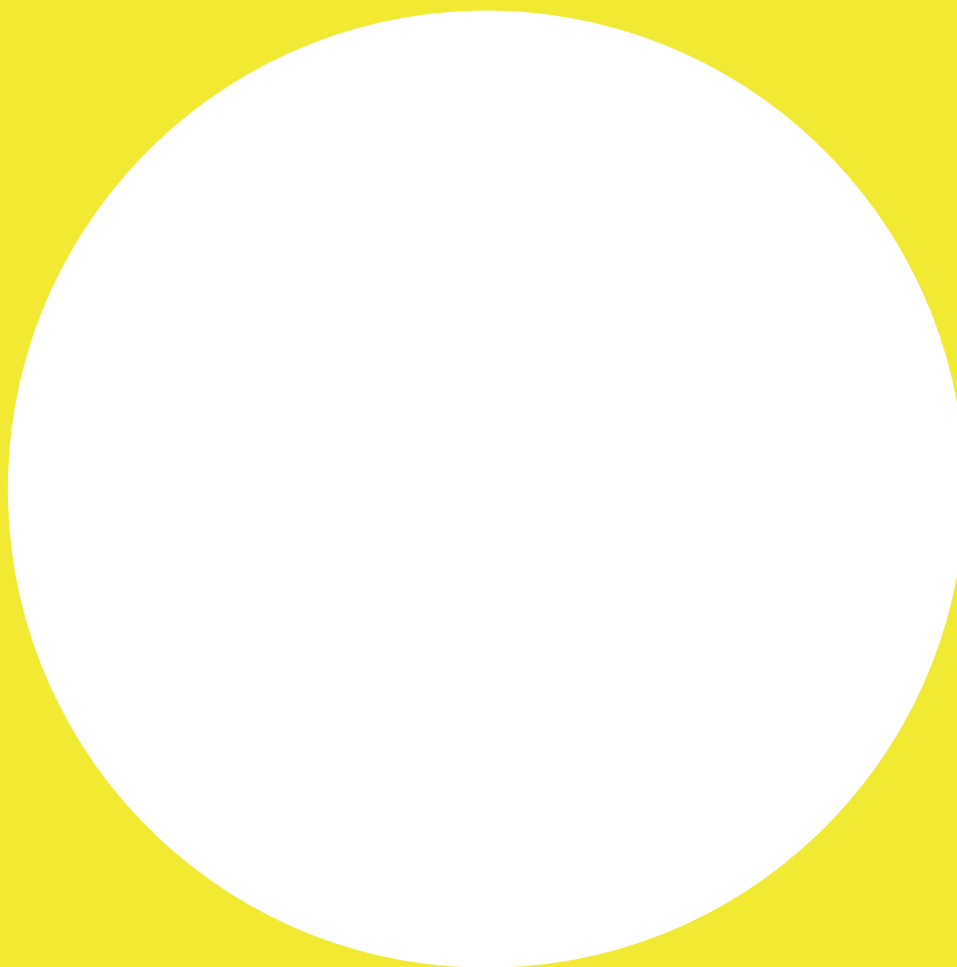


Review of efficient manual fire extinguishing methods and equipment for the fire service





FRIC Report D4.1-2020.05

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Keywords: Fire extinguishing, Firefighting, Efficient extinguishing

Quality assurance: Ann Elise Steen-Hansen, RISE Fire Research/NTNU

Front page photo: RISE Fire Research

Photo page 3: RISE Fire Research

Publisher: FRIC Fire Research and Innovation Centre

Trondheim, March 2020

ISBN 978-91-89167-94-0



Abstract

The late 90s and the early 2000s was a period with relative extensive research and innovation in the area of manual fire extinguishing methods and equipment for the fire service. New equipment such as the cutting extinguisher and extinguishing spears allowed to conduct offensive attacks from the exterior of a building, reducing the exposure of fire fighters to fire and smoke and their associated risks in general. This led to the development of new firefighting tactics, as for example the Quadrant Model of the Dutch fire service, which extends the “traditional” offensive interior attack and defensive exterior attack by the offensive exterior attack and defensive interior attack.

Recently the research focus has furthermore increasingly shifted to environmental aspects, such as the water consumption and effect of additives (i.e., foam) on humans and the environment. Extinguishing with smaller amounts of water is beneficial for the environment, reduces water damage and lowers the burden on the water delivery system.

Conclusion

In conclusion, the systems most relevant to be further tested in a fire situation in a small house or dwelling are the cutting extinguisher and the extinguishing spear.

These systems are different in operation but have both shown to be promising with regard to fulfilling the different objectives of the overall project. Being relatively easy to utilize with the right training during internal extinguishing efforts executed from the outside of the building, and being only water based to minimize contamination, due to lower water consumption, of the surrounding areas give these systems advantages over conventional equipment.

Especially if the systems are used in combination with an IR camera to locate the fire, the extinguishing efforts can be started early and effectively, and the water amount needed to control the fire may be reduced. The need for firefighters with breathing apparatus is reduced as well, hence reducing the smoke exposure to firefighters.

The fact that the fire service also recognizes the potential of using these systems early in the extinguishing efforts, and is working on implementing them, prompts the need for scientific backup.

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Preface

The Fire Research and Innovation Centre (FRIC) commenced in spring 2019. The aim is to increase the knowledge within fire safety to make optimal decisions and develop better solutions that provide increased fire safety in buildings. FRIC is led by RISE Fire Research in Trondheim, with NTNU and SINTEF as research partners. FRIC has partners from public organizations, fire safety consultants, producers and suppliers of building products and building installations, and property development and management. The research center is funded by all partners, in addition to funding from the Research Council of Norway, program BRANNSIKKERHET, project number 294649. (www.fric.no)

1 Background

The late 90s and the early 2000s was a period with relative extensive research and innovation in the area of manual fire extinguishing methods and equipment for the fire service [4]. New equipment such as the cutting extinguisher [5] and extinguishing spears allowed to conduct offensive attacks from the exterior of a building, reducing the exposure of fire fighters to fire and smoke and their associated risks in general. This led to the development of new firefighting tactics, e.g. the Quadrant Model of the Dutch fire service [6], which extends the conventional offensive interior attack and defensive exterior attack by the offensive exterior attack and defensive interior attack.

Recently the research focus has furthermore increasingly shifted to environmental aspects, such as the water consumption [7] and effect of additives (i.e., foam) on humans and the environment. Lindström et al. [8] conclude, in their study concerning firefighting in Sweden: “It is alarming that first responders in Sweden use foam more and more when research shows negative effects on both humans and nature”. This is not to say that only foam is of concern for the environmental impact of fire extinguishing, also extinguishing techniques that do not rely on additives to the extinguishing water are scrutinized in order to minimize the required water amount [7,9]. Extinguishing with smaller amounts of water is beneficial for the environment, reduces water damage and lowers the burden on the water delivery system.

The above-mentioned statement regarding foam usage, highlights furthermore the need for better research, dissemination and closer cooperation between fire services and the research community. This is also highlighted by Ingason et al. [4] in a very recent study, commissioned by the Swedish Civil Contingencies Agency (MSB). The study mapped the conditions for learning in the fire service. It showed through interviews with the fire service that there is a gap between important research knowledge and practical activities.

Ingason et al. [4] conducted furthermore workshops to identify areas that pose knowledge gaps and challenges that require research. Several of the identified areas, such as new building materials, the environmental consequences of extinguishing with foam and increasingly complex buildings are highly relevant for FRIC and will be further discussed in the present report.

1.1 Objectives

The objectives of this report are to briefly summarize the state-of-the-art for manual fire extinguishing equipment, used by the fire service for fighting of building fires, and to highlight existing knowledge gaps and challenges in this field. The report is intended to provide an overview for FRIC partners and to serve as a roadmap of topics and knowledge gaps regarding extinguishing systems that ought to be addressed by FRIC project *4.1 - Fire extinguishment*.

1.2 Methodology

The information for this report has been obtained through a literature review.

2 State-of-the-art and knowledge gaps

The extensive study conducted by Ingason et al. [4] can be used as a basis for the identification of knowledge gaps that are relevant for FRIC. This is based on the assumption that the fire service in Norway and Sweden, both Nordic countries, face similar challenges. Ingason et al. recognized nine strategic challenges (listed below) based on a literature survey and RISE's competence platforms¹. The order of these challenges is based on the prioritisation by the Swedish fire service. Areas that are within the scope of FRIC are highlighted in bold.

1. *New energy carriers in vehicles*
2. *Foam application*
3. *New building materials*
4. *Densification and robust urban planning*
5. *Technical knowledge**
6. *Large forest fires*
7. *Underground facilities*
8. *Development of "total defence"*

*) Technical knowledge includes **integrated technical systems** as well as **change in staffing and technology**.

Some of the identified challenges are relevant for FRIC in general but may be less applicable to project 4.1 task 2, specifically concerning fire extinguishing by the fire service. Note that the discussion in the present report follows the same order as presented above. However, this does not necessarily reflect the priority they have for FRIC project 4.1.

¹ RISE's competence platforms are selected focus areas that is partly founded by internal funds.

2.1 Foam application

The use of foam for firefighting applications has traditionally been the primary choice for certain types of fires, such as fires of liquid fuels, but due to the negative impact of foams² alternative methods are desired [8].

2.1.1 Foam

Foam extinguishes fires by suppressing all of the three fundamentals of a fire (fuel, oxidizer and heat), as it is separating the flame from the fuel surface, it leads to suppression of vapours (from liquid or pyrolysis of solid fuels), and it smothers and cools the fire. It furthermore has the capability to suppress reflash and reignition for a certain period of time. There is a large variety of different firefighting foams available. Foams can be categorized based on different aspects. One is the mechanism for the foam generation, which can be:

- *chemical (the foam is produced by a reaction of two chemicals that generate gases) or*
- *mechanical (physical agitation of the foam concentrate is used to produce foam).*

Chemical foams were more common earlier. Nowadays, most foams are mechanically generated. Some of the most common foams used by the fire service are:

- *Aqueous film forming foam (AFFF)*
- *Alcohol resistant aqueous film forming foam (AR-AFFF)*
- *Synthetic detergent foam (mid- to high expansion)*
- *Fluoroprotein foam*
- *Protein foam*
- *Film forming fluoroprotein foam (FFFP)*
- *Alcohol resistant film forming fluoroprotein foam (AR-FFFP)*

Foams can furthermore be categorized by their capability to extinguish either class A or class B³ fires. Class A foams break down the surface tension of water, helping it to soak into solid fuels. Class B is carbon repellent, which causes the foam to form a blanket above the liquid fuels. The application scenario, composition, and hence environmental impact, as well the application technique for *class A* and *class B* foams are therefore quite different. A third method to classify firefighting foams is by their expansion ratio which is the volume ratio of the foam to the foam solution:

- *low-expansion foam (expansion ratio 2/1 – 20/1)*
- *medium-expansion foam (expansion ratio 20/1 – 200/1)*
- *high-expansion foam (expansion ratio > 200/1)*

² The effects foam and other additives (e.g. gel) may have on humans and the environment depend on the specific product that is used.

³ Class A fire represents fire in solid materials and class B fire represents fire in liquids.

There are studies that have investigated foam composition, such as the research by Kärman [10] that analysed the content of per- and polyfluorinated alkyl substances (PFASs) including precursor compounds in eight selected firefighting foams, available in Sweden. However, from the above it is clear that there exists a large variety in foams, which is also among the reasons why it can be challenging for fire services to assess the environmental impact of foams. The interviews conducted by Ingason et al. [4] showed that:

- *There is great uncertainty regarding the health and environmental effects of today's extinguishing foams. Furthermore, there is a certain distrust in product declarations and information provided by the manufacturers.*
- *Even though alternative methods are frequently used, there is still a need for supporting information and knowledge to decide when and if foam can be used depending on the situation.*
- *There is a need for support on how the environmental impact of fire extinguishing can be reduced, which does not apply to foam only.*

In addition to foam, there are several other additives that can be employed by the fire service, such as fire-retardant gel and X-Fog. Fire-retardant gel has shown to have a good effect for reduce mitigating fire spreading to non-ignited fuel and can be used to minimize fire spread [11]. X-Fog is an additive that contains ammonium-chloride and -phosphate which reduces the surface tension of water helping to create smaller droplets, resulting in larger surface area per unit water. Holmsted [12] studied the use of X-Fog as an additive with different application methods like cutting extinguisher, standard variable nozzle, hand held fire extinguisher and extinguishing spears. This was compared to other extinguishing methods for different scenarios and concluded that employing a cutting-extinguisher with 1 vol% X-Fog overall led to the lowest water demand, inhibited reignition and left the least water remaining (i.e., reduced water damage) after the fire was extinguished.

The large variety of foams and other extinguishing additives are posing challenges to the fire service and leave knowledge gaps that should be addressed. The main focus regarding these products is, however, their impact on the environment and is, though important, not regarded as a first priority in FRIC.

2.2 New building materials, densification, and robust urban planning

The identified challenging areas *new building materials* and *densification and robust urban planning* are as such not directly linked to manual extinguishing methods and equipment. However, they may require that the fire service adapts their extinguishing methods and tactics in order to ensure efficient extinguishing.

The building industry has in the recent years experienced a renaissance of timber structures (for example cross laminated timber constructions, CLT), which is driven by their lower environmental impact and smaller carbon footprint, the possibility of energy efficient construction and good thermal insulation properties of wood. This includes also tall buildings and wood as façade cladding.

A recent literature survey conducted by Reitan et al. [13] summarized research findings in the period 2010 – 2018, which shows that the fire dynamics of exposed CLT compared to protected CLT or a non-combustible construction changes. Exposed CLT leads to an earlier flashover and a higher heat release rate (HRR) than surfaces of lower combustibility, which will affect the extinguishing efforts. Furthermore delamination of the CLT leads to a different transient fire development than in traditional wall surface materials (i.e. a charred layer separates from the CLT “suddenly” exposing a new layer of wood) [14].

Façade fires can, depending on the façade material and mounting details, spread rapidly along the exterior of a building, which can make extinguishing efforts challenging due to the fire size. If the fire is able to spread behind the cladding, for example in ventilated façades, it may also be challenging for the extinguishing agent (water, foam, etc.) to reach the fire. This is especially true for tall buildings, which exceed the working height of the fire services’ equipment. For this type of building fixed fire extinguishing systems become more important. These can be static (e.g., façade sprinkler systems) or dynamic (e.g., remote controlled or automatic water monitors [15]). However, due to densification in cities, it may be challenging for the fire service to reach the fire even for lower buildings.

The above-described challenges for façade fires are not unique to wooden façades but may also apply to other types of combustible façade claddings. Application of additional combustible insulation (e.g., different types of cellular plastics) to older buildings to make them more energy efficient may also represent a fire safety challenge.

The aim to build energy-efficient buildings also leads to more airtight constructions, requiring mechanical ventilation. This causes a different pressure build-up and potential smoke spread as shown in different numerical and experimental studies [16–18]. Mikalsen et al. [19] conclude that increased pressure may make evacuation and extinguishing efforts more difficult. Doors can be harder to open, and the risk of backdraft can also be increased in airtight buildings, as the fire quicker may become ventilation controlled compared to fires in conventional buildings.

2.3 Technical knowledge

Technical knowledge was ranked on fifth place by the fire service, based on the interviews and workshop conducted by Ingason et al. [4]. In this context *technical knowledge* includes both *integrated technical systems* and *alternative fire extinguishing methods*.

2.3.1 Integrated technical systems

Ingason et al. [4] focus on integrated extinguishing systems, arguing that increasing use of CLT and new building materials, as mentioned in the previous section 1.2, requires to supplement passive fire protection with active fire protection systems. This could be for example automated water monitors, such as mentioned in section 1.2 [15], water mist systems, sprinkler or similar.

However, one has also to consider that modern buildings may have other types of integrated systems, that can pose challenges for the fire service. This may for example concern building integrated solar panels or energy storage systems (e.g., batteries).

The consequences that solar panels and batteries may have for fire extinguishing were highlighted in the study by Mikalsen et al. [19] which was based on a literature survey, workshop, interviews as well as case-studies. The study highlights that the main challenge for fire extinguishing involving solar panels is the electricity created by them, posing a risk of both re-ignition and electrocution. Extinguishing of battery-fires is a main concern for the fire service, which is also reflected in the ranking presented in the beginning of this document (chapter 1), which puts *new energy carriers in vehicles* in first place. New energy carriers in that context are not only batteries. Batteries in vehicles are furthermore more commonly compared to battery energy storage systems, BESS, in buildings. The challenge that burning batteries pose to the fire service are, however, much the same. Battery fires require substantial cooling, which can be achieved by water. The challenge is though, that water and other conductive extinguishing media can lead to short circuiting and, hence, the fire propagation to new battery cells within a battery module or pack. Employing large amounts of extinguishing water lead furthermore to a bigger impact on the environment (untreated extinguishing water that reach the ground) and can cause larger damage to the building and its interior. The demand on the water supply system may also be challenged in such a scenario. The development of new extinguishing methods, equipment and tactics generally aims to reduce the amount of extinguishing water [7,9].

Independent of the technical system, additional complexity is added to the extinguishing and rescue effort of the fire service, raising the concern that: "... buildings and facilities have become so complex that its technical solutions are difficult to handle under stress in a real fire situation" (Ingason et al. [4]). This means also that a wider knowledge in different areas is required from the fire service.

Complexity is also added by integrated SMART⁴ technology. However, SMART technology can also be an advantage for the fire service, by for example providing increased monitoring functionalities and information. The impact of SMART technology on fire safety is the scope of FRIC project 4.4 - *Building Integrated SMART technology*.

⁴ SMART Technology is defined as Self-Monitoring Analysis and Reporting Technology which is a term borrowed from hard drive diagnostics.

2.3.2 Change in staffing and technology (alternative fire extinguishing methods)

Changes in staffing has inevitable an impact on rescue and extinguishing operations. However, staffing of the fire service is not considered within the scope of FRIC project 4.1. New and changing technology on the other hand is highly relevant, especially related to alternative fire extinguishing methods, as technology changes such as SMART technologies have been discussed in the previous section.

There are many parameters that make it difficult to implement new technology and methods, such as practice, generational changes, the fear that technology poses a risk to jobs, economics and personnel resources [4]. Hence, it is considered very important that projects, such as FRIC project 4.1, have an emphasis on communicating research findings also outside the research community, providing factual information for decision making to the fire service and other concerned parties.

2.4 Experiences of different extinguishing equipment with low water consumption

The following sections discuss different extinguishing methods that aim to increase the efficiency in terms of water demand, time and exposure to smoke and heat. They are considered alternatives or additions to conventional fire extinguishing. Conventional fire extinguishing refers in this context to the offensive interior (i.e., firefighters with breathing apparatus) attack with a standard variable nozzle.

There has not been much development regarding new extinguishing equipment for firefighters the last decade. Some of the equipment has been further developed and refined but very little new technology has been introduced. A state of the art report on safety for firefighters in relation to new types of extinguishing equipment was published by RISE in 2004 [20] and still covers most of the equipment available at the market today.

Although the development of new equipment has not progressed much the last decade, the focus on the health consequences for the firefighters and the environmental impact of fire extinguishing has come into focus. This means that the approach and extinguishing techniques used by fire fighters have changed.

Below are some short descriptions of the function and benefits of some of some of the techniques that use the least amounts of water.

2.4.1 Standard variable nozzle

A standard variable nozzle is part of the equipment that all fire stations has used for a long time. The nozzle can vary the way the water is delivered, from a compact beam with a long throwing length that delivers a large amount of water to a fine water spray with a shorter throwing length. The new focus now is using this nozzle more active in optimizing the use of water. This will minimize the secondary damage from fire and reduce the environmental impact of the extinguishing process.

2.4.2 Conventional equipment

In the report "*Slokkemetoder med lite vann*" (Efficient use of water for fire extinguishing)[7] the conventional extinguishing equipment is described as a chain saw that is utilized to penetrate the wall from the outside and a hose connected to a standard flexible nozzle that is used to apply water. Conventional methods also include firefighters using breathing apparatus.

Hox and Bøe [7] conducted in 2017 a test series comparing different extinguishing equipments and techniques. These tests concluded that the conventional fire extinguishing equipment used more water in the tests compared to cutting extinguishers, extinguishing spears and foam.

2.4.3 Water mist

Water mist is not a new technology; however, it is becoming more used due to the reduced water consumption. Water mist can be used in fixed firefighting systems or in special equipment used by the firefighters. Different equipment uses different methods to generate the water mist, the most common are high-pressure and low-pressure water mist. Generally high-pressure water mist systems produce smaller droplets than the low-pressure systems. However, it needs a high-pressure unit which potentially makes the system more complicated and costly.

The advantage of small droplets is that the large surface area of the water droplets gives a large potential to absorb heat from the fire. In addition, the water vapour from evaporation of the small droplets displaces the oxygen resulting in an inert atmosphere.

2.4.4 Cutting extinguisher

The cutting extinguisher uses high-pressure water both for cutting and extinguishing. This is accomplished using a specially designed nozzle that is able to focus the water jet so that it can cut through the construction. Abrasive can be added to the water enabling the cutting extinguisher to quickly penetrate even hard materials.

The high-pressure water is delivered by a separate high-pressure pump mounted on the fire engine. The pump can deliver pressure up to 260 bar.

Due to the high pressure the cutting extinguisher delivers a fine water mist that is utilized to extinguish fires and cool the smoke layer.

2.4.4.1 Experiences with cutting extinguishers

A Swedish study [21] evaluated the effect of the system in 79 real fire incidents and noted that:

- *In 30 of the fires the cutting extinguisher had a crucial or large positive effect on the result.*
- *There was an increase in perceived safety for fire fighters in 59 cases.*
- *In 37 cases the use of the system was evaluated to result in less water damage than by conventional extinguishing.*
- *In 32 of the cases the use of the system was evaluated to result in less environmental impact than with conventional equipment.*

Hox and Bøe [7] concluded that tests with the cutting extinguisher showed a clear advantage over the other tested types of equipment (CAFS, conventional chainsaw and hosepipe, and extinguishing lance). This is due to early access to the fire inside the building, by the cutting ability, small droplets and long shooting range. The cutting extinguisher proved better at handling the fire with regard to extinguishing time and water consumption, although some important drawbacks were reported. That being a forceful beam that can be dangerous if not correctly handled, and that it is difficult to limit the water beam's length due to the high pressure. A contributing factor to this is that the spray pattern is fixed. The system also requires handling by two persons, one for operating the water pump and one for operating the cutting extinguisher nozzle.

An article by Dikkenberg and Groenewegen [22] commented that the range of the cutting extinguisher makes the system excellent for fires some distance from the entry point. It also pointed out that the system worked well with decreasing the inside temperature down to 150 °C.

Input received from the fire service, Trondheim Brann og rednings tjeneste (TBRT), suggests that this technology is to prefer regarding fires in dwellings. They have built up some experience on this topic and the cutting extinguisher has proven to be very effective. Good facilities accommodating training has contributed to increase the knowledge of the technique. TBRT informs that having the equipment installed on two out of four trucks that are suited for the equipment, the equipment is not always available on the first truck on scene.

2.4.5 Extinguishing spears

Extinguishing spears comprise a pipe with a water nozzle at the end. The nozzle itself has a pointy tip enabling the pipe and nozzle to penetrate walls without damaging the nozzle. Once through the wall, low-pressure water mist is applied on the fire.

2.4.5.1 Experiences with extinguishing spears

Hox and Bøe [7] only tested the extinguishing spears in one test, but the test gave some indicative results suggesting that the system may have good effect on fires situated inside wall cavities. It consumed about the same amount of water as conventional equipment (chainsaw and hosepipe). The advantage with this equipment is that it works regardless of smoke production (which choked the chain saw), but it can be difficult and time consuming to drill holes through thick walls.

TBRT utilizes the extinguishing spear on some occasions. They report that the efficiency is good, but the system is seldom used as the first action, although all four fire trucks have this equipment. This is related to the set-up in the fire trucks. However, TBRT has initiated a change in the truck set-up to support more frequent use as a first-action measure.

2.5 Extinguishing foam

Extinguishing foam is created by adding a foam concentrate to the water either as a premix or at the nozzle.

2.5.1 Experiences with extinguishing foam

The study “MSB618 Förmåga och begränsningar av förekommande släcksystem vid brand i byggnad - fokus på miljöarbete» (Abilities and limitations of extinguishing systems in building fires – Environmental focus) [8] shows that the use of foam can be beneficial on the extinguishing effect:

- *Foam breaks the surface tension of water and increases the moisturizing of the surface. It also sticks to surfaces better than water which makes the cooling effect better.*
- *The foam protects surfaces from heat radiation.*
- *Use of some types of foam may also reduce the probability of re-ignition.*

But it can also represent disadvantages:

- *Foam makes the floor slippery.*
- *Technical investigations of the fire scene cannot be conducted before the foam has disintegrated.*
- *A beam of foam has a shorter throwing length than water.*

A study from Sweden [10] points out that most foams in used today contains high concentrations of PFAS (per- and poly- fluoric -alkyl) chemicals known to have negative effects on the environment.

2.5.2 CAFS - Compressed Air Foam System

CAFS is a technology for extinguishing of building fires but has been on the market in the USA and Canada for several decades and has been utilized in protection of buildings from forest fires. It uses compressed air which is added to a foam solution and together with a nozzle that propels the foam further than standard nozzles can do. It has been shown to be useful in areas where the water supply is limited.

The nature of a thick foam makes it ideal to spray on warm surfaces on which it sticks and expands, it also evaporates slower than water. This cools the surfaces which in turn reduces the evaporation of pyrolysis gases [23]. A Swedish study [10] point out that the foams used in systems like this contain high concentrations of PFAS chemicals known to have hazardous effects on the environment.

2.5.2.1 Experiences with CAFS

Experiences with CAFS compared to traditional extinguishing systems are [7]:

- *Flexibility due to lighter hoses, several types of nozzles, higher altitude reach (due to less water in volume CAFS can be pumped twice as high as water at the same pressure).*
- *Due to less evaporation the sight is better. This again leads to a more efficient extinguishing effort.*
- *One is more able to limit the fire to the ignition room.*
- *Less use of water due to quicker extinguishing and decreases the demand for firefighters with breathing apparatus (due to a shorter extinguishing time).*

Hox and Bøe [7] concluded that the CAFS consumed less water than the other tested equipment, partly due to the use of an IR-camera which allowed for more focused effort. On the other hand, the time to prepare the equipment for use (i.e. drilling hole through thick or walls with hard materials) was a drawback.

2.5.3 Fire retardant gel

First used in the 1960 this is, similar to foam, a powder added to the water making it thick and gelatinous. It is also often made of polymers and some types of clay that do not represent an environmental hazard.

Tests performed by RISE showed that gel applied to exterior surfaces delayed the fire spread [11].

3 Discussion

Since the early 2000s the focus has shifted from developing new technology and new extinguishing equipment to the environmental impact of the extinguishing effort. This includes both the work environment for the firefighters and the environmental impact of pollution both to the air and to the ground.

This has raised some questions regarding the use of chemical additives in the extinguishing process. This has led to the development of more environmentally friendly additives. However, questions are raised concerning the long-term effects of additives on the environment, and more research is needed.

Due to the concerns regarding the use of additives a preferred alternative is to use only water in the extinguishing effort. Using only water does not eliminate the negative environmental impact of the extinguishing effort. The water will be contaminated during the extinguishing processes and pose an environmental hazard when running to the ground. The amount of water used is therefore an important factor in an effort to reduce the total pollution from a fire.

Effort has been made to develop tactics that both protects the firefighter from unnecessary exposure to smoke and heat and minimize the use of water needed to extinguish fires. This can be achieved by using the standard variable nozzle more efficiently or using equipment specially designed for optimizing the extinguishing and cooling effect of water and by minimizing the exposure of the firefighter.

4 Conclusions

In conclusion, the systems most relevant to be further tested in a fire situation in a small house or dwelling are the cutting extinguisher and the extinguishing spear. These systems are different in operation but have both shown to be promising regarding fulfilling the different objectives of the overall project. Being relatively easy to utilize with the right training during internal extinguishing efforts executed from the outside of the building, and being only water based to minimize contamination, from additives, of the surrounding areas give these systems advantages over conventional equipment.


Especially if the systems are used in combination with an IR camera to locate the fire, the extinguishing efforts can be started early and effectively, and the water amount needed to control the fire may be reduced. The need for firefighters with breathing apparatus is reduced as well, hence reducing the smoke exposure to firefighters.

The fact that the fire service also recognizes the potential of using these systems early in the extinguishing efforts, and is working on implementing them, prompts the need for scientific backup.

References

- [1] A. Steen Hansen, R. F. Mikalsen, and U. E. Jensen, "Smouldering combustion in loose-fill wood fibre thermal insulation. An experimental study.," *Fire Technol*, vol. 54, no. 6, pp. 1585–1608, 2018.
- [2] C. Sesseng, N. K. Reitan, and S. Fjær, "Mapping of gas concentrations, effect of dead-air space and effect of alternative detection technology in smouldering fires," SP Fire Research AS, Project number: 20053:2, 2016.
- [3] K. Storesund, A. Steen-Hansen, and A. Bergstrand, "Fire safe upholstered furniture – Alternative strategies to the use of chemical flame retardants," SP Fire Research AS, Trondheim, Norway, SPFR report A15 20124:2, Dec. 2015.
- [4] H. Ingason *et al.*, "Effektiva Räddningsinsatser," ISBN 978-91-7383-969-3, Sep. 2019.
- [5] S. Älvsborg, "Cutting extinguishing concept -practical and operational use," Swedish Civil Contingencies Agency, MSB0167, 2010.
- [6] René Hagen, Annemieke Hendriks, and Jaap Molenaar, "Quadrant Model for Fighting Structure Fires," Version 2.0, Nov. 2014.
- [7] K. Hox and A. S. Bøe, "Slokkemetoder med lite vann," SP Fire Research, Trondheim, Norway, A17 20099-01:1, 2017.
- [8] J. Lindström, G. Appel, K. Palmkvist, and K. O. Bialas, "MSB618 Förmåga och begränsningar av förekommande släcksystem vid brand i byggnad - fokus på miljöarbete," SP Sveriges Tekniska Forskningsinstitut, Södra Älvsborgs Räddningstjänstförbund (SÄRF), Myndigheten för samhällsskydd och beredskap, ISBN: 978-91-7383-390-5, Nov. 2013.
- [9] A. K. Storesund, K. Hox, A. G. Bøe, and R. Wighus, "NBL A13126 Slokkevannsmengder," SINTEF NBL as, Trondheim, ISBN: 978-82-14-00123-5, Oct. 2013.
- [10] A. Kärrman, "Chemical Analysis of Selected Fire-fighting Foams on the Swedish Market 2014," Swedish Chemicals Agency, Stockholm, Sweden, 511 163, May. 2015.
- [11] A. Steen-Hansen, G. Jensen, P. A. Hansen, R. Wighus, T. Steiro, and K. E. Larsen, "NBL A03197 Byen brenner! Hvordan forhindre storbranner i tett verneverdig trehusbebyggelse med Røros som eksempel.," SINTEF NBL as, Trondheim, Jan. 2004.
- [12] G. Holmstedt, "Bedömning av försök utförda för att jämföra släckverkan mot A-brand med A-skum, vatten och vatten med tillsats av ytspänningsnedsättande medel.," p. 35.
- [13] N. K. Reitan, R. F. Mikalsen, and K. L. Friquin, "Brannsikkerhet ved bruk av massivtre i bygninger," RISE Fire Research, Trondheim, Norge, (Upublisert, publiseres tidlig 2019).
- [14] A. Frangi, M. Fontana, M. Knobloch, and G. Boichichio, "Fire behaviour of cross-laminated solid timber panels," *Fire Saf. Sci.*, vol. 9, pp. 1279–1290, 2008.
- [15] P. Peña and Z. L. Magnone, "Exterior Fire Suppression System for High-Rise Buildings with Combustible Cladding."
- [16] C. Fourneau, N. Cornil, C. Delvosalle, H. Breulet, S. Desmet, and S. Brohez, "Comparison of Fire Hazards in Passive and Conventional Houses," *Chemical Engineering Transactions*, vol. 26, 2012.
- [17] S. Brohez and I. Caravita, "Fire induced pressure in airtight houses: Experiments and FDS validation," *Fire Safety Journal*, vol. 114, p. 103008, Jun. 2020.
- [18] S. Hostikka, R. K. Janardhan, U. Riaz, and T. Sikanen, "Fire-induced pressure and smoke spreading in mechanically ventilated buildings with air-tight envelopes," *Fire Safety Journal*, vol. 91, pp. 380–388, 2017.
- [19] R. F. Mikalsen *et al.*, "Energieffektive bygg og brannsikkerhet," RISE Fire Research, Trondheim, Norge, RISE-rapport 2019:02, ISBN: 978-91-88907-16-5, Apr. 2019.

- [20] A. W. Brandt, A. Steen-Hansen, and J. P. Stensaas, "NBL A04137 Nytt slokkeutstyr og nye slokketeknikker - økt sikkerhet for brannmannskapene?," SINTEF NBL as, ISBN: 82-14-02445-5, Jun. 2004.
- [21] T. Snickars, "Skärsläckarprojektet," Räddningstjänsten Lomma-Staffanstorps, Räddningstjänsten Syd, Södertörns brandförsvärsförbund, Arbetsmiljöverket, Cold Cut Systems och Myndigheten för samhällsskydd och beredskap., Jun. 2013.
- [22] Rijk van den Dikkenberg and Karin Groenewegen, "Techniques for the offensive exterior attack in fighting ventilation controlled structure fires," in *Fourteenth International Interflam Conference*, London, UK, 2016, vol. 1, pp. 329–340.
- [23] E. Lyckeback and J. Öhrn, "Lund report 5334: Investigation on the gas-cooling effects of CAFS," Lund University, Lund, Sweden, 2012.



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