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NEWS FROM SP FIRE RESEARCH

brandposten

English Edition

Editorial/Björn Sundström

Is it possible to run a passenger liner on methanol?

The Baltic Sea, the North Sea, and the English Channel are strictly regulated with regard to sulphur emissions. The sulphur content of the oil on which ships are normally run exceeds these limits, which is why Stena Line has chosen to test a highly innovative solution; using methanol to fuel *Stena Germanica*, one of the largest passenger liners in the world. This will, however, place new demands on the handling of fuel, fire extinguishing systems, etc. There is no way to convert to using methanol without first conducting extensive risk analyses and examining the implications for fire safety design. SP Fire Research has undertaken these processes, which have given excellent results, and the running of *Stena Germanica* on methanol was approved this January! For more information about this project, see page 16.

As of 2011, the EU requires that all cigarettes be self-extinguishing when left unattended in order to reduce the risk of igniting upholstered furniture. These requirements were first introduced in the USA and, following similar legislation by the EU, are now enforced in Sweden as well. An ASTM standard is used to determine whether or not cigarettes fulfil these requirements. The long-term results of these requirements, however, may be questioned on the basis that the effects of their introduction are not reflected by Swedish fire statistics – although this may be the result of a narrow base of data. Having been commissioned by the MSB, the Swedish Civil Contingencies Agency, we investigated cigarettes on the Swedish market to find out whether they fulfil the EU requirements. They do. However, we also found that self-extinguishing cigarettes are capable of igniting upholstered furniture since in real fire scenarios, they can burn their full length. These results are supported by some studies, but there are also others that disagree. Thus, opinions are divided regarding the benefits of self-extinguishing cigarettes. In our opinion, it is necessary to get to the bottom of the question "what kind of fire protection do self-extinguishing cigarettes actually provide"?

Huge quantities of goods of all kinds are transported through the train tunnels under Antwerp and to the rest of Europe. Here, naturally, fire safety comes into focus. Since 2007, SP Fire Research has been involved in the testing, design, and risk evaluation of the foam systems for these tunnels, which have now opened to traffic. An advanced fire protection solution involving 5,500 foam generators was developed, which you can read more about on page 28.

It is necessary to design a tunnel with passenger traffic so as to allow the safe evacuation of a large number of people; an obvious question, however, is how people act during evacuations. Karl Fridolf's PhD thesis discusses the best way of ensuring effective evacuation during a tunnel fire.

We have developed a training package on avoiding vehicle fires aiming at manufacturers, operators, and repair shops, in an effort to spread our experience and knowledge regarding 'best practice'. Read more on page 10.

SP Fire Research AS in Trondheim is progressing by leaps and bounds, which is evident from the large number of articles and publications available. New employees are being hired at a rapid pace, and Greg Baker, a renowned fire researcher, has joined us, having moved from far-flung New Zealand to Trondheim.

Chen, Mia, Mattias, Helene, Pierre, Stephan, Roger, Robert O, Juan, Greg, Audun, and Robert H; a warm welcome to SP Fire Research in Sweden and Norway!

Björn Sundström

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Cover picutre: Fire test of a fuel hose in accordance with method ISO 7840 Annex A. Photo: Håkan Modin.

Safer battery systems in electrified vehicles

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Lithium-ion batteries (Li-ion) offer great energy and power densities accompanied with long battery life time. In an abuse situation however, e.g. in case of mechanical deformation or overtemperatures, the flammable electrolyte of the Li-ion battery might pose a risk.

Li-ion is widely used in various consumer products and are beginning to be used in electrified vehicles (xEV). xEVs have the potential to be safer than conventional combustion engine vehicles, simply because they have less or no flammable gasoline/diesel. Additionally, the xEVs have potential for safety enhancement due to e.g. freedom of design and a greater stability performance with lower center of gravity due to the large Li-ion battery pack. However, new technologies may introduce new unknown risks. It is important to study these risks to be able to proper address them by e.g. vehicle design.

Today there are no intrinsically safe Li-ion cells with usable properties. The experience from the consumer market shows that there is a small probability (ppm-level or less) for internal short circuiting in Li-ion cells, potentially resulting in a so called thermal runaway and a battery fire. In a large battery pack, with many cells, the probability of a thermal runaway will of course increase due to the use of more cells. This leads to an increased risk of a cell safety incident occurring and it is thus important to minimize its consequence. For example, the cell-to-cell propagation of a thermal runaway in a single cell can be affected by battery pack design.

SP is involved in the project "*Safer battery systems in electrified vehicles – development of knowledge, design and requirements to secure a broad introduction of electrified vehicles*", together with Atlas Copco, Chalmers University of Technology and Elforsk and with financial support from the Swedish Energy Agency. The project includes various abuse (destructive) tests on commercial Li-ion battery cells to study the cell response in terms of e.g. temperature, gas, fire and explosion in electrical abuse tests including overcharge and short circuit tests and exposure to fire. Figure 1 shows an example of fire due to overcharge and Figure 2 shows battery cells exposed to a propane flame. The tests showed that higher battery electrical charge level (State-Of-Charge) gives a higher heat release rate (HRR) while the total heat release (THR) is roughly the same for all charge levels. Also gas emissions were measured. The Li-ion cell contains fluorine that can form highly toxic compounds such as hydrogen fluoride (HF) that can be released.

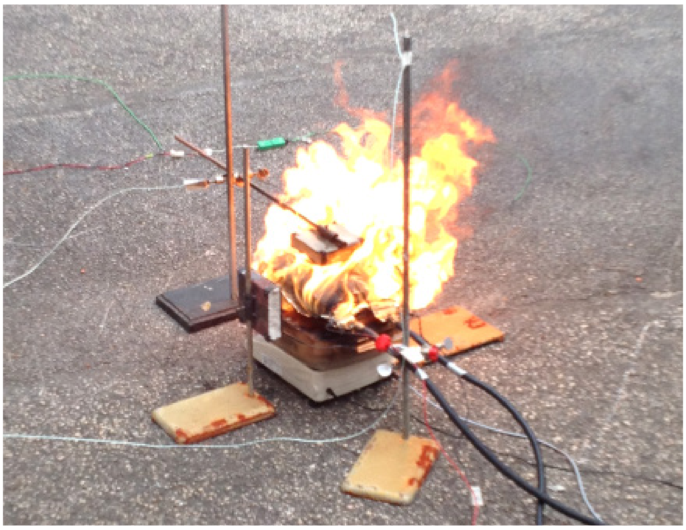

PHOTO: FREDRIK LARSSON, SP ELECTRONICS

Figure 1 Fire in a Li-ion cell due to overcharge.

PHOTO: PETRA ANDERSSON, SP FIRE RESEARCH

Figure 2 Li-ion 5-cell-pack when exposed to a propane flame. Ignited gases from cell venting can clearly be seen.

Performing experimental abuse tests is expensive and therefore thermal simulation is a useful tool. To this end, simulations means have been developed. The simulation tool models the heat transfer in a pack of five cells with the aim to be able to predict the cell-to-cell heat spread for a 5-cell-pack. The simulations are performed in the Finite-Element software Comsol Multiphysics and the results are corroborated to the experimental results. Obtaining adequate data of the battery cells is crucial for the computational model since precise measurements of these data are not available; data from the literature is used in combination with sensitivity studies of the thermal parameters. The layout of the cell indicates that the thermal properties are highly anisotropic and it is showed that this anisotropicity in the thermal conductivity is of importance. The results from the test and the simulations agree relatively well until the next adjacent cell is starting to react and thus can this rather simplified method be used to predict the propagation of a thermal runaway with accurate material data input.

Method for investigation and evaluation of fire incidents

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SP Fire Research AS has published a new report that describes a simple method for investigating and evaluating fire incidents. The report was prepared for the Norwegian Directorate for Civil Protection (DSB).

What should be evaluated and why?

Evaluation of fire incidents can be a very useful tool to collect experience and knowledge about how fires start and why they develop as they do. The following questions are important:

- What happened, where and when?
- What failed?
- What worked well?
- Why did it happen? Can underlying causes be identified?
- How can we most efficiently prevent new incidents?

Through evaluations of fire incidents important data and information about fires can be collected. Such information can be used to assess existing regulations, to develop future regulations, it can be used by insurance companies in risk assessments, by manufacturers of building products, or be useful to other parties working with fire safety. The information will be a valuable supplement to the existing fire statistics, and may reveal needs for improving the fire statistics and the way the statistical data is collected.

The proposed new Norwegian regulation on fire prevention and inspection requires that municipalities assess if the fire preventive work has had the expected effect after fire incidents that had (or could have had) serious consequences for life, health, environment or material property. DSB therefore wanted us to outline a method for the evaluation of fire incidents. The method should especially be relevant for less comprehensive evaluations where there is either a limited number of factors that shall be investigated, or where the situation is relatively clear.

A simple systematic method

As a basis to outline the method we have studied the literature on fire investigation in particular and on accident investigation in general. The evaluation involves a mapping and assessment of the origin and development of the incident. A systematic method will make the assessment simpler.

PHOTO: ANNE STEEN-HANSEN, FIRE RESEARCH AS

Figure 1 The report describes a simple method for investigating and evaluating fire incidents.

The method describes:

- How the evaluation can be planned and performed
- Necessary assumptions and limitations
- What information could be relevant, and where and how to find the information
- How to record the information systematically
- Relevant informants
- Other factors that could be relevant

The method is applied to a fire incident in a Norwegian nursing home in 2014. The evaluation of this incident is not complete, but is meant to be an example of how the method can be applied.

The report (in Norwegian) can be downloaded from www.spfr.no.

Fire and offshore wind

SP Fire Research recently received funding from the OffshoreVäst consortium to launch a pre-study on the topic of fire protection and safety of offshore wind turbines. The funding is complemented with funding from SP's Offshore competence platform, and the purpose of the pre-study is to explore and describe current practices and research related to fire related risks in offshore wind turbines. The overall goal is to map the status of fire protection and safety in offshore wind turbines, and to provide recommendations for future research, which in a longer perspective could promote both innovative and cost efficient solutions to facilitate a continued growth within the offshore wind industry. The project, which is supported by the G9 Offshore Wind Health & Safety Association, is led by Karl Fridolf (BRk), and is carried out in collaboration between SP Fire Research in Sweden and Norway. The intention is to present the results in a journal paper in the end of November this year. If you are interested in the project, or if you are an industry representative who want to contribute to the project, please do not hesitate to contact Karl.

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Rail Tunnel Evacuation

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Rail tunnel fires are rare, but when they do occur the consequences can be catastrophic, particularly if they involve passenger trains which cannot be driven out of the tunnel. The passengers aboard the train must then not only realise that they are in a dangerous situation which requires them to act quickly, but also make the active decision to evacuate the train so as to reach a safe location, either inside or outside the tunnel. Moreover, a basic principle is that they should be able to do so on their own, without help from fire and rescue services.

A safe railway tunnel is therefore one which allows people to reach safety in case of fire, even when trains have to be evacuated inside the tunnel. In order to construct safe railway tunnels, knowledge is required of both human behaviour during tunnel fires and the difficulties people may encounter during evacuation. This knowledge was very limited until the recent presentation of new research in the field, which shows, among other things, that much of what we know of people's behaviour in relation to fires in normal buildings is applicable to fire scenarios in tunnels.

One important conclusion is that people aboard a train rarely panic during tunnel fires; on the contrary, it often takes some time for people to react and make the decision to evacuate. Factors influencing the decision include access to information, the passenger's role aboard the train, the expectations associated with this role, and the actions of other passengers. Taken as a whole, the results can be used to show the critical role information plays to passengers on trains in the event of a fire in a tunnel.

The research also reveals several unique aspects and problems which people face during an evacuation of a train in a tunnel, and suggests several solutions to these problems. One example is to minimise the height difference between the train and the tunnel floor. When there is no platform to exit onto, people must find a way to reach ground level, a distance that may exceed a metre. In general, this distance may make it problematic for people to exit, but these difficulties are even more pronounced for those with a disability.

One measure which would facilitate an evacuation would be to build elevated footpaths in railway tunnels. Such a solution would also be beneficial in that evacuation could then proceed on a level surface rather than on macadam, which may be problematic to walk on.

Another identified problem relates to the inclination of people evacuating a railway tunnel to move towards the tunnel's openings. This is due to the fact that, in the event of fire, people tend to move towards known spaces and, in a tunnel, many people associate this with the tunnel's portals. The problem with this behaviour is that it may unnecessarily prolong the time it takes for people to reach safety, as they avoid using existing emergency exits along the way.

Several solutions are proposed to this problem. Fitting the tunnel's emergency exits with loudspeakers which can send out an alarm signal followed by a spoken message, leading them towards the exit, may be a very effective way of making people aware of the existence of emergency exits. As compared to other forms of directions, for example light systems, loudspeaker systems have been proven to be a far more effective means of ensuring that people use emergency exits, even when smoke obscures one's vision. Such systems are both uncomplicated and inexpensive, which also allows them to be used to increase safety in existing tunnels.

The research is an important contribution to understanding human behaviour during tunnel fires, and the results can be used to ensure that new safety measures are well adapted to expected human behaviour patterns.

This article is a summary of Karl's PhD thesis. Karl succesfully defended his thesis at a public seminar at the Faculty of Engineering (LTH), Lund University, on June 12th.

PHOTOS: KARL FRIDOLF, SP FIRE RESEARCH

Fire testing and certification for materials and products used in the shipping and offshore industry

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Products for use within the offshore industry must be accompanied by a proper fire technical documentation which describes the properties and performance of the actual product according to the relevant requirements (e.g. IMO, NORSOK etc.) Ignitability, production of smoke and toxic gases and flame spread are key characteristics when considering surface materials.

For materials and products used in the shipping industry the IMO 2010 FTP Code applies. This is an international document and it is mandatory for all countries that have adopted it. The code consists of 11 parts where parts 1, 2, 5, 7, 8, 9 and 10 all deal with properties connected to "reaction to fire", while parts 3, 4 and 11 deal with "resistance to fire". There is no part 6 since that part has been merged with part 5.

- Part 1 Non-combustibility test
- Part 2 Smoke and toxicity test
- Part 3 Test for "A", "B" and "F" class divisions
- Part 4 Test for fire door control systems
- Part 5 Test for surface flammability (test for surface materials and primary deck coverings)
- Part 6 Blank
- Part 7 Test for vertically supported textiles and films
- Part 8 Test for upholstered furniture
- Part 9 Test for bedding components
- Part 10 Test for fire-restricting materials for high-speed craft
- Part 11 Test for fire-resisting divisions of high-speed craft

The regulations for the international offshore industry are not as harmonized as they are for the maritime industry. In Norway there are performance-based offshore regulations, and material specifications may be operator-dependent. However, the FTP Code is an acknowledged document and well known as basis for product documentation, referred to by both the authorities and NORSOK standards.

SP Fire Research has long experience with testing and product documentation related to fire safety. The report SINTEF NBL A08122, published by SINTEF NBL as, now SP Fire Research AS, presents guidance for the choice of test methods for various products used in the offshore industry. For establishing a suitable test program for materials and products intended for use in offshore establishments, feel free to contact us for counseling and guidance.

A material or product that has been tested and approved according to the IMO 2010 FTP Code may be certified and labelled with regards to the Maritime Equipment Directive (MED). The certification is intended to document that the material or product achieves the required properties with regards to fire safety (type approval) and that the properties are maintained in production over time (production control). These certificates are necessary in order for the producer to mark their products with the mark of conformity, the "wheelmark".

The fire laboratories of SP Fire Research in both Sweden and Norway are recognized as test laboratories by the IMO and are accredited to perform tests according to IMO 2010 FTP Code. SP Fire Research is appointed by the Norwegian and Swedish authorities respectively, as notified bodies to undertake conformity assessments for marine equipment related to fire protection, and hence to issue MED certificates. For more information please contact us or visit our website www.sp.se or www.spfr.no.

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New technology can make rescue work safer

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Close collaboration is required between fire and rescue services, the industry, and researchers in order to develop new technology for use in case of underground fires. "Development is progressing rapidly – but we have to make sure the right things are prioritised", two researchers at the SP Technical Research Institute of Sweden write.

Fire in an underground environment is a difficult challenge to face for both the local fire and rescue services and a private organisation. The greater the complexity of a facility, the better prepared everyone involved must be. At a complex facility, all of the various technological systems must work under all circumstances, and the margin for error is far less than for everyday accidents. There is a danger in complacently assuming that what has always worked before will continue to do so tomorrow.

We are happy to be able to contribute to the advancement of research in the field in collaboration with those who have the most need of the results – the fire and rescue services and the industry. We possess expert understanding of the development and propagation of fire and the capabilities of fire and rescue services, and this is complemented by the knowledge of the industry with regard to safety in mines and tunnels. As part of all five of our most recent large research projects on underground fires, both the business community and society in general have contributed with knowledge, involvement, and funding. This is however not enough. If we are to continue to build our cities and sub-surface infrastructure, and the mining industry is to continue to be one of our strongest industries north of the Dalälven river, we need to do more; we must work together. The industry must continue to take responsibility and maintain its vigilance. Fire and rescue services need to develop tactics and methods for moving through a complex, multi-level underground facility and for efficiently extinguishing fires without putting firefighters at risk. Legislation must be adapted to such facilities, and to performed research and the reality in which we live today. We need to develop technology which supports rescue operations and which can eliminate the necessity for personnel to enter in person in order to extinguish a fire. We need to develop vehicles which do not burn and, if a fire nevertheless occur, protection systems which efficiently extinguish it.

This is, of course, no easy task. Nor is it possible to deal with within a single organisation; rather, it requires large-scale co-operation and team efforts. There is a good word for this – co-production with all partners involved. If we set out together towards a common goal, using a sustainable strategy, and prioritise the right things, we are bound to succeed. This means that research funding must be allocated and open to applications from universities and other research institutions. Research needs to be conducted in close co-production between those conducting the research and the end users – regardless of whether this group is constituted of fire and rescue services or the industry. Identifying relevant areas in the borderline between research and innovation requires both interdisciplinary collaboration and that we, as researchers, are able to communicate our results.

So, what have we accomplished so far, and what is left to do? Sweden is at the forefront of fire research in general, and world-leading in certain areas regarding fires in underground constructions. In Swedish hard rock mines fire spread is less difficult to handle than in other European coal mines, as the rock itself cools the smoke and the surface does not contribute to the propagation of fire.

The probability that a rescue chamber will heat up is low, but the smoke spread constitute a problem. At present, we possess relatively complete knowledge of how fires in mines start, and for how long a mining vehicle burns. There is, however, a discrepancy between recommendations, legislation, and reality. Four hours' availability of fresh air in a rescue chamber is insufficient due to the fact that a combusting mining vehicle can burn in excess of this and, in such a scenario, it is far from certain that fire and rescue personnel will be able to reach the rescue chamber before the air is depleted. The industry, however, is well aware of this fact, and new regulations are in the process of being drawn up.

Another problem which requires a solution relates to keeping

PHOTO: HAUKUR INGASON, SP FIRE RESEARCH

A rescue operation in a mine may be very complex. The picture shows a rescue attempt commissioned by the MSB in the Tist mine near Sala, Sweden.

track of where vehicles, personnel and fire fighters are during a fire and rescue operation. A reliable positioning system contributes to the safety of both the personnel in the mine and the fire and rescue personnel. If we expect fire and rescue services to be able to continue to solve problems in buildings and facilities of ever-increasing complexity, innovative technological advancements are required. We need to achieve better knowledge transfer between robotics and fire & rescue, IR-imaging need to be better adjusted to fire & rescue in underground environments and expertise and technology better linked at all operational levels. In recent years, research has propelled us towards this goal, but we are not yet there. We know that due to the limitations of the present regulations and today's technology, it is difficult to reach further than 2-300 metres into a smoke-filled tunnel, and that the response routes of many tunnels and systems exceed this distance. The most obvious solution to this issue is, naturally, to avoid having to send in personnel, and to instead extinguish fires using advanced technological solutions. With the fire extinguished, the environment in the tunnel will improve and thus no longer expose miners and others to danger, in turn allowing fire and rescue services to allocate their resources to evacuating personnel. We are, however, not yet at this stage, and this is why there is a need to closely examine this part of the legislation, to ensure safe BA-operations (Breathing Apparatus) in facilities where they may be expected to advance further into a smoke-filled environment. The legislation regulating BA-operations is, at present, adapted to enclosure fires in normal buildings, rather than to complex subterranean facilities. That we have an occupational health and safety legislation which ensures a safe working environment for BA firefighters is excellent. However, at present it is not possible to simultaneously adhere to the legislation, perform an effective rescue operation, and move far into a smoke-filled tunnel. In practice, it is impossible to practice for this kind of contingency, as it is prohibited; this does not, however, prevent the prohibited rescue operation from being attempted when the emergency nevertheless occurs, although it is then carried out without the proper training or preparations. Reconsidering legislation should not involve making conditions less safe, but rather making them at least as safe, if not safer, but by different measures. Different conditions require different methods.

There is a considerable difference between a fire in a hard rock or concrete tunnel and one in a building. In a tunnel, the surface layers are non-combustible and flashovers do not occur if there is a sufficient airflow. It may occur locally in a vehicle, but not in the environment of the tunnel itself. There are, of course, risks in a mine, but the depots and underground spaces in which these risks are greatest are almost always protected by a sprinkler system. In addition, sprinklers are required in larger mining vehicles, although only in the engine compartment. Methods for assessing the effectiveness of a sprinkler exist but are not always in full function, and there is at present no standard for vehicles operated underground.

Important research, development, and innovation are yet to be performed. 'Research driven innovation' is a beautiful term; the ambition is to make this a reality. Researchers are often experts at solving problems, but not always as interested in marketing the results – they are already on their way to solving the next exciting problem. In light of this, we believe that many research financiers are wise to involve the industry in certain kinds of projects. We need real collaborations, with real co-production, and with meetings between real people. Together we have the resources to solve these problems!

Bus manufacturer staff trained by SP in fire risk mitigation

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SP Fire Research recently provided training toTemsa Global's engineering, quality assurance and publications personnel at their bus manufacturing facility in Turkey. The training course provided specific focus on the fire risks of buses; this service is also available for other vehicle types.

The goal of the training was to provide a basic knowledge of fires, fire risks, mitigation methods and best practices that can provide the highest practicable level of safety while keeping risks as low as reasonably possible.

The first part of the course included management of fire hazards from various hydrocarbon fuels (diesel, hydraulic fluid, brake fluid) and also from plastics in cabling, insulation and sealants. Aging of materials and components can increase fire risks, while fuel type, operational mode, climate, and duty cycle also play a role in determining the hazards, type of risks, their frequency and severity.

The second phase of the training focused on the basics of how and when to conduct a Fire Risk Assessment. The four stages: planning, design, production and operation are linked to appropriate mitigation methods. FAor instance, the best practice is to eliminate a risk, which is more easily achieved during the planning and design phase. In some cases this is not practical (due to costs and/or technology restrictions) so controlling the risk using safety and warning devices such as fire detection is recommended. The last option, although not considered the most effective approach when used alone, is the use of safety training and documentation.

Technical development in relation to new legislation and new types of fuels and engines will increase the need to understand old and new fire risks. SP Fire Research will, together with industry, continue to develop suitable methods and training for fire risk management of vehicles and offer more advanced courses on a variety of subjects such as electrical fires and hybrid vehicle risks.

PHOTOS: TEMSA

Joey Peoples, Vehicle Fire Safety Group at SP Fire Research, during the training class at Temsa Global.

Temsa Global bus model LD.

Workshop on Fire Safety and Bio-Based Building Products in Berlin

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Timber building products have a very long history of use as structural members. However, with the introduction of performance based design, changes to many national building regulations have opened the market for new and exciting bio-based building products, see Figure 1. Consequently during the last decade the portfolio of building products made from bio-based raw materials has increased enormously. However, large differences between regulations in countries exist and the use of combustible building products in some applications is often limited by national regulations. A poor understanding of the behaviour of these materials in fire, as well as the risks of using them, often stifles innovation. Therefore the COST Action FP1404 was started to collect and share national knowledge about the behavior of bio-based building products in fire. COST – European Cooperation in Science and Technology – is one of the longest-running European instruments and supports networks centred around nationally funded research projects which provide financial support for joint activities, such as workshops, short term scientific missions and publications.

The COST action FP1404 Fire safe use of bio-based building products aims to create a platform for networking, exchange and collection of performance data, experiences, authority- and climate requirements which affect the design with respect to the Fire Safe Use of Bio-based Building Products.

To help to achieve this aim, the action is organizing a 2-day workshop in Berlin on the 6th and the 7th of October. The workshop will be hosted by TUM - Technical University of Munich and is open to industry representatives, COST members and experts in fire safety and bio-based building products.

Important days

- Deadline for abstracts: 2015-07-26
- Acceptance of abstracts: 2015-08-17
- Deadline for registration: 2015-09-01
- Workshop 6th and 7th of October

For further information see www.costfp1404.com.

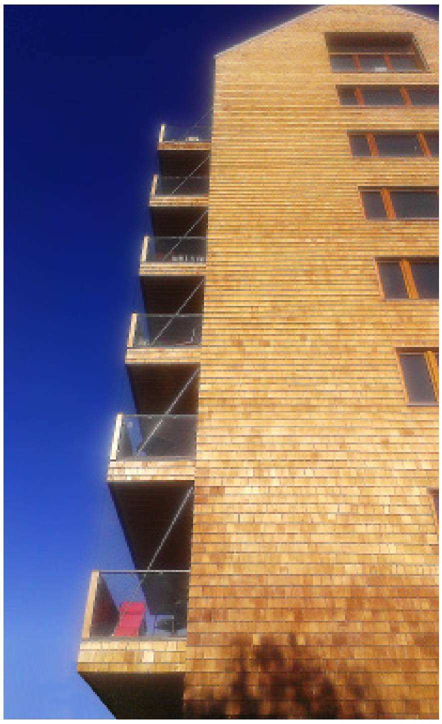

PHOTO: JOACHIM SCHMID, SP SUSTAINABLE ENVIRONMENT

Figure 1 **Changes to building regulations in Europe are enabling taller timber buildings and innovative use of bio based building products in, e.g. facades.**

Expanded collaboration with Hungary

For several years, SP has had an established research collaboration with several Hungarian universities and fire and rescue services, particularly in Budapest. The collaborative project *Svédületes!* has resulted in a knowledge boost and increased fire safety in both countries, and further continuation of the beneficial collaboration is currently planned. The *ACSEPT* project, which focuses on safety in infrastructure, is planned together with partners in Madrid, Budapest, London, Stockholm, and Helsinki, and resulted in a conference held at the Swedish embassy in order to identify opportunities for further collaboration. The participants included a Swedish delegation from SP Fire Research/Mälardalen University, and a delegation from Budapest led by Dr. Tibor Tollár, Director General, National Directorate General for Disaster Management. We met with representatives for the fire and rescue services in Budapest, including Professor Makovényi from the Ybl Miklós School of Architecture at Szent István University, among others. Dr Tollár was very positive regarding past and future collaborations and the conference, which was considered to be a success, resulted in the identification of a number of areas for further collaboration, as well as the establishing of a number of contacts. We look forward to developing the collaboration, and would particularly like to thank the Swedish Ambassador and his colleagues, who were so gracious as to organise and participate in the conference.

PHOTO: THE SWEDISH EMBASSY BUDAPEST

In the middle, the Swedish Ambassador to Budapest, Niclas Trouvé, with the Swedish delegation on the left. To the right of the Ambassador is Dr. Tollár, the Director General of the Hungarian equivalent of the MSB, and the Hungarian delegation to the right of him.

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Water sprinkler systems and public water supply networks – a watershed

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Throughout the country, there are great differences with regard to the water and sewer authorities' assessment of both how and when fire sprinkler systems may be connected to the water supply network and when capacity tests may take place – from a free rein to an outright ban. What are the reasons behind these differences, and are limitations based on actual risks or groundless fears? These questions will be investigated in a collaborative project between SP Fire Research, SP Urban Water Management, and SP Chemistry.

The use of automatic sprinkler systems has increased in Sweden over the past few years, as they save both lives and property. They are often used in fire protection design to reduce the requirements on other protective measures, and so as to bring about more flexible fire prevention solutions. Government requirements regarding sprinklers in certain healthcare environments, including hospitals and residential care facilities, have been in place since 2013. This means that the number of sprinkler systems installed can be expected to increase even more in the future.

It is often possible to supply the water for the sprinkler systems either directly from the public water supply network, or assisted by booster pumps. Local authorities are, however, concerned that problems may arise during the full-scale capacity test which is required by the SS-EN 12845 standard:

- If administered incorrectly, the rapid closing of the valve after the capacity test has been completed may lead to burst pipes or valves upstream due to the resulting pressure shocks.
- High flow rates may cause sediments to come loose, resulting in 'brown water' in the pipes. Unless measures are taken to cleanse the pipes, this pollution may cause discomfort for other users.
- In systems in which the capacity of the pump is inadequately dimensioned, the test conditions may create a negative pressure upstream in the pipe, and draw pollution into the pipes.
- Negative pressure in old pipes may lead to collapse.

Throughout the country, there are great differences with regard to water and sewer authorities' assessment of both how fire sprinkler systems are approved for use and how and when capacity tests may take place – from a free rein to an outright ban. Many local authorities, for example that of the City of Stockholm, generally allow the connecting and testing of sprinkler systems. In other areas, the possibility of connecting sprinkler systems to the public water supply network is limited. In Gothenburg, for example, connecting and testing the system's maximum flow is allowed immediately after installation; full-scale capacity testing may not, however, be carried out afterwards, and the test may then only use a limited flow. There are also areas in which capacity tests are banned entirely, and where all systems will eventually be disconnected from the public water supply network. Regardless of the existence of occupancies which are legally required to use sprinkler systems, local authorities are not obligated to supply water, as there are other potential solutions which involve water reservoirs and pumps owned by the occupancies themselves.

The combination of increasing usage of sprinkler systems in Sweden and new restrictions and prohibitions on connections may lead to the following problems:

- Increased cost for installation and operation when sprinklers are a legal requirement. As this mainly involves public occupancies, for example hospitals, this may lead to sub-optimal allocation of public finances and unnecessary costs for society in general.
- Sprinkler systems will not be installed unless there is a legal requirement to do so, due to the increased cost involved in the need for water reservoirs and pumps.
- The present lack of space in densely built-up areas will be further exacerbated by the increasing need to install water reservoirs for existing facilities.
- Using sprinkler pumps and basins instead of natural pressure may, in a live situation, lead to a less reliable water supply due to the risk of pump failure.
- In recent years, residential sprinklers have become more and more common in Sweden. This development is a key part of the MSB's "evidence-based zero vision on residential fires" – that there should be no severe injuries or loss of life as a result of a fire. If connecting such systems to public water supply networks is not allowed, this trend will likely decline, and it will be more difficult to reach the zero vision.
- Fewer sprinkler systems means that more fires are allowed to grow large before fire and rescue services arrive, which may result in a greater quantity of water being needed to extinguish the fire and, in turn, a higher environmental impact.

The *Water sprinkler systems, capacity tests, and public water supply networks* project is partly funded by the organisation Sprinklerfrämjandet, and at the time of writing we are looking for additional financiers so as to be able to complete the project according to plan. The project's objective is to draw up guidelines for how the local authorities of Sweden are to handle authorisation for connecting sprinkler systems, and how the sprinkler industry is to perform design, installation, and testing in order to minimise problems related to drinking water quality while achieving an adequate level of fire safety. Some examples of questions which are to be addressed include:

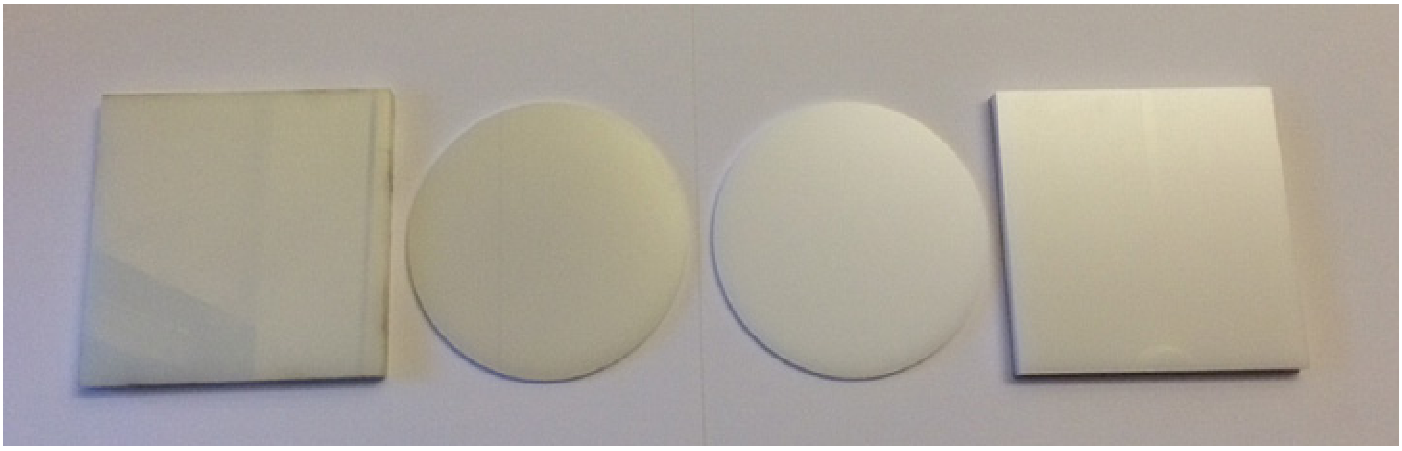
- Which of the expected problems have occurred in Sweden?
- What caused these problems?
- What can be done with regard to operating procedures and regulations so as to minimise these problems?

- For which kinds of applications, conditions, and maximum flows should connection be permitted or denied?
- How and when should capacity tests be performed, and how can possible problems be minimised?
- Which backflow prevention devices should be used?
- If parts of the water supply network must be shut down, what priority will sprinkler systems receive in relation to other consumption? Are the local authorities responsible for providing information about limited water supply?
- How should sprinkler standards, industry guidelines, insurance requirements, local authorities' guidelines, and water and sewage standards be amended in order to minimise problems?

The project is expected to finish in 2015. If you have experience which you deem to be of interest to the project, please contact the authors of this article.

Smart surface cladding for improved fire-retardant properties

Within the EU project SESBE, SP Fire Research has investigated the possibility of coating façade elements with TCO (Transparent Conductive Oxides), in order to delay or prevent fire propagation from a burning building to adjacent ones. Ignition tests using PMMA (plexiglass) coated with TCO show that the time until ignition was up to three times longer in comparison with an untreated PMMA sample.



PMMA samples with and without metal-oxide cladding.

Roughly one third of the energy released during a fire is emitted as thermal radiation. This is the most important form of heat transfer between flames and an object at a long distance, or from a hot layer of fire gas to an object located below the fire gas layer. How much of this energy is then absorbed by the exposed object depends on the emissivity of the surface layer. For a façade, the emissivity of short-wave radiation, such as that of the sun, largely depends on its colour. A black surface may absorb up to 90% of the incoming radiation energy from the sun, while a white surface may absorb as little as 20-30%. Radiation from a fire has a significantly longer wave-length than that of radiation from the sun, and the colour of the surface has less of an impact on emissivity. Regular paint (regardless of colour) often absorbs over 90% of long-wave radiation.

In order to protect a façade from fire, SP Fire Research has, within the EU project *SESBE*, investigated the possibility of coating façades with different kinds of TCO (Transparent Conductive Oxide). Such a surface layer has a thickness of only a few hundred nanometres. An important property of these metal oxides is that they are transparent to visible light, and so would not affect the appearance of the façade, while simultaneously reflecting long-wave radiation.

The metal oxides which have been investigated are ITO (Indium Tin Oxide) and ZnO (Zinc Oxide). The test showed that a PMMA sample coated with ITO takes roughly three times longer to ignite than an untreated PMMA one, while a sample treated with ZnO takes twice as long to ignite as an untreated one, when exposed to a 25 kW/m^2 of thermal radiation.

If these coatings were applied on a large scale to façades, the propagation of fire from a burning building to adjacent ones would in some cases be prevented or delayed. Moreover, lower emissivity would result in a minor decrease in the loss of heat from the façade.

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Product documentation at SP Fire Research AS

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SP Fire Research AS (SPFR) has issued documentation for building products since the 1990's. In this documentation SPFR is confirming, by reference to the regulations on technical requirements for buildings (TEK10), that the product meets the Norwegian authorities' requirements for fire safety. We publish product documentation both according to the European Construction Products Regulation (CPR) and according to the Norwegian standard NS 3919 (Fire classification of materials, building elements, linings and surfaces). The Old Norwegian class designations are used in parallel with the European classification system for a transitional period, until the NS 3919 will be withdrawn.

Background

The requirements for documentation of construction products are established in TEK10. The manufacturer and all distributive trades shall ensure that the product characteristics have been documented before the product is sold and/or used in buildings. It must be documented that the product can be used for the intended purpose and that the finished construction complies with the requirements in TEK10.

Difference between documentation for the sale and use of building materials

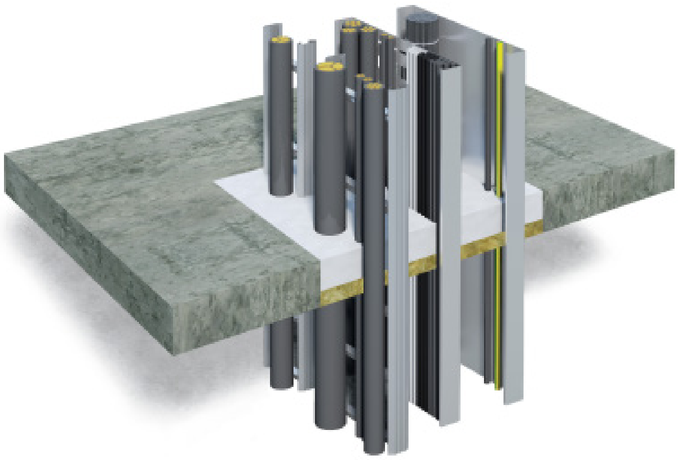
There is a difference between a product documentation intended for trading such as the Declaration of Performance (DoP), and the documentation from SPFR, which document that the product is suitable for use in buildings in Norway. Even though a product has a documentation that proves that it can be sold on the Norwegian market, i.e. the product is CE marked, this does not mean that the product can be used in any construction. Technical requirements for construction works are established at national level and vary from country to country. There may be special requirements in Norway which also need to be documented.

SPFR Product Documentation

The SPFR Product Documentation is voluntary, but it does not exempt the producer from the requirement of a documentation for the product. Since the responsible company of a building matter has to demonstrate that the products meet the technical requirements in TEK10, a SPFR Product Documentation is something that we offer the market, where SPFR document that the product is suitable for use. This requires knowledge concerning test standards, test methods, which characteristics of the product that shall be documented, and what kind of production control the product shall be subjected to. All product documentations issued by SPFR are published and are available on our website during the validity period of the documentation.

Contents

The SPFR Documentation (published as SINTEF Documentation until 2015) contains information on the validity and general requirements of the product documentation, manufacturer and product responsible, product description, area of application, fire properties, special conditions for use and installation and the basis of the documentation. In the SPFR Documentation there can be a lot of important technical information about the use of the product that do not appear in this documentation intended for trading of the product.



Fire sealing

Fireplaces

Example of two product types (fire sealing and fireplaces) that have a SPFR Documentation.

Database for Rolling Stock Material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SP Fire Research has developed a database to gather classifications of materials and products that has been tested according to EN 45545-2 – Railway applications – Fire protection on railway vehicles – Part 2: Requirements for fire behaviour of materials and components.

The database was introduced when SP Fire Research attended the Fire Protection of Rolling Stock conference in Berlin this year. The topic that SP presented was "How to address the increasing amount of testing needed in the transition to EN 45545-2".

There is a common demand from producers of materials and products as well as from train builders to easier be able to find materials and products approved for use in rolling stock in accordance with the harmonized European standard EN 45545-2. SP has therefore created a searchable open access database to facilitate this.

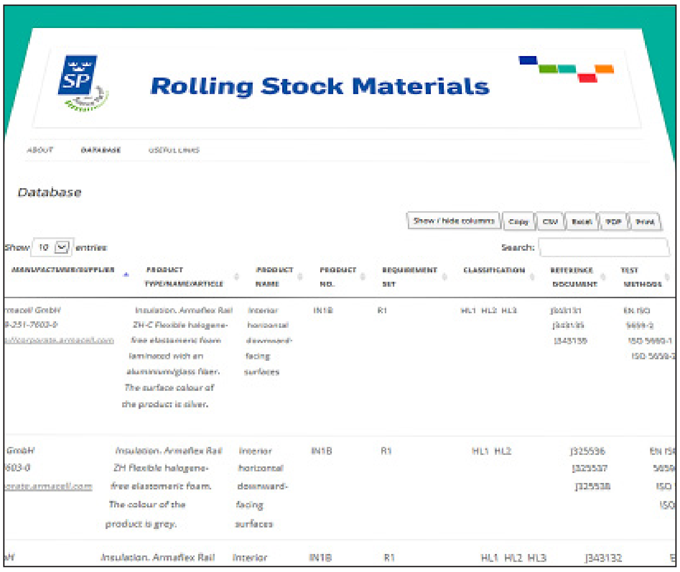
The database is searchable for the following parameters:

- Name and contact details of manufacturers/suppliers
- Name or type of material/product
- Product no. according to EN 45545-2 (F1, EX6A, etc.)
- Product name according to EN 45545-2 (Hoses, PCB, etc.)
- Requirement set (R1, R2, etc.)
- Classification (HL1-HL3)
- Test methods

The classifications listed in this database are based on tests performed by accredited test institutes.

For SP's clients the publication is free of charge. For materials and products that have been tested at other test labs the publication comes with a fee. Contact SP for more information on the procedure for publishing.

You will find the database at www.rollingstockmaterials.com.



Screenshot from the database of materials and products that have been tested and classified in accordance with EN 45545-2 - Railway applications – Fire protection on railway vehicles – Part 2: Requirements for fire behaviour of materials and components.

Anne Steen Hansen as the new president of EGOLF

EGOLF, the European Group of Organisations for Fire Testing, Inspection and Certification, has elected a new president, Anne Steen Hansen, SP Fire Research AS, as of spring 2016. EGOLF is the main representative body for third party, independent, and nationally recognised organisations involved at a European level in fire safety testing, inspection, and certification activities. Laboratories in 29 countries are represented. EGOLF is committed to ensuring, among other things, the quality and harmonisation of the testing and certification procedures of its members. Read more at http://www.egolf.org.uk/

Congratulations to Anne as she takes on the great responsibilities of her exciting new position!

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Fire safety approved for the world's first ship to run on methanol

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The world's first ship operating on methanol is approved after SP performed risk assessment and design of the fire safety based on SOLAS II-2 regulation 17 "Alternative design and arrangements". Methanol has for long been handled with traditional fire protection in cargo pump-rooms on tankers, but a deeper understanding of the fuel called for a new approach to achieve sufficient fire safety.

Solution to the SECA challenge

The Stena Germanica is a so called ro-pax ferry, bringing vehicles and passengers across the Baltic Sea. This area is together with the North Sea and the English Channel a so called Sulphur Emission Control Area where stricter regulations to minimize emissions have faced the shipping industry with some serious challenges. Similar restrictions apply around North America and several more areas are planned around the world for the future. The new requirements have demanded new technological solutions, including use of alternative fuels and exhaust gas after-treatment. Many shipping companies have chosen to make use of LNG to meet the requirements and avoid gas after-treatment. The same is achieved using methanol, but for this fuel the transportation and storage is far less complicated, both on the ship and ashore. Furthermore, there is a great benefit with methanol in the possibility to make it renewable from biomass in large scale in the future. Therefore Stena chose methanol for the Stena Germanica when it came to complying with the new regulations.

The regulatory way for low flashpoint fuels

The flashpoint* of methanol is far from as low as of LNG or gasoline but still lower than what is permitted by the international ship fire safety regulations in SOLAS (Safety Of Life At Sea). An international code under SOLAS on safety for ships using gases and other low-flashpoint fuels (the IGF Code) is under development. However, until such a code is ratified the only regulatory way forward is to show equivalent safety through SOLAS regulation I/5 or II-2/17. These regulations provide openings for alternative design and arrangements for fire safety but require that safety is not compromised. A fire risk assessment was therefore carried out for the Stena Germanica to demonstrate how the particularities of methanol would be managed to assure that fire safety was not adversely affected. It was performed by SP Fire Research as part of a large technical methanol conversion project at Stena and involved classification society Lloyd's Register, engine manufacturer Wärtsilä and ship designer ScandiNaos as key partners."

Beyond traditional fire protection

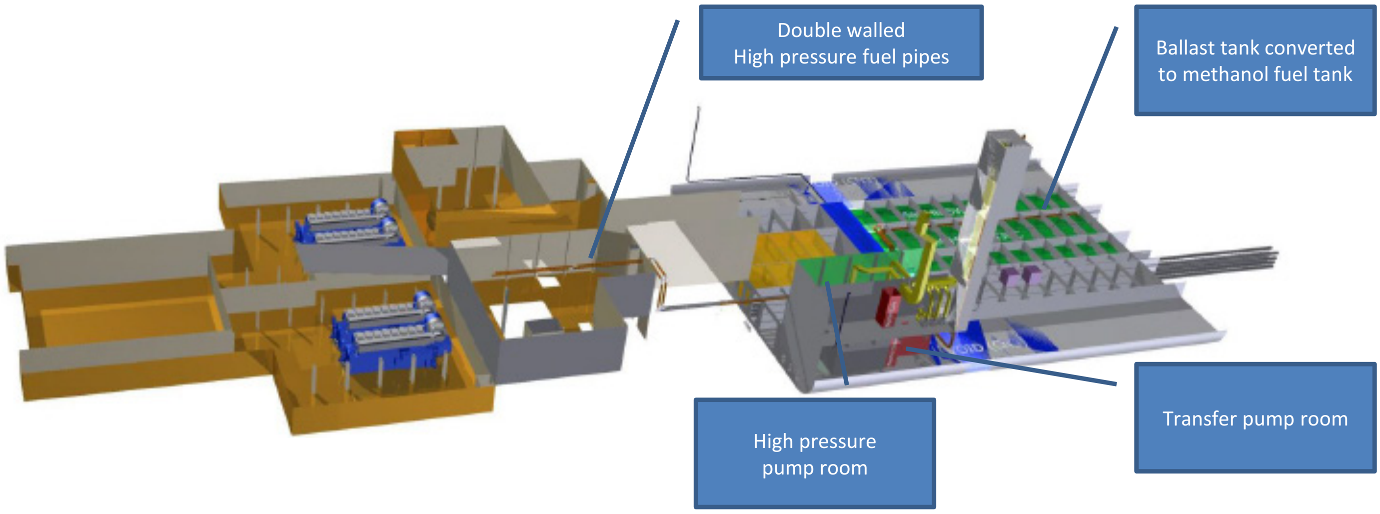
In the first steps of the fire risk assessment it became clear that not only fire hazards associated with the lower flashpoint have to be regarded for alternative fuels, even if this may be the only deviation. What is thereby addressed is generally the increased probability that flammable vapors of a low flashpoint fuel will accumulate and possibly ignite in case of a leakage. However, it is not sufficient to only minimize the probability of leakage and ignition. A sound fire safety design must, as any regulatory framework, address all levels of fire safety.

In the fire risk assessment, fire detection and fire extinguishment were also identified as areas in need of further investigation. For example, how is detection and localization achieved when a methanol

PHOTO: BO RANDSTEDT

The smoke from the Stena Germanica is but a memory as the ship has converted to methanol.

*Flashpoint is the lowest temperature at which a fuel can be ignited; if the temperature is lower the fuel will not vaporize a sufficient amount of fuel gases.



Methanol installations including bunker tank, pump room and piping for fuel transfer.

fire does not show visible flames or produce smoke? And how is extinguishment performed when the fuel in addition to the low flashpoint also has wide flammability limits and bound oxygen? These questions went beyond traditional fire protection and required further analysis.

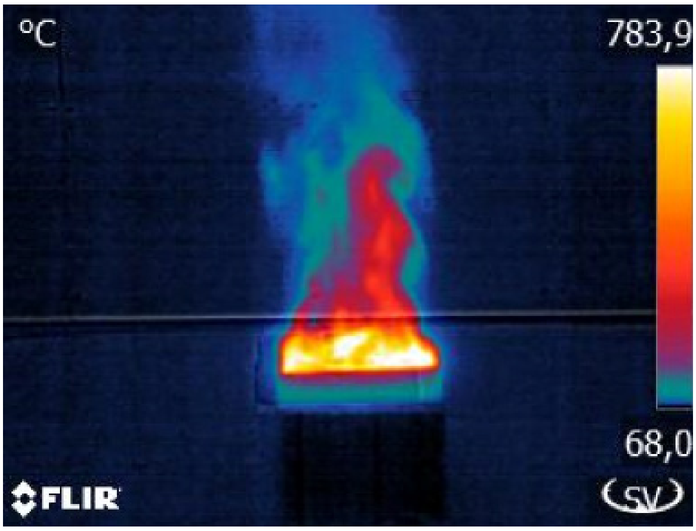
It was decided that the ship should be designed at least as safe as a conventional ship in each affected area of fire safety. To manage this, a number of risk control measures were added. For example, all fuel piping was designed double walled and butt welded. The only space where methanol is managed in single walled pipes is the pump room. Here a robust drainage system was designed and the equipment used is suitable for explosive environment (ATEX). Furthermore, a smart gas detection system was designed automated with the ventilation and the pump system; if methanol is detected the ventilation is increased and if a high level of methanol is detected (still far below the flammability limit) the 700 bar methanol transfer to the engines is stopped. An automatic seamless transition is then made to run on diesel only and methanol pipes are flushed with nitrogen. The methanol storage tank will be constantly inerted with nitrogen to avoid a combustible atmosphere. Furthermore, the tank will be surrounded by water on all sides (seawater and permanent ballast water tanks) which will directly neutralize the miscible fuel in case of a leakage. Bunker tanks at the bottom of the ship thus allow safe and efficient storage.

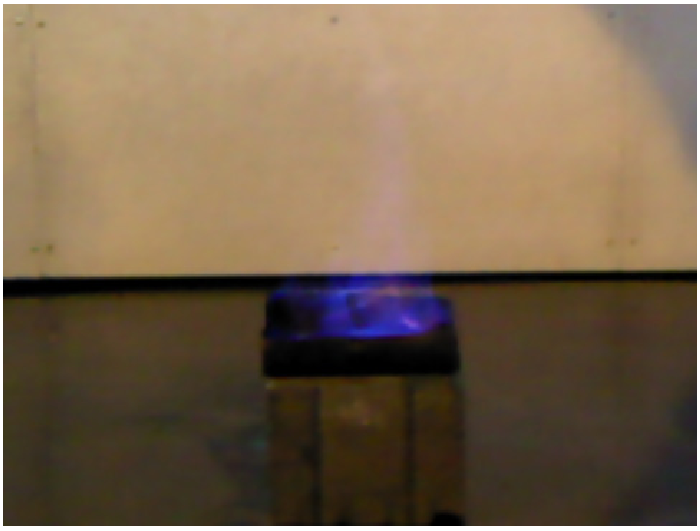
Detection was managed by smart installations of detectors made to distinguish the electromagnetic radiation emitted when carbon dioxide is produced at combustion. Thereby the detection system was made independent of smoke and visible flame signatures. To localize fires when performing manual firefighting, infrared cameras were provided to the fire patrols.

Effects of fixed fire-extinguishing systems

The fixed fire-extinguishing systems required particular engineering efforts. In particular two common system alternatives were evaluated: inert gas (carbon dioxide, CO_2) and high pressure water-mist. Several particularities of methanol led to realize that extinguishment would be harder to achieve. Methanol can for example burn down to an oxygen level of 12%, which makes it relatively less sensitive to dispersion. The effectiveness of an inert gas system with CO_2 is thereby reduced and more gas is required to achieve an equivalent extinguishing effect as for diesel.

When it comes to the effectiveness of a water-based system the insensitivity to oxygen dispersion plays part of the role. Furthermore, the low flashpoint makes direct surface cooling less effective and the lack of soot in flames makes flame cooling irrelevant. For a water-based system the primary extinguishing effect is instead dilution.





Detection and localization becomes crucial as a methanol fire neither produces visible flames nor smoke.

PHOTO: ALEXANDER LEANDERSSON, SP FIRE RESEARCH

Increased capacity of the CO_2 system is necessary for methanol (has bound oxygen).

PHOTO: ALEXANDER LEANDERSSON, SP FIRE RESEARCH

The primary extinguishing effect for water based systems is dilution.

PHOTO: MAGNUS ARVIDSON, SP FIRE RESEARCH

Water mist is not as effective for a fuel with low-flashpoint and wide flammability limits.

Fire safe ship and regulations

The fire risk assessment showed that the fire safety challenges of methanol are manageable. It also stressed that it is not sufficient to only address a low flashpoint deviation when considering alternative fuels. To assure that at least the same level of safety is achieved in each affected area, safety margins were used depending on the access to reliable data. Some conservative stands were necessary, for example with regards to fixed fire-extinguishment. The need for knowledge and verification in this area has now led to the initiation of a new research project called proFlash. The project is coordinated by SP Fire Research and aims to further evaluate the effectiveness of fire-extinguishing systems for methanol and LNG by theoretical studies and full-scale testing. The results will work as direct input to the IMO correspondence group developing the IGF Code part applying to use of methanol fuel. The project may also give reason to further develop the merely two pages of fire safety requirements in the part applying to LNG, which is only formalization away from ratification.

Approval of the Stena Germanica fire risk assessment was given by the Swedish Flag in January 2015. At the end of the same month the shipyard started the new fire protection installations. By managing each introduced fire hazard Stena is now confident that fire safety has not only been maintained but improved by the conversion to methanol. Hopes are that the findings in this project and continued research will give a better understanding of alternative ship fuels and safer conversions to methanol and LNG in the future.

Can self-extinguishing cigarettes reduce the number of fires?

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In a recently concluded study, it was established that the cigarettes sold on the Swedish market fulfil the requirements of EN 16156 for self-extinguishing cigarettes. Despite this, fire statistics and testing for various combinations of furniture show that the cigarettes are still able to ignite furniture. The question then is: does the European requirement on self-extinguishing cigarettes really serve its purpose?

Since November 2011, the EU has required that cigarettes sold within its borders must be self-extinguishing – these are so-called RIP (Reduced Ignition Propensity) cigarettes. The requirement was introduced in order to reduce the number of fires caused by cigarettes. Today, three years later, it has not produced any observable effects – in relation to both the statistics for fire-related deaths, and fire statistics in general. Thus, commissioned by the Swedish Civil Contingencies Agency (MSB), SP has performed a study with the purpose of finding an explanation. The study involved both experiments and the gathering of experiences and data from experiments conducted in other countries which have had similar safety requirements on cigarettes for many years.

Example of a common design for a self-extinguishing cigarette. Thin bands of paper are placed inside the cigarette and, when the burning tip of the cigarette reaches to the 'speed bump', the rate of combustion and the oxygen supply are reduced, in turn causing the cigarette to self-extinguish.

PHOTO: NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY

Requirements exist, but supervision of the market is lacking

Self-extinguishing cigarettes were developed to reduce the likelihood of upholstered furniture and mattresses being ignited, which constitutes the cause of a large percentage of all fire-related deaths. This is the reason self-extinguishing cigarettes are designed to go out of their own when no longer in use. This is normally accomplished by incorporating narrow paper bands inside the cigarette, which work as a kind of 'speed bump'. The bands limit the burn rate of the cigarette and reduce the air permeability (the supply of air/oxygen) to the burning tip, in turn causing the cigarette to be more prone to self-extinguish, particularly if no one actively draws air through it.

In Europe, EN 16156 regulates the requirements on self-extinguishing cigarettes. The regulation states that no more than 25% of 40 cigarettes should burn their full length when tested on an experimental substrate consisting of 10 layers of a standardised filter paper. During testing, a cigarette is placed on the filter paper, which does not burn or glow but rather works as a cooling flange and conducts heat away from the cigarette. How long the cigarette burns then becomes a measure of how much heat is generated inside the cigarette, and so its potential for igniting materials which it comes into contact with. If the cigarette burns with a high intensity, it will continue to do so despite the loss of heat. If it burns more steadily, the loss of heat to the substrate will result in the self-extinguishing of the cigarette.

At present, there is no market control where the authorities check that cigarettes sold in the EU are, in fact, self-extinguishing. A primary objective for the project was thus to investigate whether the cigarettes sold on the Swedish market are self-extinguishing. The three cigarette brands selected for testing according to EN 16156 all fulfilled the requirements for RIP cigarettes by a wide margin.

The cigarettes burn their full length

Despite the fact that the cigarettes marketed were proven to be of the self-extinguishing type, Swedish fire investigations and statistics show that cigarettes are still causing a large number of fire-related deaths. SP performed a number of fire tests on various combinations of furniture using both RIP cigarettes, which conformed to the EN 16156 standard, and a conventional cigarette. Most of the tests were conducted according to EN 1201-1, which is the standardised testing method used to test the ability of a piece of furniture to withstand a burning cigarette. Some of the tests were performed using a modified testing method in which the burning cigarette was covered by various kinds of textile materials, such as blankets. The results clearly show that, in many cases, the so-called RIP cigarettes burned their full length. In the furniture tests which were conducted according to EN 1201-1 alone, 68% of the RIP cigarettes burned their full length, in spite of their being of a 'self-extinguishing' type. In several cases, the fabric and upholstering material began to smoulder. The testing method which ascertains whether a cigarette brand is self-extinguishing thus correlates poorly with reality.

The fire tests performed within the study far from cover all possible materials on the Swedish market or all of the possible configurations that may exist in reality. The point is, however, that since such a high percentage of the cigarettes burn their full length, there is naturally a risk of ignition if the combination of materials is the right one, which has been proven in these tests.

Different opinions on usage

A literature study shows that the use of self-extinguishing cigarettes has been debated both before and after the requirements were first introduced in New York in 2004. Several studies both support and speak against the use of the cigarettes. One of the most frequently employed arguments against the use of self-extinguishing cigarettes is that upholstery material, surface fabrics, and the test configuration are factors that have greater impact on ignition propensity than the actual type of cigarette. The results of SP's fire testing support this argument.

Influence of fire suppression on combustion products in tunnel fires

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Nowadays the use of water-based fire suppression systems in tunnels has attracted much attention and the regulations and standards are also changing with regard to its use [1]. At present it is clear that by equipping a tunnel with a deluge water-based fire suppression system of enough capacity, e.g. greater than 10 mm/min for a water spray system, the design fire can be reduced to a lower level [2]. It is, however, not clear how the combustion products are released in such cases. As the fire is suppressed due to the intervention of the water sprays, strong interaction between the combustion and water sprays exist. This results in changes in the production of combustion products, which in turn changes the environment in the tunnel. Therefore this issue is very important for analysis of evacuation in a tunnel fire after activation of a suppression system.

PHOTO: YING ZHEN LI, SP FIRE RESEARCH

Figure 1 **A photo of A wood pallet fire in the tunnel right after activation of the fire suppression system.**

Experiments

Fire tests with and without a low-pressure fire suppression system were carried out to investigate the effect of fire suppression on production of key combustion products. The key parameters accounted for in the tests include fuel type, ventilation velocity, suppression and activation time.

Pre-tests were carried out in a fire laboratory under a large industrial calorimeter measuring heat release rates and gas flows. This was followed by tests carried out in a 15 m long, 2.8 m wide and 1.4 m high model scale tunnel with a scaling ratio of 1:4, see Figure 1.

Results and discussion

The parameters focused on are the yield and production rate of the key combustion products - CO and soot. The yield of one combustion product, *Y* (kg/kg), is defined as the amount of the combustion product produced by consuming 1 kg of fuel.

The CO yields in the free burn tests tend to decrease slightly with the ventilation velocity and the time. In tests with fire suppression, the CO yields generally increase with the decreasing heat release rates. Significant increases (3.5 to 4.5 times) in CO yield are found in tests with later activation when the fire is close to the extinguishment (low heat release rates), especially for wood pallet fires, see Figure 2. However in most tests with suppression, the contribution of the high CO yield (Figure 2) to the CO production rate (Figure 3) is limited as the corresponding heat release rates are at a low level. Given that the maximum CO concentration at mid tunnel height in the free burn test is still the highest for all the fuels and velocities tested, see for example Figure 4, the free burn tests could still represent the worst scenarios from the point of view of CO concentration and evacuation. It is also found that early activation reduces the CO concentration significantly.

The soot yields in the free burn test tend to decrease with the ventilation velocity and increase with time. After activation when the heat release rate is lower than a certain value, e.g. 150 kW – 200 kW, the soot yields increase significantly with time. This period is very short and also corresponds to very small heat release rates. Therefore the contribution to the smoke production rate is limited even if the soot yield is high. In all the tests the maximum soot production rate in the free-burn test is the highest. During the whole period, it can be concluded that the free-burn test can be considered as the worst case in

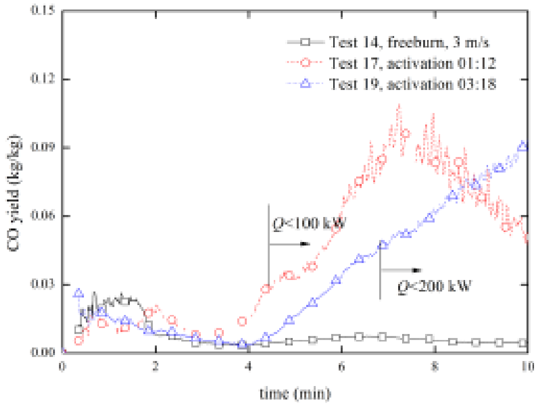

Figure 2 CO yield in the free burn and fire suppression tests at 3 m/s for wood pallet fires.

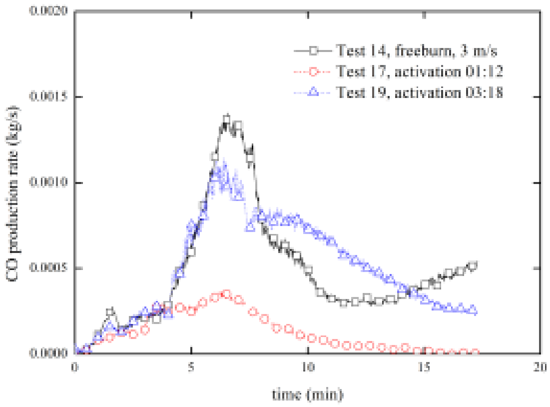

Figure 3 CO production rates in the free burn and fire suppression tests at 3 m/s for wood pallet fires.

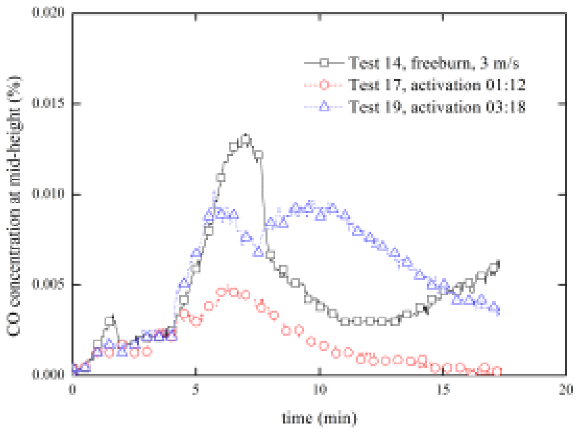

Figure 4 CO concentration in the free burn and fire suppression tests at 3 m/s for wood pallet fires.

terms of visibility.

The visibility in the free burn tests for all the fuels is generally the lowest compared to fire suppression tests due to the fact that the heat release rate decreased immediately after activation of the fire suppression system.

In summary, test results of CO concentration at the early stage indicate that in most cases, the free burn test corresponds to the worst scenario despite that in the decay period of a fire with late activation the CO concentration could be higher. Further, test results of visibility show that that the free burn test corresponds to the minimum, that is worst, value.

Based on the test data and the above analysis, it can be concluded that for the fires tested, *low-pressure fire suppression does not cause significant adverse effect in case that the fire can be effectively suppressed after activation, that is, the fire size has been reduced to less than 40 % of that in the free-burn test*. To achieve this goal, early activation and high water density is required. In case that the fire is not effectively suppressed, e.g. when the water density is too low or activation is too late, the CO concentration and visibility could be worse than in the free-burn test.

Therefore, *from the point of view of production of combustion products, only fire suppression systems with sufficient capability and early activation are recommended to be used in tunnels*.

More information can be found in SP Report 2015:09.

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Fuel storage safety in Norway


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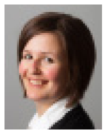
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There have been several accidents related to fuel storage in Norway. Examples include fires caused by self-heating of waste or in biofuel silos, and ignition of oil storage tanks with subsequent explosions. For the time being, fires related to fuel storage in Norway have had little impact on people, the economy and the environment compared to major international accidents. However, the Petroleum Safety Authority in Norway (PSA) has expressed concern regarding the increasing number of hydrocarbon leaks in the onshore petroleum industry[1], and the Norwegian Directorate for Civil Protection (DSB) has called for a more comprehensive risk analysis of the Oslo Port industrial area[2].

Project description

In an internal project SP Fire Research AS (Norway) has described the extent of land-based storage of fuel in Norway, including issues related to fire safety. The project report provides a brief overview of fuel types, related storage facilities and relevant laws and regulations governing fuel storage in Norway. The report will be published in the near future.

Fuel storage in residential homes and industry

Norwegian buildings currently use electric heating more extensively compared to other Nordic countries, where district heating based on biomass (e.g. wood pellets) is more common. However, there are still more than 100,000 operational oil boilers in Norway, and small-scale storage of propane for barbecues can also pose a risk when it comes to fire safety in residential homes.

Increased energy efficiency requirements and demands for lower greenhouse gas emissions will lead to higher demand for biofuels and district heating. This will increase the need for storage of biofuels in buildings and district heating facilities. Production of both bioenergy and district heating involves storage of large amounts of waste and wood products, which can self-heat and self-ignite under certain conditions. Even though there is currently little storage of biofuels in Norway compared to other countries, it is important to focus on fire safety at these facilities. Many of them are located close to settlements or urban areas to keep transportation costs low.

The widespread production of fossil fuels in Norway requires a large number of land-based storage facilities. Norway has the largest oil production in Europe and is the tenth largest exporter in the world. Natural gas production in Norway has increased significantly over the last two decades. Oil and gas is transported from offshore facilities, via processing terminals, to terminals along the Norwegian coast (17 main terminals and 45 distribution facilities[3]), where the fuel is stored before it is further distributed. Several of these terminals are located close to urban areas.

Fuel storage in parked vehicles

A parked vehicle may be defined as a fuel storage unit. A large amount of cars and busses, containing different types of fuels may be parked in a confined area. Many of the new types of energy carriers for vehicles have different fire and explosion characteristics than traditional fossil fuels, and may cause unpredictable fire safety issues. In addition, there are many motorhomes and caravans in Norway, containing paraffin or propane tanks for heating and cooking. The consequence of a fire accident in parked vehicles depends on whether the vehicles are parked close to buildings, or in parking garages under buildings or other populated areas.

Input from stakeholders and further work

During this project, different stakeholders gave their input on fire safe storage of fuels in Norway. They pinpointed the following issues, among others:

- Inadequate regulations on gasoline and diesel storage on private property.
- Insufficient knowledge of regulations governing gas storage.
- A need for improved inspections by the authorities, and better systems for internal controls.

PHOTO: JOHAN FREDRIKSSON

Fire in outdoor wood chip storage.

PHOTO: RAGNI FJELLGAARD MIKALSEN, FIRE RESEARCH AS

Small-scale fire experiment of wood pellets, performed at the test facility of SP Fire Research AS (Norge).

- The risk of smoldering fires and spontaneous ignition in wooden biomass.
- Are regulations adequate with regard to gas-powered vehicles parked underground?

As a continuation of this project, SP Fire Research AS (Norway) is now working on research projects on smoldering fires[4] and on gas powered vehicles in enclosed spaces[5].

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2 *Sydhavna (Sjursøya)- an area with increased risk*, The Norwegian Directorate for Civil Protection (DSB), Report HR 2277, ISBN 978-82-7768-333-1, 2014.

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4 The research program *EMRIS (Emerging Risks from Smoldering Fires)* started in January 2015. A more detailed description is found on page 27 in this edition of Brandposten.

5 SP Fire Research AS (Norway) started the research project *Electric and gas powered vehicles in enclosed spaces* in March 2015. The project is funded by The Norwegian Directorate for Civil Protection DSB).

Tactics and methodology for fires in underground environments

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A rescue operation in an underground environment is a very complex process. The nature and magnitude of the problems which may occur in connection with fire rescue operations can vary depending on the individual fire and rescue service organisation's abilities and the complexity of the facility in which the rescue operation is to take place. Depending on where the fire occurs in the facility and what is on fire, the conditions may vary for different kinds of operation. Thus, there is a great need for guidance with regard to risk assessment and the decision-making process regarding the choice of method. Different facilities require different solutions depending on their location in Sweden and the resources of the individual fire and rescue service organisation.

The *Tactics and Methodology for fires in Underground Constructions* (TMU) project was initiated to support the development of knowledge of fire and rescue services, and ran between 2012 and 2014. The purpose of the TMU project was to develop tactics and methodology to facilitate rescue operations in underground environments.

The results of the project consist primarily of improved methods, new educational material for fire and rescue services, the instructors of the fire and rescue services, and universities, and knowledge which contributes to safer and more efficient rescue operations, benefitting both fire and rescue personnel and persons in distress. The project yielded results usable by both the educational programmes of the MSB and advisers in the field. Moreover, the results are useful to regional administrative boards in their capacity as supervisory authorities, to the Swedish Work Environment Authority with regard to work environment issues related to smoke diving operations, to owners of facilities in their systematic fire prevention efforts, to fire and rescue services in their roles during accidents, and to universities in their training of engineers. Others who may find the results useful are construction planners for large projects, police and ambulance personnel, researchers in the field of fires and tunnels, and the media during coverage of accidents.

Conclusion

The project has clearly shown the difficulties in performing rescue operations in underground constructions. The primary problems during a rescue operation are *long distances*, the limited supply of breathable air, difficulties in reaching the site in time, and the ability to survey the site and orient oneself so as to gain an overall perspective on the accident. However, the project provides several different solutions to many of the problems.

Participants

SP, Mälardalens University, LTH Faculty of Fire Safety Engineering, Lund University, and the fire and rescue services of Borås *(SERF)* and Stockholm *(SSBF)* initiated the project in January 2012, and it concluded in March 2015.

Summary report (In Swedish)

Ingason, H., Vylund, L., Lönnermark, A., Kumm, M., Fridolf, K., Frantzich, H., Palm, A., and Palmkvist, K., "Taktik och Metodik vid brand i Undermarksanläggningar (TMU) - Sammanfattningsrapport", SP Sveriges Tekniska Forskningsinstitut, SP Rapport 2015:17, 2015.

PHOTO: HAUKUR INGASON, SP FIRE RESEARCH

Fighting a fire in an underground environment requires planning, tactics, technology, and knowledge about what is on fire.

What fire loads will a fire division resist?

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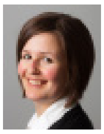

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A number of examples of fire divisions have been found on facilities in the petroleum industry where the fire resistance has been reduced compared to the general requirements in the regulations. The reduction is justified by calculations and analyses. The Petroleum Safety Authority Norway (PSA) needed an assessment of what fire loads fire divisions really will resist when they are exposed to a realistic fire.

SP Fire Research AS in Trondheim analysed the problem, and the assessments are published in the report *Tåleevne til brannvegger (English translation: Ability of Fire Divisions to Resist Fires)* from November 2014. The report (in Norwegian) can be downloaded from www.spfr.no.

Regulations

Requirements for fire divisions in the petroleum industry are given in *Regulations relating to Design and Outfitting of Facilities, etc. in the Petroleum Activities (the facilities regulations)* and in *Regulations of 31 January 1984 No. 227 concerning precautionary measures against fire and explosion on mobile offshore units*. The standard *NORSOK S-001 Technical Safety* states principles for safety and gives requirements for design of offshore facilities for production of oil and gas. The NORSOK standards are developed by the Norwegian petroleum industry to ensure adequate safety, value adding and cost effectiveness for existing and future petroleum industry developments in Norway.

The NORSOK standards shall as far as possible replace company specifications, and can be used as references for the authorities' regulations. NORSOK S-001 requires that fire divisions that may be exposed to a hydrocarbon fire to be H-classified, i.e. that it shall be tested for fire resistance when exposed to the hydrocarbon time-temperature curve (the HC curve), see figure 1. According to NORSOK S-001 external walls of living quarters shall as a minimum be classified as A-60. If the walls could possibly be exposed to a heat flux density above 100 kW/m², the divisions shall minimum be classified as H-60.

What fire loads do fire divisions resist?

To assess if the possible fire exposure exceeds 100 kW/m², a risk based decision model is used. The model is highly dependent on the applied frequency of the different types of fires. Examples can be found where fire divisions with classification A-60 are used in areas where they can be exposed to hydrocarbon fires, and it is therefore of great importance to know how large the fire loads is that this type of fire division will resist.

The limiting value of 100 kW/m² in NORSOK was determined many years ago, and there is a need to update the knowledge of relevant and realistic fire exposures. PSA therefore announced a limited tender where the task was to perform an evaluation to present the best available knowledge on the topic of fire resistance of different types of fire divisions.

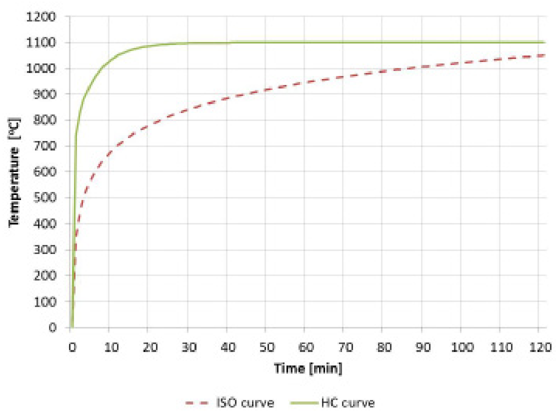

Figure 1 Time-temperature curve for HC-fire exposure and ISO-fire exposure.

The goal of the project was to establish an updated picture of what fire loads fire divisions will resist when exposed to real fires. A study of relevant documentation and literature was performed, to answer several questions related to fire divisions exposed to fire, specified by PSA.

In the project report these problems are discussed and assessed. The problems to be addressed are related to different types of fire divisions that are exposed to different types of fire loads, different geometries and if the relevant regulations are sufficient.

Conclusions and recommendations

The most important conclusions from this project are:

- There is very limited documentation available to be able to assess if a fire division of class A will resist a hydrocarbon fire. Relevant test data and test documentation must be developed as a basis to assess if existing A-60 fire divisions are acceptable in locations where it may be exposed to a hydrocarbon fire.
- The type and thickness of insulation material used in the divisions are crucial for the ability of the construction to resist the load from a hydrocarbon fire, depending on whether the insulation is mounted on the exposed or non-exposed side of the division. The optimal location of the insulation depends on the purpose of the fire division, e.g. if the element needs protection to obtain sufficient integrity, stability or insulation.
- As an example, a test of a 1.5 mm insulated steel sheet without joints showed that this element was able to resist a hydrocarbon fire for 120 minutes without loss of integrity. In this test the insulation was mounted on the non-exposed side. This must be regarded as conservative in relation to the steel temperature that occurred, as the heat in this case would have been stored in the steel.

In cases where the real fire exposure is defined to be higher than a heat flux density of 100 kW/m², it will be difficult to document that fire divisions of class A are satisfactory without further relevant documentation from tests. The more the heat flux density exceeds 100 kW/m² the lower the probability will be that fire divisions of class A are acceptable.

On this basis we recommend that a test program should be performed where different types of existing fire divisions with A-classification are exposed to hydrocarbon fires with a specified fire load. This will reveal if there is a need to upgrade existing fire divisions.

The project work has made it clear that there is a need for updating the knowledge on fire loads relevant for hydrocarbon fires, and possibly also a revision of relevant regulations. The project report shows experimental results that document that the heat from a hydrocarbon fire can result in higher fire loads than what today's standards and test methods reflect. This is the case for both open and enclosed fires.

An update of knowledge on this topic is crucial for future problems to be addressed in relation to protecting against winter conditions (winterization) of offshore platforms, where enclosed fires may lead to higher fire loads than can be handled by the current regulations.

Modeling of pressure rise in a room fire

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Pressure rise due to a fire in a room can result in major smoke spread to other spaces which hinders the evacuation and causes deaths in non-fire regions and may even result in structural failure, especially for a fire initially occurred in a closed room with only door gaps or small ventilation ducts connected to other rooms. The pressure rise can be easily built up in case of a fire in such a room. Due to the pressure difference, the smoke is pushed out through door cracks or ventilation ducts to other rooms or spaces. This problem can be severe in both residence building and public buildings, e.g. in a hospital where a large amount of patients have problems in mobility.

To fill in the knowledge gap in the pressure rises in room fires, a simple CFD model, Pressure Rise Simulator (PRS), is developed to simulate the fire-induced pressure rise in a single room with natural ventilation or mechanical ventilation. Test data from full scale fire tests performed in a room with a ventilation duct by FOI were used for validation. Comparison of the results with FDS simulations was also performed. Further, the influence of room sizes, design fire curves, wall materials, openings and mechanical ventilation systems on the pressure rise and pressure drop was investigated.

Validation of CFD modeling

An example of comparing the measured pressure rises with the results predicted by PRS and FDS is shown in Figure 1. The results show that PRS predicts both the pressure rise and pressure drop in the room very accurately. In contrast, FDS predicts the overpressure rise relatively well (slight undershooting in the simulations) but cannot predict the under-pressure using the extinction model. The same trend was found for the oxygen concentration and gas velocity in the ventilation duct.

Parametric study

Effect of room size

A larger room could result in a greater pressure rise and also a greater pressure drop. The difference in pressure rise between different rooms decreases with the increasing room size. The reason could be that in a larger room, the average temperature and average soot volume fraction is lower and thus the heat loss could be smaller. Meanwhile, the fire in a large room can sustain for a longer time and accumulate more heat which results in larger pressure drop after the fire is self-extinguished.

Effect of design fire curve

The maximum pressure rise for the fast curve is much higher than that for the medium curve, and the ratio ranges from 1.5 to 3 in the simulated scenarios. This indicates the importance of the fire growth rate on the pressure rise. However, the difference in the pressure drops is very limited. The reason could be that the total heat released by the fire in a room with a small opening before self-extinguishment is mainly dependent on the oxygen available. This amount of heat to a large extent determines the heat accumulated in the smoke inside the room. After extinguishment, the heat source is removed but the smoke is continually losing heat to the walls. This causes a sudden drop in the pressure. The pressure rise and drop do not increase continually with the fire size. For small fire sizes, the pressure rise increases with the fire size. However, as the fire size reaches to a certain level the pressure rise and drop do not vary with the fire size. The reason is that before the fire reaches the maximum designed fire size, it has been self-extinguished.

Effect of wall material

For a given fire curve, the wall materials have limited influence on both pressure rise and pressure drop. An exception is mineral wool where the pressure rise is clearly higher than the others (the increase is around 15%). The reason is that the mineral wool is highly thermal resistant and results in much less heat loss to the internal walls than the others.

Effect of opening size

The maximum pressure rise decreases rapidly with the increasing opening area, see Figure 2. From the results it can be concluded that

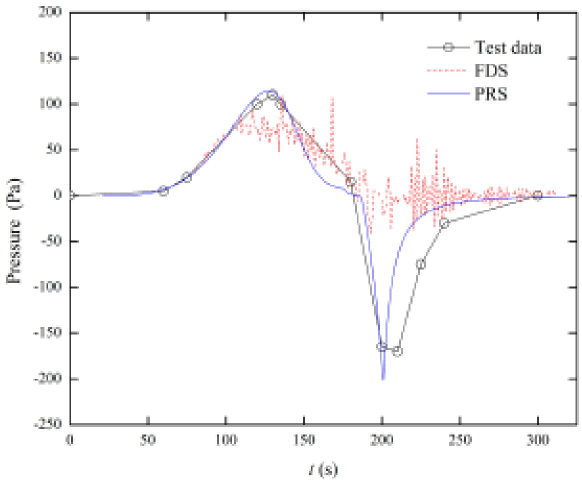

Figure 1 Comparison of the measured room pressures with the results predicted by FDS and PRS.

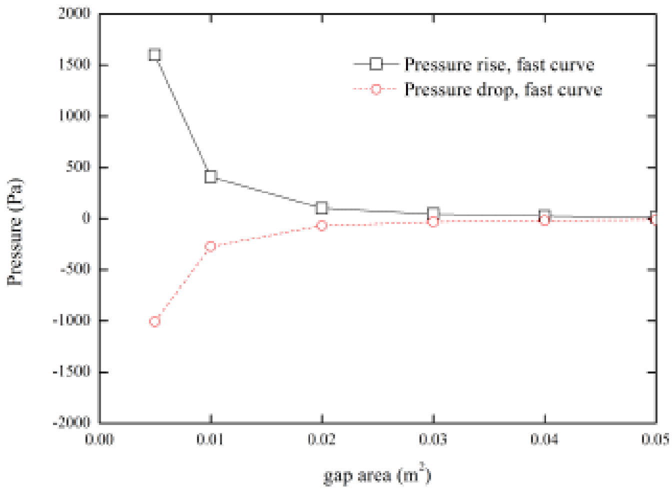

Figure 2 Pressure rise as a function of opening area for the fast curve fire.

the opening size is the most influential factor on the pressure rise and pressure drop.

Effect of mechanical ventilation
The pressure rise in a room with mechanical ventilation decreases with the increasing flow rates but this decreasing effect becomes insignificant for high flow rates. In most of the simulated cases, the pressure rise inside the room is higher than both the supply pressure and the exhaust pressure. Therefore both vents act as pressure release valves. However, in tests with supply pressures higher than the pressure rises, the supplied flows increase the pressure inside the room. Therefore the supply vent behaves differently for a low pressure rise and a high pressure rise inside the room.

Measures to reduce the pressure rise

For a given fire scenario, there are two solutions to reduce the pressure rise: (1) enlarging the openings at floor level for a room with natural ventilation (some smoke spread may still occur), and (2) shutting off the supply flow and lowering the exhaust pressure for a room with mechanical ventilation (possible to prevent smoke spread to other spaces).

More information can be found in SP Report 2015:08.

EMRIS (Emerging Risks from Smoldering Fires)

SP Fire Research AS contributes to the new research program EMRIS (Emerging Risks from Smoldering Fires).

A smouldering fire is a fire without flames. It can start and propagate at rather low temperatures, and the combustion produces smoke. Smouldering fires can be difficult to detect and difficult to extinguish, and the combustion can last for long periods of time. Smouldering fires can develop into larger fires and explosions and therefore represent a fire risk in dwellings, stored biomass, silos for storage of flour, powder and corn, in waste deposits and in goods transportation.

The research program EMRIS (Emerging Risks from Smoldering Fires) started in January 2015. The purpose of the program is to learn more about the phenomenon of smouldering, with regard to initiation, development and possibilities for extinguishment. EMRIS is led by Professor Vidar Frette at the Stord/Haugesund University College in Norway, and other partners are Otto-von-Guericke University Magdeburg (Germany), Lund University (Sweden) and SP Fire Research AS in Trondheim. The research program is funded by the Research Council of Norway and will last for 3 years. There are several PhD-candidates in EMRIS, and we are very proud of that one of them is a staff member at SP Fire Research in Trondheim. Ragni Fjellgaard Mikalsen will study smouldering fires in wood pellets, and has started her experimental work. SP Fire Research will contribute to EMRIS with both experimental work and scientific expertise. We are looking forward to fruitful cooperation in the EMRIS project group.

Read more about EMRIS on the research program's website: www.hsh.no/fou/fouprogram/ts/emris.htm

Terminology
smouldering combustion: combustion of a material without flame and without visible light (ISO 13943:2008)

Swedish: glödbrand
Norwegian: ulmebrann

PHOTO: ANNE STEEN-HANSEN, FIRE RESEARCH AS

Ragni Fjellgaard Mikalsen, PhD-candidate in EMRIS.

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Foam firefighting system in rail tunnels ensures safe transport of goods to Europe

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Since 2007, SP Fire Research has been involved in the development of a foam firefighting system to protect rail tunnels carrying freight trains in Antwerp's harbour district. SP's role in the project, with a total budget of over EUR 870 million, has been to evaluate the performance of the firefighting system, to provide data for determining the necessary system design capacities, and to act as an independent third party for tests of the systems in Antwerp. The tunnel system was opened for traffic in December 2014.

In February 2007, SP was invited by Svenska Skum AB (nowadays part of Tyco Fire Protection Products) to witness a demonstration test of a high expansion foam system in a test tunnel at the If Sikkerhets-senter in Norway. The demonstration was a result of initial discussions between Tyco and TUC RAIL, the Belgian company that had been instructed to specify the requirements for the extensive project for improved rail transport to Antwerp's' harbour area.

Almost eight years later, in 2014, the Liefkenshoek Rail Link ("Liefkenshoekspoorverbinding") is ready. 16,2 km long and up to 40 m below ground level, it runs under two canals and the River Schelde. About 13 km of the link is in tunnel, consisting of a twin-track tunnel, the Beveren Tunnel, and a double tube tunnel, the Boor Tunnel. The foam firefighting system that SP has assisted to develop consists of 5500 foam generators installed in 60 m long sections that are activated three at the time (i.e. 180 m) in the event of a fire (see Figure 1).

The owner of the rail link is Infrabel, Belgium's state-owned equivalent of Sweden's National Transport Administration. Infrabel has in turn employed the TUC RAIL consultancy as the requirements specifier and project supervisor.

The project was awarded to Locorail, a consortium consisting of the companies BAM, Vinci and CFE. The physical design and build construction was carried out by Locobouw, in turn a consortium of several companies.

The firefighting system has been designed and built by Locofire, a consortium of BAM Techniek bv and Aquasecurity NV. It is based on a system developed by Svenska Skum AB in the 1980s under the name of HotFoam®. Svenska Skum AB is nowadays part of Tyco Fire Protection Products, which was also involved in the project.

Figure 1 **A map of Antwerp's harbour area, showing the new Liefkenshoek Rail Link (green). The black sections show the two tunnels; the twin-track Beveren Tunnel and the double tube Boor Tunnel. The red route is the earlier connection. Map: By the courtesy of the Port of Antwerp.**

PHOTO: MAGNUS BOBERT, SP FIRE RESEARCH

Figure 2 **A simulated locomotive and freight wagon in the tunnel section. The 'locomotive' contains a 4,5 m^2 pool of heptane and a diesel oil spray.**

High expansion foam generated by fire gases, known as inside air system

The system that was demonstrated in Norway in 2007 was a HotFoam® system, a high expansion 'inside air' foam system having foam generators that using air from inside the protected space. High expansion foam is a foam extinguishing media consisting of high expansion foam that can fill a protected space. Fixed high expansion foam systems are traditionally used in buildings in which some particular object is to be protected, such as a store or an aircraft hangar. High expansion foam is also used by fire and rescue services as a manual system to fill rooms or buildings with foam. In conventional high expansion foam systems the foam generator is placed such that it draws air from outside the building, i.e. the air and fire gases in the protected room must be ventilated away at the same rate as the foam is applied. If not, a positive pressure will build up, and no foam can be generated. In an 'inside air' system, the foam generators are installed in the building, using the inside air (fire gases) to generate their foam. The generators are of a simpler and more robust design, without fans as normally used in conventional high expansion foam systems. In addition, there is no need to ventilate the space while the foam is being delivered. The drawback of such a system is that foam production falls off with higher temperatures of the fire gases, and can also be affected by the composition of the gases. 'Inside air' systems therefore require special foam concentrates that are more resistant to fire gases. The HotFoam® system has specially designed foam generators and a foam concentrate specifically developed for inside air applications.

Initial fire tests in SP's large fire test hall

SP Fire Research was asked by Svenska Skum AB to develop and perform a test programme to represent likely fires in a freight rail tunnel. A simulated locomotive and wagon were built and loaded with various types of fire loads. As the rail tunnel in Antwerp will be used for the transport of various cargoes, including chemicals and a range of fuels, potential fire sources of pool fires, spray fires and pallets were chosen. A series of tests was carried out in December 2007 in a section of tunnel that was built in SP's large fire test hall. The tunnel section was about the same as that of the Antwerp tunnels, i.e. with a cross-sectional area of about 40 m^2, see Figure 2.

In addition to deciding suitable fire scenarios, a key part of the work was also to provide basis for determining the necessary design capacity of the HotFoam® system.

For a water-based fire-fighting system, (e.g. sprinklers, foam), the quantity of extinguishing media applied per unit of time and per unit of area is a critical parameter, i.e. application rate. As high expansion foam fills a space, the unit of volume could be used instead of units of area, but in fact the application rate, expressed as l/min m^2, is also used for high expansion foam. The parameter filling rate, i.e. the rate at which the level of foam rises in the space (m/min), is often also used for traditional high expansion foam systems. This can be relevant if we know by how much the foam expands for a given system, i.e. the expansion ratio. In the case of an inside air system, foam production varies considerably, depending on the temperature and composition of the fire gases. If we are to talk about the filling rate, it is then preferable to use the term 'nominal filling rate', which is calculated from the application rate and the expansion ratio at a particular water pressure. For example, it was found in our fire tests in the tunnel section that, after foam had been produced for a while at some particular application rate, the filling rate fell to zero. In other words, the application rate was insufficient to extinguish the fire. After a number of tests, we arrived at the minimum necessary application rate. See Figure 3.

Tests in the 100 m long If tunnel in Norway

A series of fire tests was performed in the 100 m long test tunnel at If Sikkerhetssenter in Norway in March 2008. Fire scenarios and fire-fighting system capacities were chosen on the basis of the results of the tests in SP's large fire test hall. A total of 30 foam generators, distributed over three sections, were used in order to achieve the nominal application rate. The fire scenarios were those that had been used previously, although in certain cases a considerably higher fire load was created than could be employed in the test hall. The potential heat release rates from the various tests ranged from 9 MW to 100 MW.

The If tunnel has a cross-sectional area of about 40 m^2, which corresponds to the cross-sectional area of one of the Antwerp tunnels (the Boor tunnel). However, the If tunnel is considerably shorter,

PHOTOS: MAGNUS BOBERT, SP FIRE RESEARCH

Figure 3 **The burning heptane pool when the foam has reached up to the edge of the locomotive's apertures and started to flow in. The fire was extinguished shortly after. At lower application rates, the foam did not manage to get into the locomotive, with the filling rate falling to zero when the foam had reached part-way up the locomotive.**

Figure 4 **Simulated locomotive and freight wagon loaded with wooden pallets in the If tunnel.**

Figure 5 **The southern end of the If tunnel after conclusion of a test, showing foam pouring out of the tunnel.**

PHOTO: MAGNUS BOBERT, SP FIRE RESEARCH

Figure 6 The If tunnel with the HotFoam® system installed. In the foreground can be seen one of the three depth gauges used to measure the foam depth, monitored by video cameras. Some foam is still left on the walls and floor of the tunnel after a test.

PHOTO: MAGNUS BOBERT, SP FIRE RESEARCH

Figure 8 The foam system installed in the Boor tunnel in Antwerp.

PHOTO: JARI ANTINLUOMA

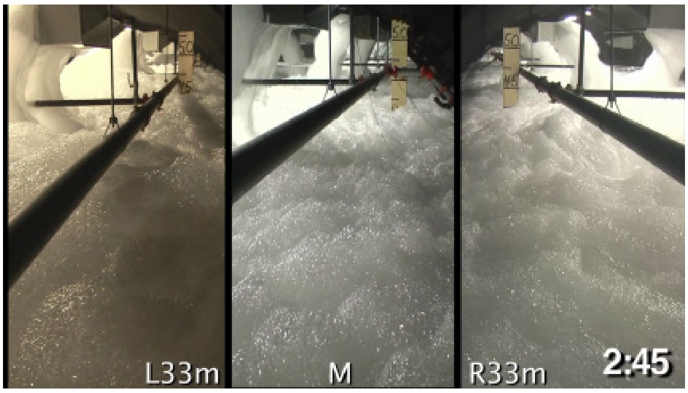

Figure 7 Stills from a video film after 2:45 minutes when the foam had reached almost 4,5 m at the respective measurement positions. The middle picture shows the foam depth at the centre of the tunnel (M), while those to the left and right show foam depths 33 m in each direction.

PHOTO: OSCAR BIALAS, SP FIRE RESEARCH

Figure 9 Testing the foam system in the Beveren tunnel in Antwerp.

which means that one entire 180 m long section (3×60 m) could not be used. Simulation of the considerably longer Antwerp tunnel was achieved by partly blocking the tunnel's openings. The assumption was that the foam produced in a 180 m section in a longer tunnel would to some extent hold back foam produced by foam generators further in towards the centre of the section. See Figures 4-5.

New tests

The work of the rail link project continued, with one of the elements being evaluation of other suppliers of foam extinguishing systems.

SP was contacted by Locofire at the end of 2011 to discuss additional tests in order to measure the actual filling rate of the foam. It was decided to perform additional foam filling tests in the If tunnel, without a fire, with the HotFoam® system installed, and as far as reasonably possible with the same conditions as during the 2008 fire tests. With the assumptions, and under the test conditions, a filling rate of 1,9 m/min was measured, and this was set as a requirement for the real system in Antwerp. See Figure 6-7.

Fill tests in Antwerp

On behalf of Locofire, SP attended and witnessed tests performed in the two tunnels in Antwerp. SP's role was to attend and, as an independent third party, to monitor the tests and to prepare a report on the test conditions and results. The system installed in the tunnels was based on the foam generators used in the HotFoam® system, somewhat modified in respect of the way in which the generators were mounted. Tests were performed in December 2012 and January 2013. The test results showed that the filling rate in some of the tests was lower than had been expected, and that foam production varied from one test to another. See Figures 8-9. Facing chemistry changes of such a long development project, a new foam concentrate had to be reformulated that could meet or exceed design criteria's from the beginning of the test in 2007.

New tests, with a new foam concentrate

During 2014, SP performed foam filling tests and fire tests in the If tunnel, using the new generation foam concentrate HotFoam 2%, in the same way as for the 2008 and 2012 tests. The measured filling rate in these tests was 2,1 m/min, which became the criterion for the Antwerp tunnels. The fire tests using the new foam concentrate showed similar performance to that of the 2008 fire tests. The performance requirements were regarded as fulfilled with the use of the new concentrate. Only final tests in one of the Antwerp tunnels now remained.

In addition to the tests for the tunnel application, it was also specified that the foam concentrate should fulfil the requirements for which the system using the old concentrate was already certified, such as for engine rooms in ships in accordance with IMO requirements. These tests were performed by SP in 2013.

Foam filling tests were performed in one of the Antwerp tunnels in April 2014 under SP's supervision. The filling rate was measured as 2,9 m/min, thus clearly exceeding the criterion of 2,1 m/min.

The tunnel was officially opened on 9th December 2014, and the first trains passed through it on 16th December. ■

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Fire-induced ceiling jet characteristics in tunnels under different ventilation conditions

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In the past decades, research on tunnel fire has mainly focused on design fires and smoke control in longitudinally ventilated tunnels. There is a clear lack of research on detailed ceiling jet characteristics in tunnel fires. In open fires, we can easily use established equations to calculate the flame height, gas temperature and gas velocity as a function of height. However, in tunnel fires, there are no similar tools to estimate these key parameters. The investigation of ceiling jet characteristics give valuable information about, e.g. the flame length and the possible fire spread, which indicate the hazards of any given tunnel fire, and are the key parameters in the design of a tunnel fire safety system.

Theoretical analyses and experimental work were carried out to investigate the ceiling jet characteristics in tunnel fires including a specific focus on the initial one-dimensional conditions for the ceiling jets. The key characteristic parameters focused on are flame lengths, ceiling jet velocity, ceiling jet mass flow rate, gas temperatures, radiation and fire spread.

Experiments

A total of 43 tests were carried out in two model tunnels with a scaling ratio of 1:10. The parameters tested include heat release rate, ventilation velocity, fire source height and tunnel geometry. The model tunnels are 12.5 m long and 0.6 m high. The tunnel widths are 1 m and 0.6 m. A photo of the 1 m wide model tunnel is shown in Figure 1. In each test, either the ventilation velocity is fixed with a varying heat release rate, or the heat release rate is fixed with a varying velocity. The heat release rate, HRR, varied between 16 kW and 632 kW, corresponding to full scale, HRR of 5 MW and 200 MW respectively. Both natural ventilation and forced ventilation conditions were tested. Fire spread to fuel targets close to the floor was also tested.

Flame length

Under low ventilation, i.e. when the dimensionless velocity is less than 0.3, there exists both upstream flame and downstream flame, and the upstream flame length decreases linearly with the increasing velocity. Under high ventilation, i.e. when the dimensionless velocity is greater than 0.3, only downstream flame exists. Regardless of ventilation velocity, the downstream flame length increases linearly with the heat release rate, and decreases with tunnel width and effective tunnel height, see Figure 2. The total flame length, i.e. the sum of downstream and upstream flame lengths, can be as long as twice the downstream flame lengths. Correlations for downstream flame lengths, upstream flame lengths, and total flame lengths are proposed.

PHOTO: YING ZHEN LI, SP FIRE RESEARCH

Figure 1 **A photo of the 1 m wide model tunnel in scale 1:10.**

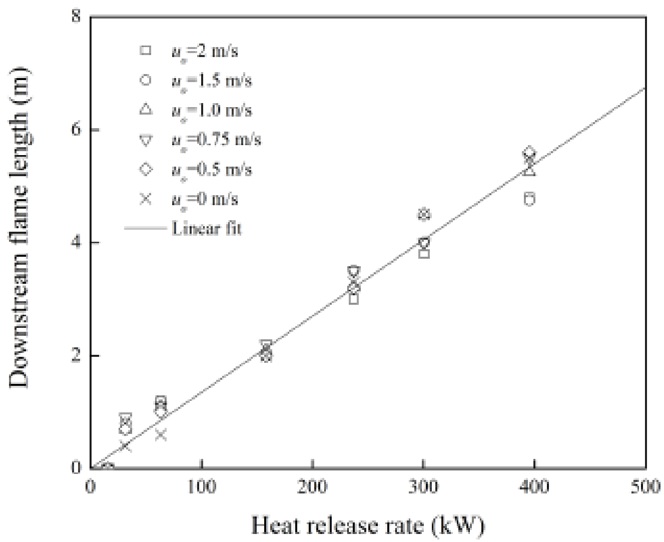

Figure 2 **Downstream flame lengths in one series of tests.**

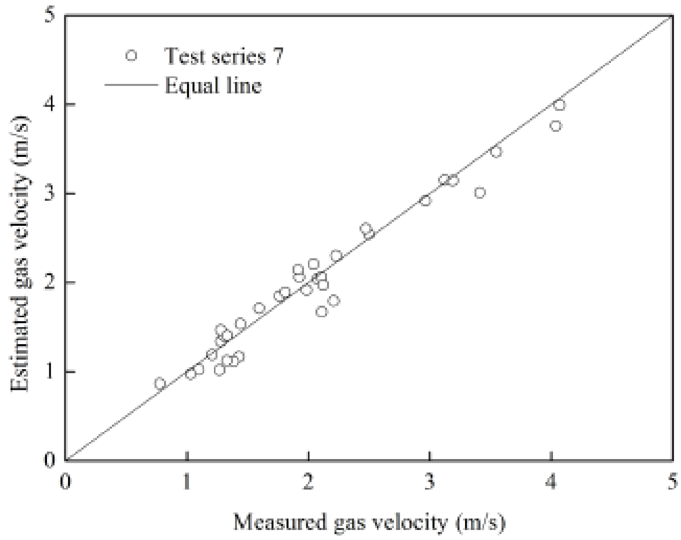

Figure 3 **Comparison of measured and estimated ceiling jet velocities for one series of tests.**

Ceiling jet velocity

Theoretical model of ceiling jet velocity in tunnels under different ventilation conditions is proposed and validated using test data. Under natural ventilation, the ceiling jet velocity increases with heat release rate and decreases with effective tunnel height. Under forced ventilation, the ceiling jet velocity increases with the ventilation velocity and the ceiling jet temperature. A comparison of measured and estimated velocities is shown in Figure 3.

Ceiling jet flow rate

The mass flow rate of the fire plume increases with heat release rate and effective tunnel height, under natural ventilation. Under high ventilation, the smoke mass flow rate increases linearly with ventilation velocity, independent of heat release rate. Therefore the smoke flow rate is not a constant for a given fire size as documented in some regulations.

Distribution of gas temperature

For large tunnel fires, there exist virtual origins. Between the virtual origins and the fire source, the gas temperatures decrease very slowly. This is due to the large amount of heat released within the intensive ceiling combustion region. Correlations for both the ceiling gas temperatures and the virtual origins under low and high ventilation are proposed.

Ceiling jet radiation

For tunnel surfaces in the upper smoke layer that are directly exposed to smoky gases and/or flames, the incident heat flux in the upper smoke layer can be simply correlated with the smoke temperature. For the lower layer, the view factor must be accounted for, together with the ceiling jet temperature and the emissivity of the smoke volume.

Fire spread

Fire spread to targets on the floor level or at a certain height above floor occurred when the radiation heat flux is greater than approximately 20 kW/m^2. The net heat flux on the fuel surface at the ignition is found to be a positive value.

More information can be found in SP Report 2015:23. The correlations proposed in the work can be applied for performance-based tunnel fire safety design.

Karl Fridolf receives SFPE Award

Karl Fridolf has been selected as SFPE Foundation's 2015 Student Scholar recipient for his doctoral research on rail tunnel evacuation. He receives the award as his research has hit two critical areas in fire safety engineering, more specifically tunnels and human behavior. As we see more fire safety engineering in tunnel design, we believe Karl's research to be beneficial in the FSE community as it provides insight on how people behave during emergencies in tunnels. Congratulations!

The Foundation's Student Scholar Award was established in 2006 by the Board of Governors of the SFPE Educational and Scientific Foundation to recognize students that are performing research to advance the science and practice of fire protection engineering and includes a $1,000 award honorarium. Prior recipients have included Alistair Bartlett, Isaac Leventon, Johan Andersson and Axel Jonsson (see full listing at http://foundation.sfpe.org/foundation-student-scholar/).

In November, Karl will travel to Philadelphia in the U.S. to collect his award. While there, he will join an award luncheon ceremony, and present his research at the SFPE annual conference and expo.

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New employees at SP Fire Research, Sweden

Chen Huang

Chen has worked as a researcher in the Fire Dynamics section since January 2015. She holds an MSc in Mechanical Engineering and has studied in three universities in three cities (Dalian, Tianjin, and Shanghai) in China. In 2009, she decided to pursue a PhD at Chalmers University of Technology. There, she studied numerical modelling using open source code regarding spray and turbulent combustion in engines. During her postgraduate studies she spent three months as a visiting researcher at Politecnico di Milano. In her spare time, she enjoys jogging and spending time with her family.

Mattias Pettersson

Mattias Pettersson began working as a technician at the Fire Resistance section in January 2015. Mattias has been a trained mason for 10 years, during which time he took courses in different plastering systems and with the SPEF. He has also worked as a warehouse manager, with acoustic systems, and with facade and concrete impregnation. In recent years, Mattias has developed a strong interest in distributed computing and contributes calculating power to medical research. He played hockey at an early age, before trying his hand with several martial arts and trial biking. He likes to spend his vacations motorcycling and enjoying nature.

Mia Kumm

Mia has worked as a researcher since February 2015. For the past 10 years, Mia, who was a full-time employee at Mälardalen University, has collaborated closely with the team at SP Tunnel and Underground Safety, primarily in research regarding fire and rescue services' operations in underground environments. She still teaches at the university. Mia holds a Licentiate of Engineering with Specialisation in Fire Technology, and has previously worked both as an instructor at the SRSA school at Rosersberg and as a fire safety consultant. Her hobbies include moving log houses, and she keeps eight horses at her farm in Västerås.

Helene Degerman

Helene works as a project leader , and her most recent post was as a consultant to ÅF AB in the Human Factors and Systems Safety area. Helene holds an MSc in Risk Management, and works with design processes to facilitate efficient and safe flows and interactions in technology and organisational development. Helene works at the Lund office. She spends her spare time in various combinations of the following: with her two dogs, outdoors, attempting to realise grand dreams of becoming an author, and following an unwavering drive to save the world from all evil.

Pierre Ingmarsson

Pierre is a project manager at the Fire Dynamics section, with a particular focus on renewable energy. He is a member of the steering group committee of TP Ocean, Ocean Energy Forum (the European Commission, Ocean Energy Europe), and supports marine energy in Sweden through the initiatives OffshoreVäst and the Maritime Cluster of West Sweden, Region Västra Götaland. Pierre holds an MSc from Luleå University of Technology with a strong background from managing R&D projects in the automotive industry.

German student at SP Fire Research

Stephan Mann

Stephan is a new master´s degree student from the Otto von Guericke University Magdeburg, Germany. For the next six month he is doing his thesis in the field of quantitative risk analysis at SP Fire Research. Under the supervision of Haukur Ingason he will evaluate a fire risk index model for tunnel construction sites by using Bayesian networks. According to his 10 years professional background as a fire officer he will aligned the model especially to fire services with responsibility to tunnel construction sites. His passions away from fire protection research are Boogie Woogie dance and rock climbing.

New employees at SP Fire Research, Norway

Roger Mårvik
Roger started working at SP Fire Research in January 2015, and since then he has mainly been involved in testing of fire places and stove guards. Roger is educated as an engineer both in food technology and industrial instrumentation. Previously he has worked in positions with responsibility for sale and marketing, e.g. at KCI-Medical and at Mettler Toledo AS.

Robert Olofsson
Robert started working at SP Fire Research in March 2015. He is graduated as a fire safety engineer from the Stord/Haugesund University College in 2014. Robert has until now been involved in fire resistance testing and testing of materials' reaction to fire.

Juan Ottesen
Juan started working as a technician at SP Fire Research in January 2015. He holds apprenticeship certificates as a welder, an industrial plumber and a sheet-metal worker. He has several certificates for welding and has worked on offshore platforms in the North Sea and also in mechanical contractor operations onshore.

Greg Baker
Greg started working as a Chief Scientist at SP Fire Research in April 2015. He comes from BRANZ Ltd in Wellington, New Zealand, where he led the Fire and Structural Engineering Section and the Fire Research Team. At SP Fire Research he will participate in research projects and contribute to develop new business areas especially within the building sector and fire safety engineering.

Audun Orrestad
Audun started working at SP Fire Research in March 2015. He has a Master of Science degree in product development and materials. He previously worked as an engineer in the consultancy company Reinertsen AS, where he had several duties related to petroleum activities. At SP Fire Research he is engaged in different types of large-scale fire tests.

Robert Harley Mostad
Robert started working as an engineer at SP Fire Research in September 2014. He holds an apprenticeship certificate as an ICT system operator, and earlier worked as a production and service engineer at Conoptica AS. At SP Fire Research he works with testing of materials' reaction to fire, and is also responsible for instrumentation and ICT.

One step closer to CE-marking of cables

The product standard EN 50575 (Power, control and communication cables) was published in The Official Journal of the European Union (OJ) July 10.

The publication of this standard is expected to lead to the following important dates:

- December 1st, 2015: CE marking comes into force – CE marking becomes possible for cables for use in permanent installations in buildings and civil engineering constructions in Europe
- December 1st, 2016: CE marking is mandatory (end of coexistence)

SP has applied to the national Swedish Accreditation Body SWEDAC in order to become a Notified Body for EN 50575. Once EN 50575 is published in Nando (New Approach Notified and Designated Organizations) Information System, which will be after December 1st this year, then SP will receive the Notification and consequently be allowed to issue CE-marking certificates.

In addition during this spring SP has on behalf of EUROPACABLE carried out a project with the purpose of proposing rules for extended field of application (EXAP) for Euro-classification of optical fibre cables. Test results from reaction-to-fire tests of optical fibre cables from different cable families have been analyzed and the results have been published in SP report 2015:32 - http://www.sp.se/sv/publications/Sidor/Publikationer.aspx?PublId=23598.

The proposal has become a Best Practice document of European Fire Sector Group SH02 and the Best Practice document will later this year be transferred into a Position Paper. Fire testing of optical fibre cables with reduced number of tests, in the same manner as for power cables, is possible already today based on the EXAP in the Best Practice document. After December 1st 2015, and once the Position Paper is published, CE-marking of optical fibre cables with reduced number of required tests is expected to be possible.

Please make sure to stay updated at: www.sp.se/cables.

New SP reports SP Fire Research, Sweden

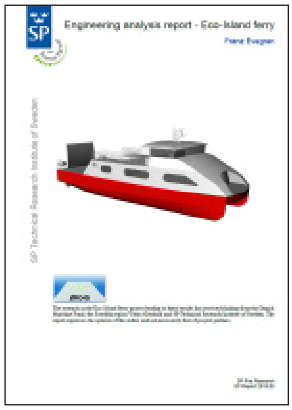
SP Rapport 2015:03

Engineering analysis report – Norwegian Future

Franz Evegren

This report documents the engineering analysis in accordance with SOLAS chapter II-2 regulation 17 (performance-based design) for the panamax cruise vessel the Norwegian Future with five upper decks designed in FRP composite instead of steel. Thermal insulation was provided on all interior surfaces in order to achieve 60 minutes of fire protection. A number of deviations to prescriptive and functional requirements were still identified since FRP composite is combustible. Fire development on open deck and fire spread through openings and vertically along the outboard sides of the ship were identified as fire scenarios where differences in fire safety would be significant. Different combinations of risk control measures, forming 21 trial alternative designs, were quantified through fire tests and simulations. A performance criterion for a safety factor of 100% left four acceptable trial alternative designs.

SP Rapport 2015:05

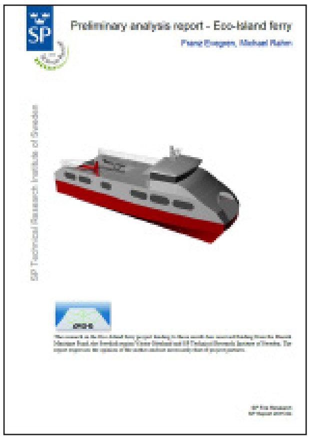


Engineering analysis report – Eco-Island ferry

Franz Evegren

This report documents the engineering analysis in accordance with SOLAS chapter II-2 regulation 17 (performance-based design) for the fictitious ship called the Eco-Island ferry. It is a small ro-ro ship built fully in FRP composite, designed to replace an existing steel ferry with space for about 6 cars and 200 passengers. It was shown to pose a number of deviations to prescriptive and functional requirements; primarily concerning that FRP composite is combustible. In the quantitative assessment different combinations of risk control measures, forming 21 trial alternative designs, were evaluated. A performance criterion with a safety factor of 50% left three acceptable trial alternative designs. Uncertainties were managed by assigning distributions to all quantified probabilities and consequence, which showed that the result was within a 90% confidence interval.

SP Rapport 2015:04

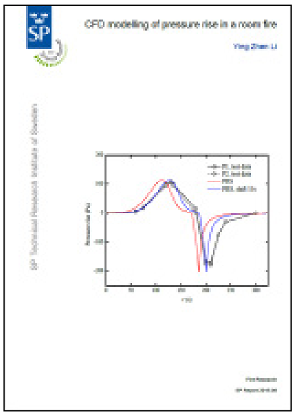


Preliminary analysis report – Eco-Island ferry

Franz Evegren och Michael Rahm

This report documents the preliminary analysis in qualitative terms in accordance with SOLAS chapter II-2 regulation 17 (performance-based design) for the Eco-Island ferry. The island ferry has a capacity of 200 passengers and 6 cars and was designed with structures in FRP composite instead of steel. A number of prescriptive and functional fire safety requirements are challenged by such a design. Primarily exterior surfaces are made combustible and internal divisions have combustible material behind the surface of low flame-spread characteristics, which may affect fire growth as well as smoke generation and toxicity. Seven different groups of spaces were identified with similar conditions for fire scenarios and several suitable risk control measures were identified. This lays out the foundation for the forthcoming quantitative analysis where trial alternative designs are evaluated through the developed fire scenarios.

SP Rapport 2015:08



CFD modelling of pressure rise in a room fire

Ying Zhen Li

Pressure rise due to a fire in a room can cause severe problems with smoke spread to other spaces. A simple CFD model, Pressure Rise Simulator (PRS), is developed to simulate the fire-induced pressure rise in a single room with natural ventilation and mechanical ventilation. Test data from full scale tests are used for validation. The influences of room sizes, fire sizes, wall materials, openings and mechanical ventilation systems on the pressure rise and pressure drop are investigated. Read more on page 26.

SP Rapport 2015:09

Influence of fire suppression on combustion products in tunnel fires

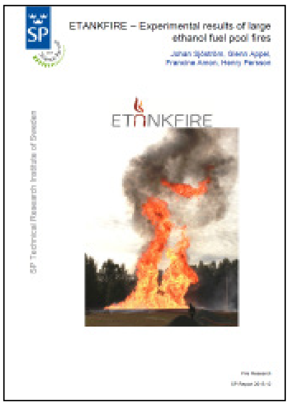
Ying Zhen Li, Haukur Ingason, Lotta Vylund och Glenn Appel

Model scale tunnel fire tests with and without fire suppression were carried out to investigate effects of fire suppression on production of key combustion products including CO and soot. The key parameters accounted for in the tests include fuel type, ventilation velocity and activation time. Guidance for use of fire suppression systems is provided from the point of view of production of combustion products. Read more on page 20.

Reports from SP Fire Research can be downloaded at www.sp.se (the publications tab)

Use the lower search box and click the arrow in the search box (not enter).

SP Rapport 2015:12



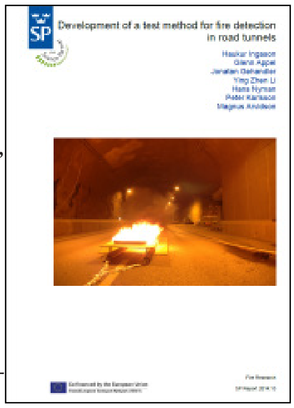
ETANKFIRE – Experimental results of large ethanol fuel pool fires

Henry Persson, Glenn Appel, Johan Sjöström och Francine Amon

This report presents the results of the full-scale fire experiments which were performed using ethanol fuels within the framework of the ETANKFIRE project. The purpose of the experiments was to investigate the combustion properties of both ethanol (E97) and E85 in order to study the heat flux produced by a large-scale fire and compare it to that of, for example, a petrol fire. Two experiments, one with each type of fuel, were performed on a fire surface with a diameter of 18 metres (254 m^2). Each experiment used 20,000 litres of fuel, which after ignition was allowed to burn wholly undisturbed until all of the fuel had been consumed. Extensive measurements were performed of, for example, burn rate, flame height, and heat flux at various distances and directions, which are presented in the report. It is known from small-scale experiments that ethanol-rich fuels emit roughly half of the heat flux into the surrounding environment as, for example, petrol. A comparison between the new data from the large-scale experiments and the calculations and existing test data for, for example, petrol showed that the heat flux levels of an ethanol fire may be 2-3 times higher than that of a corresponding petrol fire, which means that there is an increased risk of fire propagation, a greater need for cooling, and more limitations on the performance of the fire and rescue personnel.

The experiments were one part of the ETANKFIRE project, which is a Joint Industry Project, for which Släckmedelscentralen - SMC AB, Lantmännen, BRANDFORSK, and Shell Research Ltd funded the experiments in question. The next stage in the ETANKFIRE project is to study methodology and tactics for extinguishing storage tank fires involving ethanol fuels, and the project welcomes communication from potential new partners. For more information, please visit http://www.sp.se/en/index/research/etankfire/ Sidor/default.aspx, or contact Henry Persson.

SP Rapport 2015:13

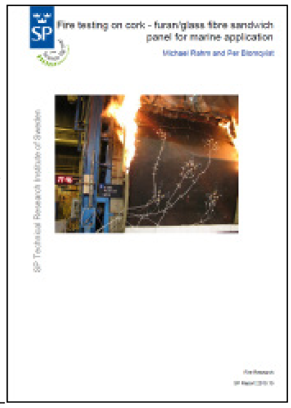


Development of a test method for fire detection in road tunnels

Haukur Ingason, Glenn Appel, Jonatan Gehandler, Ying Zhen Li, Hans Nyman, Peter Karlsson, Magnus Arvidson

The report discusses an experiment which was commissioned by the Swedish Transport Administration in order to develop a suitable method for testing detection systems in road tunnels. A proposal for a suitable testing method to test detections systems for flames, smoke, and line detectors, as well as camera detection systems in road tunnels is presented. It forms part of an EU project in which various technical systems which are to be used in the Stockholm Bypass were evaluated.

SP Rapport 2015:15



Fire testing on cork – furan/glass fibre sandwich panel for marine application

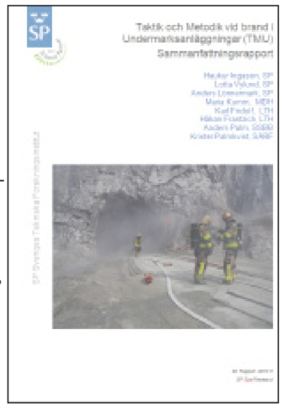
Michael Rahm och Per Blomqvist

As one part of the FIRE-RESIST project, an EU-funded project which aimed to improve the fire resistance of high-performance polymer matrix composite materials for selected transport sectors (air, rail, sea), a case study with a maritime application was defined and evaluated against relevant requirements. The selected component for the case study was a load-bearing composite bulkhead for the superstructure of a RoPax ship. The introduction of a combustible material into load-bearing constructions in a SOLAS ship constitutes a deviation from the prescriptive fire safety requirements. The correct way to handle such a deviation is to perform ae engineering analysis according to SOLAS II/2-17 - "alternative design and arrangements".

A limited analysis of the fire safety was performed within the project, and the result of this analysis was the creation of a set of performance criteria with regard to both fire resistance and reaction to fire that the component for the maritime case study must fulfil.

A series of fire tests were performed in order to verify compliance with the performance criteria. These tests are documented in this report.

SP Rapport 2015:17

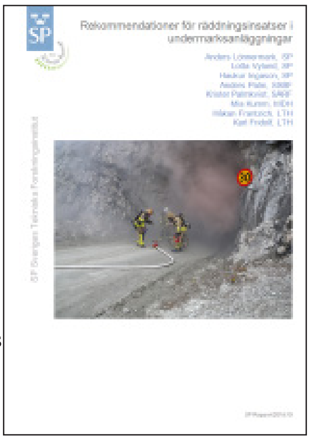


Taktik och Metodik vid brand i Undermarksanläggningar (TMU) - sammanfattningsrapport (= Tactics and Methodology for fires in Underground Constructions (TMU) - final summary report)

Haukur Ingason, Lotta Vylund, Anders Lönnermark, Maria Kumm, Karl Fridolf, Håkan Franzich, Anders Palm, Krister Palmkvist

The report summarises the results from the MSB project Tactics and Methodology for fires in Underground Constructions (TMU). A fire rescue operation in an underground environment is a very complex process. Depending on where the fire occurs in the facility and what is on fire, the conditions may vary for different kinds of fire rescue operation. Thus, there is a great need for guidance with regard to risk assessment and the decision-making process regarding the choice of method. The report describes the complexity of various emergency situations, and presents the full-scale tests performed in collaboration with multiple fire and rescue services. Moreover, the selection and development of various tactics and recommendations for fire rescue operations in underground constructions are presented. The project was a collaboration between SP, the Faculty of Fire Safety Engineering (LTH) at Lund University, Mälardalen University (MDH), and the fire and rescue services in Stockholm and Borås. The fire and rescue services in Sala-Heby also contributed during the full-scale tests. Read more on page 24.

SP Rapport 2015:19



Rekommendationer för räddningsinsatser i undermarksanläggningar(= Recommendations for rescue work in underground constructions)
Haukur Ingason, Lotta Vylund, Anders Lönnermark, Maria Kumm, Karl Fridolf, Håkan Franzich, Anders Palm, Krister Palmkvist
Rescue work in underground constructions often requires special tactics and methodology, and thus also specially adapted equipment, planning, and training. Moreover, different installations require different solutions depending on geographical location and the capabilities of the individual fire and rescue service organisation.

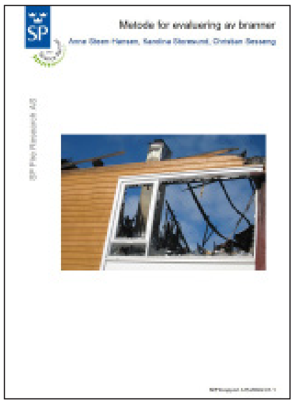
One of the tasks of the TMU project (see SP report 2015:17) was to draw up guidelines or recommendations for rescue work in different types of underground installations. Here, the term 'underground construction' primarily refers to road tunnels, railway tunnels, mines, and underground parking garages. The purpose of the report is thus to provide recommendations for government authorities, fire and rescue services, and construction planners regarding how a rescue operation in an underground constructions should be performed in an effective manner, while minimising the risk of injury for the fire and rescue personnel. Some limitations in connection with rescue work are also presented. Only in Swedish.

SP Rapport 2015:23

Fire-induced ceiling jet characteristics in tunnels under different ventilation conditions
Ying Zhen Li and Haukur Ingason
Theoretical analyses and experiments were conducted to investigate the ceiling jet characteristics in tunnel fires. A series of fire tests were carried out in two model tunnels with a scaling ratio of 1:10, with varying heat release rates, ventilation velocities, fire source heights and tunnel geometries. The key parameters investigated include flame length, ceiling jet velocity, ceiling jet mass flow rate, ceiling jet temperature distribution, radiation heat flux and fire spread were analysed and correlations for these parameters are proposed. Theoretical and experimental data are compared and evaluated. The results show a very good agreement between the test data and the proposed theoretical models. Read more on page 32.

New SP reports SP Fire Research AS, Norway

SPFR-rapport A15-20022-01-1



Metode for evaluering av branner (= (Method for investigation and evaluation of fire incidents)
Anne Steen-Hansen, Karolina Storesund, Christian Sesseng
The evaluation of an accident involves the systematic mapping and assessment of the origin and development of the incident. This report outlines a simple method for investigating and evaluating fire incidents.
The method is a tool to make the evaluation of a fire incident systematic, and comprises the following topics:

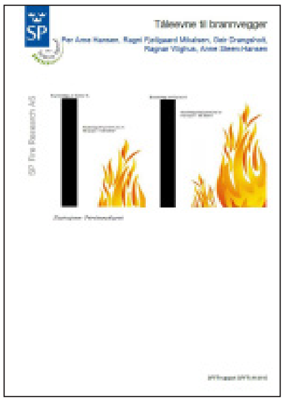
- How the evaluation can be planned and performed
- Necessary assumptions and limitations
- What information could be relevant, and where and how to find the information
- How to record the information systematically
- Relevant informants
- Other factors that could be relevant

The method should especially be relevant for less comprehensive evaluations where there either are a limited number of factors to be investigated, or where the situation is relatively clear.

The method is applied to a fire incident in a Norwegian nursing home in 2014. The evaluation of this incident is not complete, but is meant as an example of how the method can be applied.

The report is prepared for the Norwegian Directorate for Civil Protection (DSB), and is written in Norwegian.

SPFR-rapport A14116



Tåleevne til brannvegger = (What fire loads will a fire division resist?)
Per Arne Hansen, Ragni Fjellgaard Mikalsen, Geir Drangsholt, Ragnar Wighus, Anne Steen-Hansen
This report is prepared for the Petroleum Authority Norway (PSA). The background for the report is that PSA has noticed examples where the fire resistance of fire partitions on offshore installations has been reduced compared to the general requirements in the regulations. The reduction is justified by calculations and analyses, and the risk-based decision model is highly dependent on the applied frequency of the different types of fires. There are examples where fire walls with fire resistance classification A-60 are installed adjacent to areas where a hydrocarbon fire may occur.

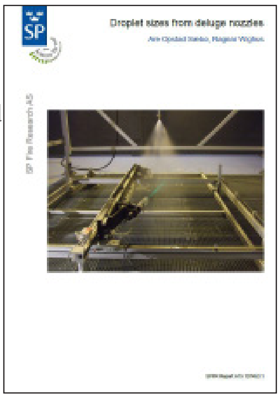
There is a need for an update and development of knowledge on fire loads relevant for hydrocarbon fires. An assessment of today's best knowledge regarding the fire resistance of different types of fire walls exposed to different types of fires should be performed based on scientific and experimental data and information.

The goal of the project was to establish an updated picture of what fire loads fire walls will resist when exposed to real fires. A study of relevant documentation and literature was performed, to answer several questions specified by PSA related to fire divisions exposed to fire.

The report is written in Norwegian. Les mer på side 25.

Rapporterna från SP Fire Research AS laddas ner från www.spfr.no.

SPFR-report A15 107453:1



Droplet sizes from deluge nozzles

Are Opstad Sæbø, Ragnar Wighus

From 2006 SP Fire Research AS performed investigations on the effects of deluge systems on oil- and gas fires, partly as generic experimental work and partly as a basis for development of computational models. Information about the droplet size was crucial to be able to calculate how the water from the deluge systems was heated and evaporated. Laser doppler anemometry, LDA, which was a relatively new technique at that time, was used to characterize several deluge nozzles, and some unexpected results appeared. Most of the droplets that were measured had a diameter less than 1000 µm (1 mm). This differed from the common knowledge of droplet sizes for this type of nozzles.

To be able to evaluate if the LDA-measurements gave reliable results, SP Fire Research carried out parallel measurements of droplet sizes at two laboratories in 2008; with an LDA-technique and a photographic technique based on laser light.

The result of the research was that the photographic method showed far larger droplets, and a closer look at the earlier measurements showed that a non-optimal optic system had been used to analyze the droplet sizes. By using a different type of optics in the LDA system, the difference between the two types of measurement was reduced. The difference was largest for droplet sizes above 1200 µm.

The conclusion from the project was that there are differences in results for droplet size distribution, when using different measurement techniques. A significant source of error was the use of non-optimal optics in the LDA measurements, leading to the largest droplets not being measured. One cannot conclude with certainty which of the measurement techniques gives the correct results, since the photographic technique also had some sources of error with regards to which droplets were disregarded in the counting routine.

The report about these measurements is written in English, and is now made public.

SPFR-rapport A15-20095-1

Studie av synlighet til høytmonterte markeringsskilt i brannrøyk ((Investigation of visibility of high)

Ragni F. Mikalsen

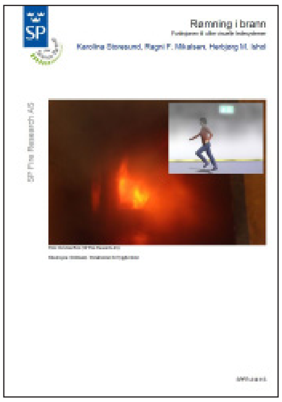
The goal of the project was to investigate the visibility of high positioned evacuation signs in smoke, i.e. evacuation signs positioned in the smoke layer.

Two experiments were conducted in a test rig consisting of a bedsit and a corridor, where one fluorescent and one electrical powered sign were mounted high up on the walls at each end of the corridor adjacent to the fire room. The experiments involved the triggering of an optical smoke alarm and sprinkler system in the test rig.

The visibility of the signs was assessed qualitatively through observations and video recordings. The levelling of the smoke and the smoke density were assessed by optical measurements of smoke density, as well as by observations of the visibility of indicators of height and depth in the corridor.

The results indicate that high positioned signs will be visible in light, diluted and non-turbulent smoke. More dense, darker and turbulent smoke will quickly obscure visibility, and the signs will not be seen any more.

SPFR-rapport A14113



Rømning i brann. Funksjonen til ulike visuelle ledesystemer. (= (Escape from fire. The function of different visual way guidance systems)

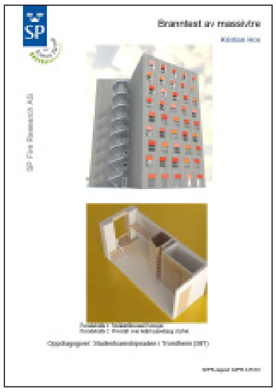
Karolina Storesund, Ragni F. Mikalsen, Herbjørg Ishol

The background of the project is the many questions the Norwegian building- and fire authorities have received regarding the requirements for performance, levels of performance, prescribed solutions and references to different standards on installation of way-guiding systems. There is obviously a high level of confusion, uncertainty and disagreement among the different parties.

A project goal has been to document the theoretical basis that should be used when assessing performance of a way-guiding system compared to the level of performance given by the guidelines to the Norwegian building regulations.

The report is prepared for the Norwegian Building Authority (DiBK) and the Norwegian Directorate for Civil Protection (DSB), and is written in Norwegian.

SPFR-rapport A15101



Branntest av massivtre (= (Fire test of cross laminated timber)

Kristian Hox

This report presents the results from two fire tests conducted in a test rig consisting of a bedsit and a corridor. The tests were performed for Studentsamskipnaden i Trondheim (SiT), which is the organization responsible for student housing in Trondheim. The bed-sit and the corridor were protected by a sprinkler system. The first test was conducted with a sprinkler system, while the second test was performed without a sprinkler system. We also wanted to study the burning and charring of an unprotected wall of massive cross laminated timber (CLT), and of a CLT wall protected by gypsum boards and insulation.

The first test showed that the sprinkler system managed to control and suppress the fire in the fire room (the bed-sit). The test without a sprinkler system in the bed-sit showed that the fire rapidly developed to flashover and that the fire spread to the surfaces in the corridor– despite the fact that there was a sprinkler system in the corridor. It was also shown that the CLT provided insulation until the wood was completely burnt through.

The walls and the ceiling in the tests were made of 100 mm CLT. The time to burn-through of the ceiling and walls was approximately 70 minutes (measured on the unprotected wall closest to the wall with the window). The report is written in Norwegian.

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