PELASTUSOPISTO

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Fast and Agile Fire Extinguishing methods for Fire & Rescue First Response

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Pelastusyksikön ensitoimenpiteitä täydentävät sammutusmenetelmät hankkeen loppuraportti

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FAST AND AGILE FIRE EXTINGUISHING METHODS FOR FIRE & RESCUE FIRST RESPONSE

Final Report of a Project

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Fast and Agile Extinguishing Methods for Fire & Rescue First Response

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ABSTRACT

PETS was a project lead by the Research, Development and Innovation Services of the Emergency Services College, Finland. This project was funded mostly by the Fire Protection Fund (Palosuojelurahasto). The main goal of the project was to study existing, on the market fire extinguishing methods that could be suitable for fighting the initial phase dwelling fire. One of the main themes was to find methods that could be deployed faster than the traditional fire hose method. Although the initial agenda concentrated on dwelling fires, the methods can be used in other types of fires as well.

The traditional method of putting out a house fire has been based on using hoses and a water reservoir on a fire truck. Although this is a very useful methodology, there are circumstances in which some lighter, complementary method can give significantly shorter response time.

Test setups for testing various extinguishing methods for Fire Service first response were defined based on the research done in the initial phase of the project. In the first phase, these extinguishing methods were tested with a standardized setup. Later of, a more realistic scenario, closer to a real house fire was constructed. Having gathered adequate knowledge from these tests, field experiments were carried out in to be demolished houses. During the project more than a hundred different extinguishing experiments were carried out. All the tests were filmed on both video and thermal imaging. Data acquisition system was also used in some of the tests to gather temperature information and heat flux measurements.

Based on the findings made in the project, an educational material for dissemination of the knowledge was created. One of the main goals of the material was to create awareness for different tools available for Fire and Rescue first response and spread the information on the tactical best practices drafted during the project. The material was used during the project on the educational road trip that involved six locations in Finland with a good geographical coverage of the whole country.

Most important partners in the project were the network of Finnish fire departments, and, especially the Fire Department of Keski-Uusimaa, the Finnish Association of Fire Chiefs and the extinguisher retail companies.

ABI/INFORM: Extinguishing method, Fire crew, handheld extinguisher, CAFS, throw extinguisher

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TIIVISTELMÄ

Pelastusopiston tutkimus, kehittämis- ja innovaatiopalveluiden toteuttaman ja Palosuojelurahaston pääasiallisesti rahoittaman Pelastusyksikön ensitoimenpiteitä täydentävät sammutusmenetelmät hankkeen tavoitteena oli tutkia markkinoilla olevien, perinteistä letkuselvitystä nopeampien sammutusmenetelmien soveltuvuutta alkuvaiheen huoneistopalon sammuttamisessa. Vaikka alkuperäinen rajaus koski huoneistopaloja, ovat menetelmät käyttökelpoisia muissakin tulipaloissa.

Perinteisesti palokunnan lähtökohtainen menetelmä tulipalon sammuttamisessa on perustunut ajoneuvon säiliössä kuljetettavan veden käyttöön ja letkujen selvittämiseen. Tämä on hyvin toimiva menetelmä, mutta joissain tilanteissa voidaan tilanne saada haltuun nopeammin ja pienemmin kokonaisvahingoin käyttämällä kevyempää, täydentävää sammutusmenetelmää.

Hankkeen alkuvaiheen selvitystyön perusteella laadittiin koeasetelmat, joihin valikoitiin erilaisia pelastusyksikön käyttöön soveltuviksi katsottuja sammuttimia ja sammutusmenetelmiä. Näitä menetelmiä testattiin aluksi vakioidulla koeasetelmalla josta siirryttiin todellista huoneistopaloa paremmin vastaavaan koeasetelmaan. Riittävän kokemuksen kartuttua tehtiin kenttäkokeita poltettavissa rakennuksissa. Erilaisia testejä tehtiin hankkeen aikana toista sataa. Kaikki testit videoitiin ja kuvattiin lämpökameralla. Osassa testeistä käytettiin myös mittausjärjestelmää lämpötilojen mittaukseen.

Tutkimuksen havaintojen pohjalta laadittiin koulutusaineisto jotta hankkeessa havaittuja hyviä käytänteitä saadaan vietyä käytäntöön. Samaa tavoitetta palveli erinomaisen hyvän vastaanoton saanut koulutuskiertue, jonka kautta pelastuslaitosten henkilöstöä koulutettiin kuudella paikkakunnalla. Koulutuskiertueen tavoitteena oli mahdollisimman laaja maatieteellinen kattavuus, jotta kaikkien pelastuslaitosten henkilöstöllä oli mahdollisuus osallistua koulutukseen.

Hankkeen tärkeimpinä yhteistyökumppaneina olivat pelastuslaitokset, eritoten Keski-Uudenmaan pelastuslaitos, Suomen Palopäällystöliitto sekä sammuttimia ja sammutuslaitteistoja myyvät yritykset.

Avainsanat: Sammutusmenetelmät, pelastusyksikkö, käsisammutin, CAFS, heittosammutin

Table of Context

1. Introduction

The Fire & Rescue Services has long tradition and practical experience in fighting fires with water hoses. This practice has its grounding on common knowledge of water being a very good medium for putting out fires and, also, being readily available on most occasions. However, as both the technology and the types of fires firemen have to combat develop, there is a demand for survey on other fire extinguishing methods.

In the recent decades, we have seen a rather fast development on the materials that are used in household furniture and interior. The amount of artificial, oil based materials has increased in our homes, as well as, offices and industry. This development in the content of materials has led to fires burning hotter and faster than before. At the same time, as energy saving has been a major factor in designing buildings, the houses are more isolated than before. This leads to houses containing the heat and smoke released in the fire, creating oxygen deprived, ventilation controlled fires. With the lack of oxygen, more harmful substances are created and both the short term risks and the long term risks for occupational safety increase.

As the time for the fire service to commence action in order to master a fire is decreasing as a result of aforementioned facts, it is crucial to develop methodology to shorten the response time. A shorter response time means both smaller damages for health and property and less burden and exposure for the rescue crew. This is the main motivation behind this survey, to find fast and agile firefighting methodology.

Fast and agile fire extinguishing methods could be used instead of, or in combination with, traditional fire hose method in a number of situations, such as small fires in large buildings (Hospitals, Shopping malls). In these circumstances the traditional fire hose method is rather slow and can give unnecessary time for the fire to spread. The new, agile extinguishing methods could clearly improve Fire & Rescue response in urban environment as the actual scene can be reached much faster than in the past.

Similarly, in rural areas the first unit to respond to a fire is often a command and control unit that has neither the crew nor the equipment to carry out the traditional fire hose extinguishing.

A substantial benefit in the early stages of a fire could be gathered by provisioning these fast and lightweight units with agile and lightweight fire extinguishing methods. This would speed up the process of getting the much needed help in time. The improvement in the Fire & Rescue service level in the countryside would be obvious.

The project, Fast and Agile Fire Extinguishing Methods for Fire & Rescue First Response, surveyed and evaluated new, innovative fire extinguishing methods in order to find out if such methods are useful as complementary methods for the existing fire hose methodology. In certain cases the new methods are sufficient as such, but most often best used in combination with the traditional fire hose.

This project investigated the usefulness of these methods through standardized burn experiments as well as field tests in actual house fires. The standard burn experiments gave exact test results that can be repeated. Similarly, the field experiments confirmed the results in an authentic environment.

2. Project Plan

The project plan was written in a very practical goal in mind, to give real day to day tools for firefighters. With this goal in mind, there was a rather heavy focus on practical experiments. The reasoning behind the practicality was to on one hand show the applicability of different extinguishing methods to the actual every day task of putting out a fire and on the other hand to produce good quality educational material such as video clips. The project was phased on a market survey, standardized tests, field tests, education material production and an educational road trip.

The market survey was done mostly from the office, but also by attending the Interschuz fair. This part of the project aimed at getting a very detailed picture regarding the mechanism, effectiveness, targeted uses and, methods of use of each identified, suitable extinguishing method. It came clear that there are a lot of different extinguishing methods on the market that showed potential for further investigation. On the selection of extinguishing methods for more detailed study, certain limitations were considered. Among these were common availability, adequate information on occupational safety as well as environmental safety implications, perceived reliability on field usage and economical considerations.

The standardized tests were carried out at the Emergency Services College training ground. Based on the results achieved in the previous project phase, the most promising extinguishing methods were selected for these tests. In these early phase tests, the extinguishing effect and differences in this effect were key factors. These first stage tests were carried out in house fire simulators. These simulators are of varying size from a sea container size to an industrial production hall environment. For these tests, a standard fire setting, fast to reconstruct was developed.

Field experiments for the extinguishing methods were carried out in actual house environment using be demolished houses. The test setting was based on research of most common causes and sources of house fires based on the statistical data gathered by Fire departments in Finland during decades. Fire extinguishing methodology and tactics using agile extinguishing methods are the core substance of this part of the study. A comparison to traditional fire hose method was carried out also from the performance perspective, not overlooking work safety issues.

Roughly half way of the project, it could be concluded that the selected extinguishing methods behaved very much the way that was anticipated without any major surprises. This lead to the project being steered more in the direction of material production with a minor sacrifice on the research part. Looking back at the outcome of the project, this was a good decision, indeed.

Recommendations and educational material was be produced based on the lessons learned. All the tests that were carried out during the project were carefully documented using video and thermal imaging. This material was then processed and utilized in teaching and the project educational road trip.

3. Past experiences, projects and studies

The selection of extinguishing methods was a combination of old and new. Some of the methods can be considered as well tried legacy devices with a twist of new properties. At the other end the more modern methods have also been in use in some countries for some years, but are new in Finland.

Of the legacy methods, some have been used in the past and are currently used by some fire departments. The usage of dry powder as an initial extinguishing method in a house fire has been used in history, but has then been forgotten. With the development of handheld extinguishers this method has resurfaced and has been studied in this project. Even in a developed house fire can the dry powder extinguisher be used bring down temperatures, reduce the possibility on a backdraft or flashover and to buy time for preparing heavier methods.

Similarly, foam based hand held extinguishers have developed in recent years in terms of foam quality, environmental safety and better reach due to higher pressure. These have been usually considered not a tool for the fire rescue professional, who rely on more sturdy solutions, but the initial extinguisher for the layman. However, with the development in extinguishing power they also should be taken seriously by the professional fire fighter as an alternative.

Many of these methods have been tested and used by fire departments around Finland and other countries, but in Finland no one has written instructions or test reports on any educational material of their usage. It was one of the aims in this project to document also the established and well used methods that up to this have remained undocumented.

3.1. European countries

In Sweden, the national safety and preparedness administration (Myndigheten för samhällsskydd och beredskap, MSB) has published an article Förmåga och begränsningar av förekommande släcksystem vid brand i byggnad – fokus på miljöarbete (Capabilities and limitations of existing extinguishing systems for fires in buildings - focus on environmental aspects). This study concentrates on the environmental aspects of extinguishing methods. Although the environmental aspect in our study is not a main focus, the impact on the environment cannot be overlooked.

Släcksystem för lätta räddningsfordon (Extinguishing systems for lightweight fire fighting vehicles) is a report of a study made by Lund University (Folkesson and Millbourn) in 2008. The study contained many of the same or similar extinguishing methods that were selected for our study. The test setup in their study was quite different from what the project group wanted to use in this study, so the results are used as reference only. It is still noteworthy, that on a high level, the results obtained in our study correspond to those made by Folkesson and Millbourn.

Larsson and Westerlund have studied high pressure extinguishing systems in their report called Högtrycksbrandsläckning - Ett beslutsunderlag för Räddningstjänsten (High-Pressure fire fighting – basic decision data for the fire service). Their conclusions that using high pressure less water damage is expected and they are faster to deploy. On the downside, high pressure systems are not expandable and have limited water flow that limits the cooling capacity.

In the FIREFIGHT II project a study was made about the properties and usage of the COBRA cutting extinguisher. The results were published in the article "Cutting Extinguishing Concept - practical and operational use" in 2008. As the cutting extinguish concept is rather well studied and the project group felt that they had enough practical experience with it, it was used as a reference with other methods and not studied as such in this project.

In the Netherlands, Ricardo Weewer and his team has made a comprehensive study based on practical experiments regarding the survivability of inhabitants in a dwelling fire. This study gave some fundamental ground on the test setup that was created on our study. As one of the main goals of our research was to see if we could faster reach the person to be rescued, this study gave good background on how important the minutes actually are.

R. van den Dikkenberg et al. have studied the flue gas cooling capabilities of different extinguishing media in their study: "Cooling experiments with water and foam". As expected, the foam based CAF (Compressed Air Foam) methods perform rather modest in comparison with water systems (high and low pressure) in gas cooling. These results have been very similar in several studies done at the University of Lund in Sweden. The report by van den Dickenberg contains a comprehensive literature review on the matter. On the other hand, the same reports show that CAF systems have faster knockdown time (putting the fire out) and better pyrolysis blockage capabilities. The study showed that low pressure (7-8 bar pump pressure) water system performed the best in the flue gas cooling. They report high pressure system as one with 25-30 bar pump pressure, but both having the same jet nozzle pressure of 7 bars and the low pressure system delivering twice the amount of water. In our study a UHPS (Ultra High Pressure System) with 100 bar pressure was tested and is referred to as ultrahigh pressure.

3.2. USA

UL (Underwriters Laboratories) Fire Fighter Safety Research Institute conducts research aiming at reducing deaths and injuries in the fire service as well as the communities. They focus on the changing dynamics of residential, commercial and industrial fires, and the impact they have on the fire service tactics and strategies.

Stephen Kerber has published study results concerning the fire behavior development In his article "Analysis of Changing Residential Fire Dynamics and Its Implications on Firefighter Operational Timeframes", and shows that the modern furniture and materials has made the fires grow much faster than in the past. This shortens the time needed for a flashover dramatically. In order to cope with this dramatic speedup, the Fire & Rescue has to come up with faster means of reaching the scene.

The International Association of Fire Chief has published a document called "Rules of Engagement for Structural Firefighting - Increasing Firefighter Survival".

Stephen Kerber published an article in 2011 giving grounding for the development many fire fighters on the field have noticed, that dwelling fires are faster, hotter and stronger than in the past. This development keeps happening, as our homes become overwhelmed with artificial, oil based materials in both furniture and textiles. This is clearly aided by modern construction style with large open spaces and, at the same time, air tight construction methods for energy preservation.

3.3. Projects in Finland

Jarkko Jäntti, Timo Loponen and Pertti Miettinen made a study in 2009 and published a report called "Selvitys vaihtoehtoisten sammutusmenetelmien Cobra ja Dspa soveltuvuudesta huoneistopalon sammutukseen." (Alternative Methods of Fire-fighting Cobra and Dspa Compatibility of Apartment Fire-fighting). This study was done in the same organization as the study this report describes. To verify existing results and to build on top of the existing knowledge, the same setup of kitchen fire was used in our study. Also, the results and recommendations could be verified regarding throw extinguishers and Cobra. There is a related publication named Huoneistopalon sammutus vaihtoehtoisilla sammutusmenetelmilllä (Apartment fire fighting using alternative extinquishing methods), in which similar tests have been carried out in actual apartment houses.

One of the motivations behind the study of these fire extinguishing methods was long routes in tall buildings and large buildings. A former student of the College, Petri Strandberg, wrote his graduate thesis about operating in high rise buildings. This thesis, Fire extinguishing tactics in high rise buildings (Operatiivinen sammutustaktiikka korkeissa rakennuksissa) was also used as source material on the experiments on the tall buildings.

A recent study Pressure management in compartment fires by Hostikka et al. shows that as the modern energy conserving building standard requires very air tight structures on building envelopes, house fires can create a strong overpressure inside building. This overpressure can be strong enough to prevent escape from such a building if there are inward opening doors. Combined with other aspects of dwelling fire behavior, this is to be taken into consideration by fire crews. Earlier material on fire gas ventilation, such as the book by Svensson, have not considered the overpressure to be this significant. However, a masters thesis from the Technical University of Eindhoven by Nick Trenbült shows similar results as Hostikka et al. by using simulations.

4. Standardized tests

The very first tests with the selected extinguishing methods were to gain experience on the usage and applicability of the methods. The backpack extinguishers were initially tested on car fires and showed that a backpack has the ability to extinguish a somewhat early stage car fire that has a short pre burn time (e.g. 5 min.), but fails to do so with a fire that has had time to heat the metallic frame or to make its way to the tires. With advanced car fire, the physical limits of the heat absorbing properties of the extinguishing medium were met and the fire could not be extinguished.

4.1 Container tests

Having gained an adequate practice on the extinguishing methods to be tested, the project group planned a fire setup to be used in a fire training container. The container is built from sea containers and has steel walls and a steel roof. The container has two sections, with the burn space somewhat raised from the observation / training section to provide better visibility and lower heat load.

The seat of fire was designed to be as close to a standard as possible by cutting equal size chipboard pieces that were positioned into a metallic grid on a specific way (Fig 1). The seat of fire was then placed on a corner of the container with chipboard walls and ceiling. One chipboard of 22 mm x 1200 mm x 2400 mm was placed on each wall with double layer on the ceiling.

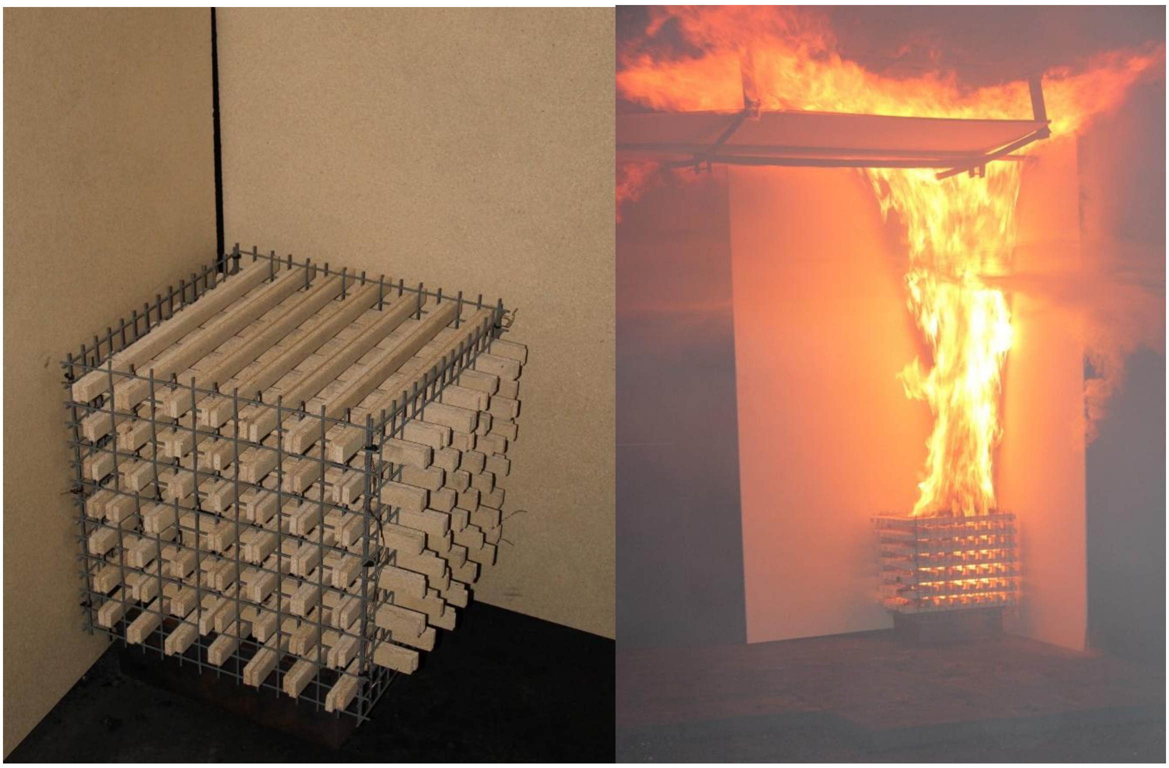

Figure 1. Standard seat of fire setting

The designed test fire and the seat of fire produced a very uniform fire behavior. The fire development was every time exactly the same in terms of time it took to develop and the intensity. With this fire, a number of extinguishers were tested and their performance evaluated. The list of tested extinguishers included various brands of foam (6 liters and 9 liters), dry powder (6 kg and 12 kg), two types of backpack extinguishers and a fire hydrant. In the initial phase 14 tests were carried out in the container environment. Further 36 container demonstrations and tests were made during the educational tour based on the interest of the audience. Some demonstrations were repeated several times.

4.2 The Fire house tests

The project group soon realized, that the steel wall container was not a very realistic presentation of a house fire and the small space also made documentation of the experiment somewhat challenging, so the same setup was then placed on a concrete wall fire house. The same setup of extinguishers, larger CAF (Compressed Air Foam) System and the Cobra system were tested. In this environment, the fire was given a longer pre burn time. The different qualities of extinguishing systems were easy to observe and document, but the longer pre burn time showed that the construct was a very challenging to extinguish. The chipboard burns much hotter than ordinary wood due to the glue on the board and the construct was so tight that getting the extinguishing medium into the center of the construct was truly difficult. This meant that the construct did not extinguish fully most of the times.

Altogether 12 experiments were done on the chipboard seat of fire in the fire house. Ten different extinguishers were tested and documented using this setup.

4.3 The Bedroom setup

To make the setup more realistic, a bedroom setup was created that reflects the common way of building a dwelling in Finland. The frame was 2 inch by 4 inch timber covered with painted plasterboard. The seat of fire was a bed with a mattress, a pillow, bed sheet and a thin cover (Figure 2).

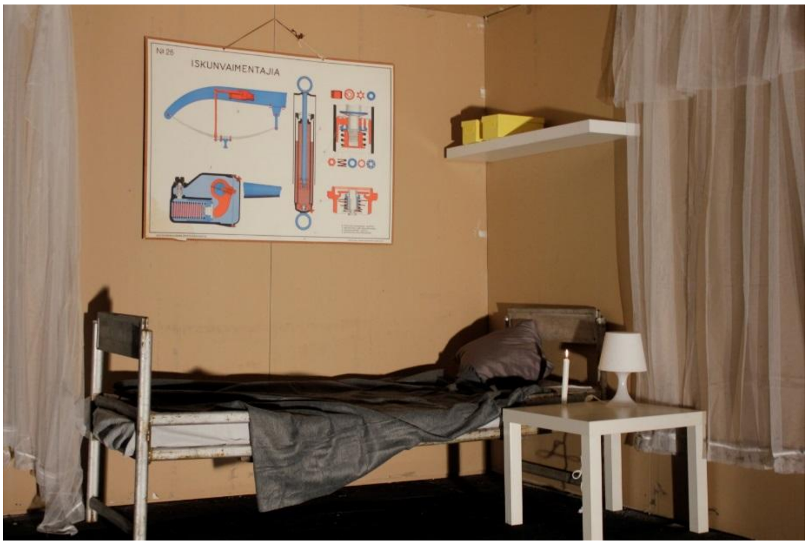

Figure 2. Bedroom setup

The bedroom fire was lit with a candle. The candle as a source of fire is not the most common, but the source was not considered the most important factor. All of the interior materials were cheap, artificial materials that also showed a rather quick and strong burn behavior (Figure 3). The smoke production was especially heavy.

Figure 3. The bedroom setup on fire

The selection of extinguishers was the same as on the previous test. The test showed some clear benefits and disadvantages of different extinguishers.

The pre burn time of the setup was four minutes, before the extinguishing started. Although the fire was strong, all of the extinguishers could extinguish the fire. In many cases, there was still reserve left on the extinguisher after the test. The quantities of used extinguishing medium were recorded (Attachment 1) along with other parameters, such as weather conditions.

The bedroom setup was burned 18 times using different extinguishers and also, combination of extinguishers. A CAF system named One Seven was tested on the bedroom setup in addition to the other extinguishers.

4.4 The kitchen setup

The third standardlike setup was created based on the statistical analysis of typical house fires. One of the most common places for a fire in a residential dwelling is the kitchen. A major cause for these fires is uncontrolled cooking, which most commonly leads to a somewhat small fire. However, in some cases, the fire may spread uninhibited and lead to a full scale house fire.

The kitchen setup (Figure 4) consisted of a regular kitchen cupboards (furniture plate, coated chipboard) and a kettle with one liter of flammable liquid (LIAV 200) that served as the initial seat of fire. The cupboards were manufactured for the purpose and had a standard amount of plastic cups and plates inside.

In addition to aforementioned, also throw extinguishers (GreenEx) and an ultra high pressure system (UHPS) were tested on the kitchen setup.

Figure 4. The kitchen setup

Nine kitchen setups were burned with ten extinguishing methods used. In one test a throw extinguisher was used to kill the initial fire and a handheld foam extinguisher was used to finish the remaining smoldering small fires.

5. Field tests

Although the repeatable standardlike tests gave good information on comparable properties of the tested extinguishers, the team also wanted to experiment on actual house fires to gain in depth knowledge and relevance to the tasks that these extinguishers will ultimately meet.

In simulated environments there are always limitations on how high fire load one can use on a test and how hot a fire the environment can handle. Creating a fully developed fire on a simulator is usually not possible. For this reason, the team made experiments on houses to be demolished. For these tests suitable houses were found somewhat easily.

As one can imagine, with tests in actual houses there is a great number of variables that affect how the house fire develops. Hence, it is not possible to carry out tests in which one would make detailed comparison of different extinguishing methods, but get a more general overview of how a particular method will behave and which benefits and, also, restrictions are relevant. Naturally, these observations are more or less subjective, meaning that they can be considered to be more of opinions than facts. However, these opinions are supported with decades of actual, hands on fire fighting experience.

The houses (see figure 5) for the experiment were rather common construction style of the 1950's. The frame is timber with saw dust as insulation material. The outer shell is also timber with tar paper as wind stopper. Inner shell is cellulose board with most often paint or wall paper on top. The houses had been empty for a couple of years without heating, so there was some condensed moisture on the materials.

Figure 5 One of the field epteriment houses

The initial seat of fire (see figure 6) was created with materials that were at hand on the site. To compensate for the missing furniture, timber boards were added to enable to reach flashover temperature in a normal time frame.

Figure 6 Initial seat of fire

Initial, pre falshover fire was tackled with handheld and throw extinguishers, some of which are show in figure 7. In addition to these, the UHPS system was tested and a traditional jet hose was as a backup.

Figure 7 The handheld extinguishers used on the field experiments

The fire was let to develop to nearly flashover for the handheld extinguisher tests and to a full flashover for the UHPS. It was quite clear that only dry powder was wffwctive against a fire that had developed to near flashover. For the GreeEx aerosol extinguisher, the room size and openings proved to be a challenge. This is not suprising, as the function of the extinguisher is based on adequate concentration of the extinguishing media and openingns will cause the aerosol to quickly ventilate out of the room.

6. Educational material and recommendations

One of the main observations of the project has been that various handheld extinguishers, throwable extinguishers and fire extinguishing systems can be used to complement the traditional fire hose. The value of these complementary methods was seen worthy of an educational road trip that also required educational material to support it. The material used on the road trip was further developed for larger audience and the experiences of two pilot courses was used on this development work. These were two day courses at the Emergency Services College one at the end of the project and the other one after the project had already finished.

The finalized educational material and videos for the professional courses are freely available to the fire and rescue personnel. This material can be used for training at fire departments, but it is also used as material for a two day course at the Emergency Services College. The educational material consists of three lecture presentations, each from forty five minutes to an hours and fifteen minutes, depending on the amount of detail desired. All the lectures notes are in Finnish, and can be found in http://www.pelastusopisto.fi/pets.

The main motivation behind the project was to study the capabilities of fire extinguishing methods on the market that could be suitable for initial methods for the fire service in a house fire. One clear aspect of the study was to find methods that could shorten the time it takes to make the first extinguish. This lead to methods that are fast to deploy, but also limited with extinguishing power.

Using these methods one has to keep in mind the limitations of set forth by fire physics. All handheld extinguishers have very limited gas cooling capabilities and are not suitable for smoke diving tools. However at the same time they give faster response time on cases in which the fire is in initial state.

The limitations of these methods mean that the user must have adequate fire reading skills. This means that the user should have both the informational background as well as certain amount of training and experience. The main concern with an extinguishing method with limited capacity is the occupational safety and risk assessment capability of the user.

One key observation in the tests was that the usage of a thermal camera is vitally important in both locating the seat of fire but even more so in avoiding circumstances that could develop beyond the capabilities of the extinguishing method. Using a thermal camera one can see more easily the early signs of an imminent flashover. It is quite clear that only the fire hose or equivalent has enough cooling capacity to handle a flashover. Getting caught in a middle of a flashover with just a handheld extinguisher is very dangerous and one must make sure this never happens.

One should also be able to recognize the signs of an imminent backdraft, as this can also be quite hazardous. Without a fire hose it can be quite difficult to protect oneself from a developed backdraught as it sometimes can get even an experienced fire fighter with the fire hose off guard.

Hence, to use these lightweight extinguishing methods requires more diligent attitude towards occupational safety and, also, more awareness in fire development and fire reading skills.

Based on the lessons learned during the project, the following recommendations for the field work were made.

When the fire is fully developed or extensive smoke is formed, and, the burning material cannot be reached with the extinguishing media, use dry powder. Deliver the powder using a window opening, door mailbox opening or any other opening that delivers air for the fire. Note that visibility will deteriorate significantly, also for a thermal camera.

When the burning material can be reached with the extinguishing media, from the doorstep for example, use foam. If the fire is fully developed, consider using dry powder in the first phase.

Combine these extinguisher types as necessary. Use dry powder to eliminate flame fire and foam to stop pyrolysis. Dry powder can be used to inert the space, making smoke diving safer.

7. Project impact analysis

In order to truly disseminate the material and experiences gathered during the project, the project team carried out an educational road show. The road show visited six cities designed to give a good geographical coverage of the country. These events were targeted to the operational workforce of fire departments, and the one day course had a couple of theory lessons and hands on training.

Figure 8 Steel container training with dry powder

In the hands on training, steel containers (Figure 8) were used for rehearsals of the handheld extinguishers and various other extinguishers. The throw extinguishers were demonstrated on the MOPSI (Mobile Fire Investigation Simulator) simulator (see Figure 9).

Figure 9 The MOPSI simulator ready for throw extinguisher demonstration

The educational tour received very good feedback from the audience and it was considered to have given very useful input for the professional tool box of the participants. It was largely agreed that the hands on part of the training was vital as merely reading a report would not have made the participants adopt these practices. The educational tour reached 180 fire service professionals from all around Finland.

The project also took part to the Safety and Security Fair held in Jyväskylä, in central Finland. On the fair the material was aimed more towards the general public, but also had elements for the professional fire fighters. On the three day fair, total six demonstration were held and the project results were discussed with the audience between the demonstrations. Some 300 safety professionals were contacted during these fairs.

8. Future work

To bring the new methods into practice, the team produced extensive training material. However, a need to update existing teaching material used in the education of new fire fighters at the Emergency Services College seemed obvious. A project on this topic starts in early 2017.

To really materialize the benefit of new, fast to deploy extinguishing methods, new way of thinking about fire service vehicles is necessary. Most European countries already have experimental projects or even day to day usage of fast, lightweight emergency vehicles that can reach the scene much faster than big trucks. These TRV (Targeted Response Vehicle) or RIV (Rapid Intervention Vehicle) type vehicles are becoming more popular and some are already in use in Finland also. However, there is no standard in Finland for these and the vehicles in use are more based on the expertise and solutions available by the manufacturers. It would clearly be necessary to have study to gain intimate, evidence based knowledge on the benefits and limitations of such solutions. To fulfil this purpose, a project called Agile First Response Vehicles was proposed, but has not yet, at the time of writing this report, received funding.

As this project has been handling and studying the fire extinguishing methodology on the fire fighter level, it has given intimate knowledge on fire development in modern household environment. This gives foothold for advancing the state of the art in strategy of fighting a dwelling fire. A rather new model on deciding between interior attack vs. exterior attack and offensive vs. defensive approach could well be adopted for fire and rescue command, but this needs to be supported by education and clear guidelines. Quite often the selection of strategy is not that obvious and decision making far from straight forward. A study outlining the telltale signs for decision making on fire extinguishing strategy would be necessary.

9. Conclusions and Final Remarks

All in all, the project has received an unforeseen interest from both the firefighter community and media. Partly this may be due to the scarcity of research and development projects that concentrate on the practical side of fire fighter work on a hands on level. Since the small droplet offensive interior attack model became widely used in the 1980's, the development on the fire extinguishing methods have had a rather steady progress with subtle changes. At the same time, the physical requirements and the increased knowledge of the exposure related to the offensive interior attack give rise to looking for alternatives. These alternatives would need to be studied further and this project has been a mere starting point.

A key element in a project such as this one is dissemination. Writing this report one can only wish that people working on the practical fire suppression would read it. However, reading the report is only a first step, as the understanding is better gained through practice and experimentation on the field. This in mind, the hands on educational tour proved to be a real success, a fact that can be studied also from the feedback that was gathered.

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