swedish standard SS 421 01 01[1] states: “Preferably arrangements that contribute to extinguish the fire in the leaked liquid shall be used, for example the use of a layer of stones (approximately 300 mm deep and with a grain size of about 40/60 mm) that extinguishes the burning liquid that enters the layer.”

A search of the literature, both national and international, standards and guidelines, finds that several describe the problems of burning oil, but that none of them states specific requirements for fire extinguishing. SP Fire Research has therefore performed fire tests simulating a transformer failure by tipping burning transformer oil into a transformer pit covered by Profile Planks. The test setup is shown in Figure 1. The transformer pit was 4 m long, 3 m wide and 1 m deep. Instrumentation consisted of thermocouples at various...
heights above and below the Profile Plank, and gas sampling probes mounted 5 cm below the plank. The oil was stored in a tippable trailer, and heated by means of an LPG burner. Three tests were carried out, as follows:

1. With the oil heated to 90 °C.
2. With the oil heated to 90 °C. The transformer pit had been filled with water to a depth of 19 cm to represent rainwater.
3. With the oil heated to 140 °C.

Figure 2 shows a series of pictures from Test 2, from which it can be seen that the flames were extinguished within a few seconds of tipping the burning oil into the pit.

Figure 3 shows how the temperature rises rapidly as the burning oil contacts the Profile Plank. The flames disappear quickly, and the temperature above the plank falls back to a low level. Beneath the planks, the temperatures remain at elevated values for a longer period of time. For Tests 1 and 2, this is due primarily to the limited ventilation through the grating, but in Test 3 (in which the oil was heated to 140 °C) there was some heat release for about two minutes.

Figure 4 shows the oxygen concentration, which quickly falls to low levels beneath the planks and helping to extinguish the fire.

Summarising, a method has been developed to evaluate the fire protection performance of covered and/or filled transformer pits. The result for the particular planks that was tested shows that the flames above the planks are extinguished within a few seconds. A complete description of the tests can be found in SP Technical Note 2013:09, which can be downloaded from www.sp.se.

Capabilities and limitations of firefighting systems in building fires– Focus on environmental aspects

‘Capabilities and limitations of firefighting systems in building fires – Focus on environmental aspects’ is a report that has been produced jointly by SP Fire Research and Södra Älvsborg Fire and Rescue Services (SÄRF). The work has been financed by the Swedish Civil Contingencies Agency (MSB), and is intended to show the available firefighting methods on the market today, and to describe their methodological capabilities when used for external firefighting, with the emphasis on the environmental and working conditions when tackling a fire in the building. The report presents a study of the literature which shows the effects on man and the environment of fire smoke, water draining off the fire and the addition of foaming agents. Six incidents are described, involving the externally applied use of alternative firefighting systems with successful results. The use of alternative firefighting methods in these cases minimised secondary damage to the buildings from water used for fighting the fires. In addition, the firefighters themselves were not exposed to the risks otherwise inherent in tackling a fire ‘internally’ using breathing apparatus. The report can be downloaded from www.msb.se. (Only in Swedish.)
Proposal for amended construction rules for cables is out on circulation for comments

The National Board for Housing, Building and Planning has recently sent out a proposal for amendment of the Building Regulations. One of the points included in the proposal is that the new Euroclasses for cables should be applied, and that older requirements should no longer be used.

According to the proposal, electricity, telecommunications and computer cables must have a reaction to fire class of not less than indicated in the Table shown below.

A minimum of Class $D_{{ca}}$,s2,d2 can be accepted for emergency evacuation routes with an exposed cable area greater than 5 %, but which are fitted with an automatic water sprinkler system. Building Class Br3 corresponds to single-storey and two-storey buildings, unless they contain public meeting rooms or are used as hotels, hospitals etc.

The proposal arises from an investigation that was carried out on behalf of the public authorities in Norway, Sweden and Denmark by SINTEF NBL in Norway, SP Fire Research and DBI in Denmark. The report includes guidelines for a simplified method of calculating the exposed cable area. These guidelines are also included in the consequence investigation accompanying the Board’s proposal.

Exact definitions of the various cable classes are given in classification standard EN 13501-6. Class $E_{{ca}}$ means that the spread of flame is restricted when the cable is exposed to a small flame. This must be tested in accordance with EN 60332-1-2 smallscale test standard, as shown in Figure 1.

To receive a Class $C_{{ca}}$ or $D_{{ca}}$ rating, cables must also be tested in accordance with EN 50399, as shown in Figure 2. Class $C_{{ca}}$ is the better of the two classes, and means that the spread of flame and heat evolution are relatively limited in real conditions when the cables are exposed to a strong fire. Class $D_{{ca}}$ corresponds to materials having reaction to fire properties similar to those of wood, and permits a greater spread of flame.

Classes s1 and s2 indicate the permissible amount of smoke production, with s1 being the better of the two. Classes d1 and d2 refer to the production of burning droplets and particles. A Class d1 material must not produce any droplets or particles during the test that burn for more than ten seconds. Class d2 means that there are no requirements in respect of droplets or particles.

The Board’s consequence investigation permits earlier levels to be regarded as fulfilling the new requirements until CE-marking of cables becomes obligatory. The proposal therefore states that requirements can also be regarded as fulfilled if cables meet the requirements specified in SS 4364000.

Table 1  Simplified fire resistance design requirements for cables in accordance with the Board’s proposal.

<table>
<thead>
<tr>
<th>Exposed cable area in proportion to adjacent wall or ceiling area</th>
<th>General requirements in buildings</th>
<th>Class Br3 buildings and areas with automatic firefighting systems</th>
<th>Emergency evacuation routes</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\geq 5%$</td>
<td>$D_{{ca}}$,s2,d2</td>
<td>$E_{{ca}}$</td>
<td>$C_{{ca}}$,s1,d1</td>
</tr>
<tr>
<td>$\leq 5%$</td>
<td></td>
<td></td>
<td>$D_{{ca}}$,s2,d2</td>
</tr>
</tbody>
</table>

Figure 1  Sketch of EN 60332-1-2 testing. Cable length is 600 mm and the heat release rate of the flame is 1 kW.

Figure 2  Testing to EN 50399. The cable length is 3.5 m and the heat release rate of the flame is 20.5 kW.
A strong, new alternative to extinguishing gravel. Tested, practical and cost effective.

Meiser manufactures the markets only full-scale tested extinguishing layer with a proven extinguishing time of three seconds. The profile plank is tested by the SP Technical Research Institute of Sweden (see SP Working Report 2013:09) and is a better alternative to extinguishing stone, for instance. The extinguishing layer makes the transformer pit easy to inspect and improves the working environment with its non-slip surface. A unique locking system with a click floor principle prevents damage from gas pressure from below. Ensure easier, less-expensive maintenance of your transformer pits!

For more information, see www.meiser.se or call +46(0)10-458 00 00.
Prerequisites and possibilities for cooperation between Sweden and Norway on fire research

Five happy fire researchers from SINTEF NBL in Norway are visiting SP Fire Research in Sweden to discuss the possibilities for fire research collaboration.

Sweden and Norway are two comparable countries in many ways. There are many common features within fire regulations and organization of authorities, and of the fire and rescue services. We have many years of experience from cooperation on fire issues. We do also have many of the same fire safety challenges and problems related to fire safety in many areas, and it would be smart to solve these problems together. By collaborating on fire research we may achieve at least twice as much as when we both work alone, and we avoid that the same work is done on both sides of the border between the countries.

Today’s status for fire research in Norway and Sweden was presented and possible solutions for future collaboration and funding of research was discussed. There are differences between Norway and Sweden regarding how the public research funding is distributed, and also differences in how much public funding is allocated to fire research. A particular challenge for the Norwegian fire research is the lack of an education in fire safety engineering on a master degree level.

After the workshop SINTEF NBL proposed that a Nordic forum for fire research should be established, where authorities with responsibility for fire safety meet regularly. This forum should prepare a common strategy for fire research in the Nordic countries.

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This is part of the background for the Norwegian Directorate for Civil Protection (DSB) and the Norwegian Building Authorities (DiBk) to invite Swedish and Norwegian participants to a workshop where collaboration on fire research between Sweden and Norway was the topic. The workshop was arranged in Oslo 11th of June 2013, and the participants came from the Swedish Civil Contingencies Agency (MSB), the Swedish National Board of Housing, Building and Planning (Boverket), the Swedish Fire Research Board (Brandforsk), SP Fire Research, the Norwegian Fire Protection Association, and SINTEF NBL in addition to DSB and DiBk.

We started the workshop with presentations from the Swedish and Norwegian authorities where they described their fire safety challenges today. The topics presented were very concurrent, some of them were:

- Fire safety for vulnerable groups
- Fatal fires
- Residential fire safety
- Large an tall buildings
- Increased use of combustible thermal insulation
- New construction techniques
- New construction materials and products
- New energy requirements for buildings

In the Norwegian White Paper Stortingsmelding nr. 35 from 2008, titled Fire Safety. Prevention and the fire services rescue duties, five national goals for the fire safety in Norway are described:

- Fewer fire fatalities
- Avoid loss of irreplaceable cultural heritage
- Avoid fires that block critical societal functions
- Increased preparedness and handling ability
- Less material damage

We propose to use the national goals in this white paper actively and describe important projects. A good idea would be to design a research program based on Stortingsmelding nr. 35. Such a research program would give many possibilities for collaboration across the border between Norway and Sweden.

Report with notes (in Norwegian only) from the workshop and a proposal of how the workshop should be followed up can be downloaded here: http://nbl.sintef.no/publication/lists/docs/NBL_A13121.pdf.
A recently completed master thesis in the field of engineering physics at the University of Umeå developed error estimation models for gas temperature measurements in fires. The results from these models show that, in certain measurement situations, substantial errors can occur, i.e. the measured temperature deviates from the gas temperature.

A thermocouple measures only its own temperature, which often differ from the gas temperature, mainly due to radiative exchange with its surroundings. It is common for gas temperatures and wall temperatures in a room fire to differ, which means that the measured temperature can differ from the gas temperature. A radiative exchange occurs when the effective ambient temperature differs from the gas temperature. Figure 1 shows a schematic diagram of such a situation.

It is of interest in some situations to measure the gas temperature, for example controlling a combustion furnace or when validating CFD models. An aspirated thermocouple consists of a protective tube in which a thermocouple is fitted. The gas, of which the temperature is to be measured, is drawn in through the pipe at a specified flow rate. The forced convection that is caused by the flow and the screening effect of the tube, reduces the measurement error. Figure 2 shows a suction pyrometer with a media ejection system. The gas is sucked into the tube at the left-hand end.

The master thesis describes error estimates produced by theoretical and numerical models of ordinary thermocouples and aspirated thermocouples in a range of measurement situations. The theoretical equations have been developed by NIST, and are based on simplified geometries, semi-empirical correlations and thermal balances. The theoretical equations have been implemented and solved in a Matlab program. Corresponding numerical models, simulating more realistic conditions, have been developed in COMSOL Multiphysics.

Figure 3 is a comparison between the theoretical measurement error, for a 0.25 mm thermocouple and an aspirated thermocouple operating at a constant gas temperature, as a function of the effective ambient temperature shown in Figure 1. In the decreasing functions, the gas temperature is maintained constant at 877 °C, while in the increasing functions, the gas temperature is a constant 27 °C. The effective ambient temperature varies from 27 °C to 1127 °C. The model includes an external gas flow velocity of 0.5 m/s around the ordinary thermocouple; the gas flow velocity in the suction pyrometer is 5 m/s.

It can be seen from figure 3 how the measurement error decreases when an aspirated thermocouple with an internal gas velocity of 5 m/s is used, compared to an unprotected thermocouple.

In theory, minimising measurement error is very straightforward: use a small thermocouple, a high suction gas velocity and reduce the emissivity of the shielding tube. However, practical conditions in a fire restrict these ideal conditions in various ways. The two error estimation models are therefore suitable for use in order to investigate the performance of different aspirated thermocouples in different measurement situations.

The work was carried out at SP Fire Research. Robert Jansson and Johan Anderson were supervisors, and the master thesis was carried out by Kim Olsson.

Figure 2 Aspirated thermocouple with integral ejector system. The gas is sucked in at the left-hand end of the protective tube.
Figure 1 One of the tests being prepared on the horizontal furnace.

Figure 2 View inside of the furnace during one of the tests.

Testing of timber elements using SP Fire Technologies new loading system

Performance based fire safety design allows engineers to use a variety of fire models which may appear to improve the level of safety when compared to the standard fire. However implementation is difficult with timber construction since the response of the material to elevated temperatures depends not only upon the material temperature but is also very dependent upon the heating rate. The effective material characteristics are not defined in the Eurocodes in such a way that anything other than a standard fire may be used [1].

As part of a research project funded by the Swedish fire research board, Brandforsk, SP have recently completed the 4th of a series of tests on timber elements with the intention of evaluating the natural variation in response of timber elements to different fires. Different fire scenarios were used in each of the tests and fire exposures representing a short, hot parametric fire; a long, cool parametric fire and the standard fire. Each test comprised 8 loaded glue laminated timber beams.

Test Setup
The fire test setup comprised 8 beams spanning in the short direction of the horizontal furnace, with new specially created roller supports used at both ends of the beams. In order to ensure that the beams were able to move independently we developed a test setup which ensured that continuity could be maintained across the top of the furnace without having the movement from one beam interfere with any of the adjacent beams.

We have recently installed a new loading system which was crucial to the successful completion of these tests. The loading system is a closed-loop system currently with four servo valves which allows for control on load or displacement curves prepared prior to any testing. At present we have 4 control channels, and many more cylinders which we can use during testing. Load was applied via a total of 16 hydraulic cylinders, 2 per beam. This means that the beams were ‘paired’, with the same load applied to both beams in a pair.

Instrumentation included thermocouples located at various depths within the timber elements, as well as surface mounted shielded thermocouples, deflection gauges, plate thermometers for furnace control as well as additional measurement points and welded thermocouples within the furnace.

Test procedure
Prior to any fire testing taking place, reference testing was undertaken at ambient conditions by SP Wood Technology. A total of 45 timber beams were available for the test. Each and every one of these was subject to stiffness measurement through dynamic frequency measurement as well as density measurement. Following reference testing, the beams were split into 5 groups of approximately equal stiffness distribution with 3 spare specimens. The first group of 10 beams was subject to bending strength testing to determine the ultimate bending strength of the wood. The remaining 4 groups were used for each of...
the fire tests.

The test was run such that once one beam in every pair failed the cylinders were either removed and any openings in the furnace were closed, or where possible the load was maintained until the second beam in the pair failed. In this way the tests were able to continue for the allotted time (up to 100 minutes in the longest case), with different load ratios and failure times for the timber specimens.

Finally, following completion of the fire test the load was removed and the specimens were removed from the furnace and cooled with water. This process took only 6 minutes between the end of the fire test and the first application of water!

Results

A major objective of the testing program was to gather statistical information about the strength and charring rate of timber during different design fires. Initial results suggest a predictable response of a timber construction exposed to a parametric fire using our horizontal furnace. Cross-sectional analysis is still on going for each of the beams from the tests, as well as for the measured temperatures within the beams. However based on the loads applied and the failure times, we are confident that this more detailed analysis of the projects output will yield satisfying results.

References


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Vinnova supports a test bed for fire and safety

SP Fire Research’s work on testing fire resistance is recognised as a unique national resource, around which what is known as a virtual test bed will be created. VINNOVA has decided that, as special policy, it will support development of this resource. One of the ways in which this will be effected will be through development of calculation expertise to assist the international competitiveness of Swedish industry.

A clear trend can be discerned towards function-based requirements for fire safety design throughout Europe. The interaction between fire dynamics and fire resistance is an area in which rapid developments have occurred in recent years, but there are still many questions as to how and when advanced calculations can be relevant. This, in conjunction with the introduction of Eurocodes for designing buildings, increases the need for a national resource facility for advanced calculation in the field of fire and safety. An important part of the work of this project is to assist an active research environment through cooperation between research institutes and universities. The aim of the resource is also to provide greater access for industry, public authorities and fire engineers to a combination of experimental resources and a virtual environment delivering world-class calculation competence. Money has been earmarked in the project to support innovative projects together with small and medium-sized companies. The total sum involved is SEK 8 million, of which VINNOVA has provided SEK 4 million. Further information is available from either of the authors.

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Laser measurements of droplet size distributions in the ‘Cutting extinguisher’

Laser measurements have been made on the water mist produced by the ‘Cutting extinguisher’ fire extinguishing system, manufactured by Cold Cut Systems AB. The results open up the possibility of a detailed understanding of how water mist is transported and of how it interacts with fires.

Several studies have shown the efficacy of firefighting using water mist produced at a high pressure. Many theoretical studies provide qualitative explanatory models of the interaction of water mist and fire, but it has not been possible to develop a more detailed physical description due to the lack of experimental data on the size and velocity of the droplets, as well as to other factors. On behalf of Cold Cut Systems AB, SP Fire Research carried out these measurements on the company’s cutting extinguisher, also known under the name of the ‘Cobra’ extinguisher. Figure 1 shows the reach of a water mist produced by a liquid pressure of 260 bar. Successful tests were also carried out on the X-Fog extinguishing additive.

One of the difficulties with spray measurements is that the droplets cannot be collected and analysed without destroying them, but have to be investigated in the spray itself, known as in-situ measurement. This requires optical measurements which, in this project, were made by the Interferometric Laser Imaging for Droplet Sizing (ILIDS) procedure, shown in diagrammatic form in Figure 2. This method enables droplet velocities and diameters between 10 and 700 μm to be measured.

Figure 3 shows the droplet size distribution in the centre of the spray at a distance of 10 m from the nozzle. According to Table 1,
The arithmetic mean value of the droplet diameter for a spray pressure of 260 bar is about 60 μm, and the velocity about 7 m/s, at a distance of 10 m from the nozzle exit. The small droplet sizes lead to a spray that effectively absorbs heat and thermal radiation. In turn, rapid heating of the spray means that it is evaporated relatively quickly, producing large quantities of water vapour and reducing the oxygen concentration in the fire space, referred to as inerting. It can also be seen from the table that the addition of X-Fog significantly reduces the droplet size. This is caused by a reduction of the surface tension of the droplets, enabling larger droplets more easily to be broken down into smaller droplets.

Measurements were also made on other types of extinguishing systems, but these had a droplet size distribution that partly exceeded the maximum size limit of 700 μm. SP Fire Research intends to develop this method of measurement, enabling it to be used for larger droplets and for more coherent sprays. The plan for continued work in 2014 also includes the performance of detailed calculations of water spray transport and extinguishing properties, starting from the measured values of droplet size and velocity distribution. It is also planned to perform a practical study of the extinguishment efficacy and of the interaction between the water mist and the fire space.

The project is financed by Vinnova’s Forska & Väx programme, Project No. 2013-00499. Further information can be found in SP Technical Note 2012:14, which can be downloaded from www.sp.se.

Philip Thomas, pioneer in fire safety engineering science, has passed away

One of the fathers of modern fire engineering science Dr. Philip Thomas has died at an age of 87. He was pioneer in so many fields of fire science. He wrote well over one hundred scientific papers on several topics and was honored by numerous awards. He was a great international leader and visionary as Coordinator of the Fire Commission of the Conseil International du Batiment (CIB W14) from 1974 to 1994, Chairman of the Technical Committee on Fire Safety of the International Organisation for Standardisation (ISO TC92) from 1976 to 1995, and founder Chairman of the International Association for Fire Safety Science from 1985 to 1991.

Philip had many friends around the world, not least here in Sweden where he made many visits. He co-operated closely on international issues with professors Ove Pettersson and Sven-Erik Magnusson and spent a considerable time at the department of fire technology at Faculty of Engineering, Lund University. We were many young researchers who had the privilege to get to know him and his family very well. He was always eager to discuss various technical as well as more general items and share his knowledge with others excited to learn from his wealth of knowledge and experiences. Philip also visited SP and Borås many times. Among other things we arranged on his initiative a CIB W14 meeting here in the early 1980s. A big event at the time and the city of Borås honored the guests by hoisting a flag on the main square for each nation represented.

Philip kept his interest in the field all his life and followed the progress in the literature. His academic excellence and personal charm made him a friend to many fire scientists throughout the world. We will all miss him as a great colleague and inspirer.

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Table 1  Measured flows, mean droplet sizes and velocities. Droplet sizes and velocities measured at the centre of the spray, 10 m from the jet nozzle.

<table>
<thead>
<tr>
<th>$P_{\text{nom}}$ [bar]</th>
<th>Fluid</th>
<th>$\dot{m}$ [lmin$^{-1}$]</th>
<th>$d_{80}$ [μm]</th>
<th>$U$ [ms$^{-1}$]</th>
</tr>
</thead>
<tbody>
<tr>
<td>200</td>
<td>Water</td>
<td>49</td>
<td>77</td>
<td>6</td>
</tr>
<tr>
<td>260</td>
<td>Water</td>
<td>57</td>
<td>62</td>
<td>7</td>
</tr>
<tr>
<td>260</td>
<td>Water + 1% X-Fog</td>
<td>-</td>
<td>38</td>
<td>5</td>
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</tbody>
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The International Maritime Organisation (IMO) is preparing proposals for new guidelines concerning the use of fibre-reinforced polymer structures on SOLAS-approved ships.1 During the previous IMO meeting of FP.56 (Sub-committee on Fire Protection) in London, it was decided that the work on the guidelines should continue in the form of a correspondence group, to report to the next meeting, to be held on 20-24 January 2014. The correspondence group, under the management of Sweden, consists of twelve member countries, and a number of observers in the form of various classification societies and organisations.

The correspondence group was authorised to discuss the following and other points:

1. To decide whether it is possible to use FRP composite structures in accordance with SOLAS Rule II-2/17 (alternative design of fire protection), bearing in mind the effect of observation of Rules II-2/2.1 (“Purpose”), II-2/2.2 (“Functional requirements”) and II-2/2.3 (“Compliance with purpose”);
2. To evaluate available fire test results and existing research and methodology concerning the use of FRP structures on ships;
3. To prepare proposals for guidelines to be used for the evaluation and testing of FRP structures;
4. To discuss whether any relevant new procedures and test criteria for fire testing and classification of FRP structures are necessary for the use of SOLAS ships.

Most of the discussions within the group concerned Item 1. The majority, including Sweden, are of the opinion that it is possible to use FRP structures on SOLAS vessels if this can be verified within the framework of SOLAS Rule II-2/17.

The purpose of Rule 17 is to describe a method of working for alternative design and provision of fire protection. Such alternative design may then differ, either partly or entirely, from the detailed requirements of SOLAS II-2 as long as the alternative approach provides at least the same level of safety as the fire protection features specified in the SOLAS II-2 detailed requirements.

However, views within the group are divided concerning the use of Rule 17, particularly in connection with application of the functional requirements in Rule 2.2 which, if applied, would prevent Rule 17 being used to justify the use of FRP in the vessel’s construction.

The group was united, however, in its view that Rule 17 permits departures from Sections B, C, D, E and G, in SOLAS and that every alternative design must meet the purpose of SOLAS Rule II-2/2.1. However, there are two views of the way in which this can be done.

The first interpretation is that the purpose of Chapter II-2 can be...
fulfilled either by fulfilling all the detailed requirements in Parts B, C, D, E and G in Chapter II-2, or by alternative design of fire protection in accordance with Part F.

If the use of an alternative fire protection design is chosen, its purpose will be fulfilled if it provides the same level of safety as do the detail requirements in Parts B, C, D, E and G. This means that it is permissible to depart from any of the detail rules, provided the alternative fire protection provision provides the same level of safety.

The second view within the group is that it is not permissible to depart from the purpose or function requirements in SOLAS Rule II-2/2.1 and 2.2, as both of these are fundamental requirements in Chapter II-2, and that Rule 17 must not be used to get around these fundamental SOLAS conditions. Reference is made in this case to a specific function requirement, which says that the use of combustible materials must be minimised.

However, the majority of the group, including Sweden, supported the first view. At the FP 56 meeting in January 2013, the first view was also supported by a majority of members.

Current detail rules in SOLAS are based on the assumption that the structure of the ship is made from non-combustible materials.

This has also been noted and discussed within the group. If Rule II-2/17 is used to justify use of combustible materials in the construction of the ship, a thorough review of the detail requirements in Chapter II-2 will be needed in order to identify the requirements that can be influenced by an alternative design. Within the group, examples of detail requirements in SOLAS II-2 have been identified, but the work on this area is not complete. The identified detail requirements are such as can be affected by the use of combustible materials in the structure of the vessel.

Continued work

Production of the guidelines is not complete, and so the group asked for a one-year extension of its work. The reason for the work not being completed within the intended time is mainly due to the fact that IMO made a late decision to bring forward the date of the next meeting by two months.

The group also proposes that aspects for its consideration should be expanded to include also the general use of FRP on board ship, and not merely in the ship’s structure. The reason for this is to gather more experience of the use of FRP in lesser on-board applications before approving its use for larger structures or entire vessels. Smaller FRP applications are also less complex and easier to evaluate than larger applications.

The report from the correspondence group has now been sent to IMO, and will be discussed at the meeting in London on 20th January 2014, when a decision will also be made as to whether this agenda item is to continue.

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1 SOLAS approved ships are all passenger vessels in international traffic and cargo vessels exceeding 500 gross registered tonnes in international traffic. Fishing vessels are not included.
OffshoreVäst (Offshore West) develops the Swedish offshore industry

SP Fire Research is the host organisation for OffshoreVäst, an enterprise with the purpose of developing opportunities for the Swedish industrial sector in the offshore field. The initiative has received development and mobilisation grants from Vinnova through the VINNVÄXT 2013 Call For Proposals, and is also partly financed by the Västra Götaland region, SP and participating companies.

OffshoreVäst is a consortium consisting of about 50 companies, sector organisations, universities and research institutes. Together, they are developing industrial segments within the offshore industry, where Sweden can be among the international leaders through strong R&D environments, innovation performance, quality and competitiveness. SP Fire Research is the host organisation, with SP’s Kerstin Hindrum as the process manager.

There has been considerable interest in joining the consortium. In the summer 2013, it was also announced that, in addition to OffshoreVäst’s own work, it would also receive mobilisation and development grants from Vinnova through the Vinnväxt 2013 project and support from the Västra Götaland region. This has enabled work to be accelerated, to cover five Work Packages (WP): WP1, Oil and Gas Recovery; WP2, Energy Recovery at Sea; WP3, Service and Maintenance; WP4, Offshore Academy, and WP5, Offshore Business Development. WP1, WP2 and WP3 are technology-concentrated and, together with the member companies, will perform market-motivated innovation projects. WP4 and WP5 will provide organisational support for the development, innovation and business processes. A management group has been appointed and, working with the process management, will support the work of developing Swedish offshore activities.

Read more on www.offshorevast.com.
Impact of climate change on forest fire risk in Sweden

The "Delta FFire" (ΔFFire) project was created to enable long term planning for resource and infrastructure investments for forest fire fighting, given a potential for increased fire risk due to climate change. SP Brandteknik is one of three partners involved in this project; the other partners are the Swedish University of Agricultural Sciences (SLU, Professor Anders Granström is the project lead, forestry expertise) and the Swedish Meteorological and Hydrological Institute (SMHI, meteorological modeling). SP’s contribution to the project is ignition testing of forest floor litter and modeling of historical fire events. This 4 year project is funded by Myndigheten för samhällsskydd och beredskap (MSB, the Swedish Civil Contingencies Agency).

The preliminary results of ignition testing as a function of moisture content of over-wintered forest floor litter commonly found in Sweden, including grass, leaves, short and long needles, moss, and humus are shown in Figure 1. The ignition source for these data is a small open flame similar to a cigarette lighter placed on the surface of the test samples. Other tests have been conducted using embedded open flames and embers (cigarettes). The effect of light wind has also been studied. Future testing may include ignition due to hot particles.

Figure 1. Preliminary ignition testing results for Swedish forest floor litter. Note that short needles are not included because they did not ever ignite.

Figure 2. Forest fire in Vettlefjäll, Sweden.
New mechanical loading system installed at SP Fire Research

In the event of fire, the load-carrying capacity of a building or a ship is important in order to ensure safe conditions for rescue work and fire fighting. Load-bearing elements such as walls and floor structures, or bulkheads and decks in ships, are required to be capable of carrying their intended loads under fire conditions for specified periods, e.g. 60 minutes.

SP’s new mechanical loading system is a flexible system capable of meeting the requirements both of standardised fire resistance tests and of more research-related tests, involving investigation of more complicated load distributions. The system is a servo-hydraulic system consisting of a hydraulic power unit, electrically-controlled servo valves, and a control PC. The operator has individual control of four different load levels, with the load curves for each channel being specified either in advance or as the tests progress. The system can also provide position control, e.g. by applying a specified rate of deformation to a test specimen under test.

Present-day regulations specify requirements only in respect of load-carrying capacity of individual elements. However, experience from fire investigations shows that confinement of the load-carrying elements affects their behaviour in a fire. This is therefore an area in which research is being carried out. Much of this work is performed by computer simulations, but the results need to be verified by realistic tests. SP’s new mechanical loading system, providing accurate control of force and position, can create realistic confinements (mechanical boundary conditions) in such structures as, for example a column/beam systems. This provides a more realistic picture of the behaviour of such structures when exposed to fire, enabling the results to be used for verification of different calculation models.
New employees with SP Fire Research

Sven Karlsson
Sven joins us as a technician in the Fire Resistance section. He has previously worked with hydraulic systems at Specma AB in Sjömarken, both as an erector and as a claims management repairer. His major interest is music, playing the bass in three bands at present. In addition, he likes to drive his motorcycle and enjoying the company of friends are also close to his heart. All this is shared with his partner, Ewa.

Anna Sandinge
Anna has been working as a project leader in the Fire Dynamics section since September 2013. She holds a degree in chemistry from Chalmers University of Technology, and joins us from the test laboratory of the IAC Group (automotive industry subcontractors), where she was group manager. She has previously worked with food analyses at AnalyCen. She enjoys her free time in the company of her husband and two daughters, Astrid and Greta.

Robert Svensson
Robert has been working with us as a project leader in the Fire Dynamics section since September 2013. He holds a degree in engineering physics, having recently graduated from Chalmers University of Technology. In his free time, he enjoys the company of his partner and daughter Alice, born in March.

Kim Olsson
Kim has been working as a project manager in the Fire Resistance section since November 2013. He has recently graduated with a degree in engineering physics, specialising in computational physics, from the University of Umeå, writing his master thesis at SP Fire Research. With a great interest in music, he grabs his guitar whenever he has a spare moment.

Christina Nordström
Christina has been employed as an administrator in the Fire Dynamics section since December 2013. She joins from the Administrative Court in Gothenburg, but has previously worked as an administrator in the field of building production and as a teacher. When she is out of office she spends her time at the gym - everything from poweryoga to strength - or with her family and friends.

New SP Reports

SP Report 2013:22
Margaret Simonson McNamee
Arson is a societal problem that needs to be addressed through multidisciplinary research. This report summarises the a number of individual projects that have been conducted within the framework of a national research program during the period 2008-2013. Further information can be found in the article on Page 12.
Financing: Swedish Fire Research Board and others.

SP Report 2013:30
Fire safety requirements for textile membranes in temporary building structures
Per Blomqvist, Anna Bergstrand, Nick Neumann, Ida Larsson, Per Thureson, Staffan Bengtson (Brandskyddslaget)
SP Fire Research and Brandskyddslaget have now concluded a Swedish Fire Research Board project investigating the risk of fire associated with the use of textile membranes in temporary building structures. This includes traditional public tents, different types of more complex event buildings, and weather protection of buildings under renovation or in process of construction. The work has evaluated small scale test methods, validating the results against large scale trials. The main result is a proposal for revised methods of testing and requirements intended to improve the level of fire safety and better harmonise with the fire resistance requirements applicable to the use of textile membranes in permanent buildings. See also the article on page 16-17.
Financing: Swedish Transport Administration.

All reports can be downloaded from www.sp.se.
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