BRANDWEER

Brandweeracademie

Exchange of Experts

Smoke explosions, smoke cooling, FSE and real fires

A short report

De Brandweeracademie is onderdeel van het Instituut Fysieke Veiligheid.

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Brandweeracademie (2020). *Exchange of Experts November 11th-15th. Smoke Explosions, Smoke Cooling, FSE and Real Fires. A Short Report*. Arnhem: IFV

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Title:	Exchange of Experts November 11th-15th. Smoke Explosions, Smoke Cooling, FSE and Real Fires. A Short Report
Date:	13 januari 2020
Status:	Final
Version:	1.0
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Review:	dr. ir. R. Weewer

Preface

This year was the fourth time that the Dutch Fire Service Academy (IFV) organized an exchange of experts in the Netherlands. As tradition would have it, this exchange was combined with the annual international Fire Safety and Science congress, and therefore provided in an international program. There was an excellent entry of participants, in the exchange as well as in the conference. The exchange not only merged research and (its translation into) practice, but also connected fire suppression and fire prevention. It was a fruitful event, because all presentations were given and discussions were held by practitioners as well as scientists.

The main objective of the annual exchanges like this held in the Netherlands, is to share knowledge, come up with research topics to collaborate on, and create a working network of people from all over the European Union on fire, fire behaviour, fire prevention and firefighting. The network that has been formed so far, is a very strong one, and still growing. We will certainly continue to organize further exchanges of experts, as we consider them a first step towards a more comprehensive and durable network of researchers and practitioners who conduct practical research for the fire service, who are willing to share this knowledge and can translate it to practice.

During the first exchange in 2016 a list of topics of general interest was determined, and every year this list is updated. This year we primarily shared knowledge about smoke: smoke propagation, smoke cooling techniques and (prevention of) smoke explosions. These are issues of great importance for the safety of fire fighters. Furthermore, we discussed the possibilities of using theory of Fire Safety Engineering in practice and the application of FSE models to understand and learn from real fires. Next year the program will be more open, in order to leave more room for discussing research with each other.

The exchange was (again) partially subsidized by the EU exchange of experts program. We are very grateful for this, as it enabled less fortunate fire services to participate. We are also grateful that others who can provide the funding themselves, were willing to do so. This made the number of participants as large as possible, and exactly that is what Fire Service Academy (IFV) wanted to achieve.

Judging by the positive reactions from all participants, the meeting was again a success! I would like to thank you, participants, for your active attitude, your presence and input, and I hope to meet you again next year. I would like to give a special thanks to my colleagues who had put much effort into organizing this exchange: Rosanne and Jan. Without you, this exchange would not have been so successful!

Ricardo Weewer

Professor of Fire Service Science
Fire Service Academy (IFV)

Contents

1 Objectives

Exchanges of Experts are an important means in answering experts' need of sharing practical and scientific knowledge on actual topics on an international level. This year the topics of the Exchange were:

1. *Fire safety engineering*: the use of FSE and a simple analytical method to take wind effect into account when using natural ventilation.
2. *Fires in modern vehicles*: what are the risks of alternative fuels and batteries? Which safety measures have good potential?
3. *Fire Impact Tool*: what is the impact of firefighting on the environment?
4. *Learning from real incidents and smoke explosions:* how can we share our knowledge? What is the IFE database and how do we use it?
5. *Smoke cooling and inertisation:* Is inertisation possible with water vapour and nitrogen? Which techniques are effective for smoke cooling?
6. *Smoke propagation:* FSE simulations from the Oudewater experiments.
7. *Research on search and rescue*: How long does it take to search a room? How does bringing a nozzle effect search time and air consumption?
8. *Time for remaining topics*.

This Exchange had three objectives:

> Exchange of research topics, practical knowledge gained from experiments, and knowledge gained from practical experiments in general.
> Maintaining a community (network) of practical researchers in Europe.
> Facilitating international collaboration.

A total of 26 experts participated in this Exchange, one of which also had a keynote during the FSS Conference.

2 General program

The Exchange of Experts took place in Arnhem, the Netherlands, and was organised by the Fire Service Academy of the Institute for Safety (IFV). The program consisted of five days, from November 11th to 15th. Following the set-up of last year, the Fire Safety Science (FSS) Congress was integrated in the program of the Exchange. The fifth day of the Exchange was optional for participants and consisted of a visit to Troned, a training centre for emergency services.

In preparation of the Exchange, all experts were asked if they would like to give a presentation on smoke cooling, smoke explosions, FSE, learning from real fires or another relevant subject. These topics were chosen from the topic list for the Exchange of Experts that was made in 2016 and from input that was provided by the experts beforehand. This resulted in eight presentations on the topics mentioned above, on fire in modern vehicles, the Fire Impact Tool and on research into search and rescue. These topics were discussed during the various sessions. Additionally, there was room for remaining topics and discussion. A detailed program of the Exchange is presented in chapter 5 of this report. The Exchange ended with a summary and evaluation of the experiences gained.

Participants

The participants were invited by approaching the existing and growing network consisting of:

> European Fire Service Academy Association (EFSCA) members
> the Arnhem Group: participants from last year's exchange
> participants from other Exchanges.

3 Report

3.1 Monday 11 November 2019

After arrival at the Fire Safety Academy of the IFV, participants were welcomed by Ricardo Weewer, professor of Fire Service Science at the Dutch Fire Service Academy. In the morning a researcher from the Fire Service Academy presented on smoke cooling and inertisation experiments. Afterwards, there was plenty of room for discussion. After lunch, other experts gave presentations on smoke cooling, the use of FSE and on an easy method to take wind effect into account when using natural ventilation. Following each presentation, there was time to discuss the topic.

3.1.1 Session 1, Smoke cooling and inertisation experiments

Lieuwe de Witte, researcher at the Fire Safety Academy of the IFV, presented on smoke cooling and inertisation experiments done in the Netherlands. Smoke gas ignitions occur from time to time and are dangerous for firefighters. Up till now, there had been no convincing scientific evidence for inertisation of smoke. In addition, there is a global discussion about the easiest and most effective technique to cool and inert smoke. The goal of the experiments was to determine whether the existing smoke gas cooling technique used by Dutch fire fighters and in other North European countries prevents smoke gas ignition. The main question was: can water (steam or mist) or nitrogen into a smoke layer prevent smoke gas ignition? For the experiments desktop flashover cabinets were used, with either cold gas mixtures or hot gas mixtures. The conclusion of the experiments was that inertisation is indeed possible with water vapor and nitrogen. For the experiments with the cold mixes there was not enough water vapor or steam to reach the inertisation point. When nitrogen was used, inertisation occurred at a level of 34% nitrogen. Concerning the hot gasses, around 42% water vapour or steam was needed to reach the inertisation point. The question is, however, whether smoke gas cooling is also inertisation. This depends, according to De Witte. The next question is then, if cold smoke gas explosions can be prevented in this way. De Witte thinks this is probably not the case. Besides, it is hard to measure if smoke explosions can or will occur. During the discussion, some experts said that smoke gas explosions do not seem to occur in their countries or are not recognized as such. In de UK, smoke gas explosions are witnessed from time to time. The subject is still unexplored and therefore this session was used to validate the report of the smoke cooling experiments.

3.1.2 Session 2, Smoke cooling experiments

Rijk van den Dikkenberg, researcher at the Fire Safety Academy of the IFV and firefighter, gave a presentation on smoke cooling experiments conducted in the Netherlands. The goal of the experiments was to collect data about smoke gas cooling and find an answer to the question how to cool smoke in an easy way. Different techniques were used: 3d cooling with high pressure, 3d cooling with low pressure, the reverse U technique and CAFS. The set up consisted of a brick hallway with a fire compartment at the end and an emergency exit in the middle. The temperature and humidity were measured, as well as how much time it took to reach the fire, how much water was needed to the fire. Using videos, Van den Dikkenberg

showed the set-up and the experiments. The research has not been completed yet. Van den Dikkenberg emphasised that he only presented the first observations. Some participants wanted to know which is the best technique; Ricardo Weewer answered that this depends on the situation. Karel Lambert added that in some cases, for example with poor families, one does not want to use too much water, as water can severely damage a residential building. The question is then, how firefighters know how much water they need. The discussion showed that with respect to this question, various rules of thumb are used in different EU countries.

Figure 3.1 Rijk van den Dikkenberg showing footage of the smoke cooling experiments

3.1.3 Session 3, use of FSE & simple method to take wind effect into account when using natural ventilation

Nils Johansson, associate senior lecturer at Division of Fire Safety Engineering at Lund University Sweden, presented on the use of fire dynamics within the fire service. Within the Swedish fire services, there is a good level of knowledge of fire theory. A variety of engineering tools are already used in fire safety designs. However, fire dynamics theory could be applied more often within in the fire service, for example in predicting fire development. Johansson first explained what fire dynamics is and how it is used today. He showed, based on a literature review, that fire dynamics theory is mainly used for improving and planning operational activities. In some cases fire dynamics is used for fire forecasting. Interviews have shown that firefighters rarely use calculations in their work, that there is a need to use fire dynamics theory for more complicated or rare incidents where there is a lack of practical experience, and that fire fighters see a need for further education or for refreshment of their knowledge. There is an imbalance of knowhow between fire consultants and the fire service when it comes to fire modelling. FSE simulations are of great value for evaluating and explaining real fires. The use of FSE is still limited for some tasks of the fire service. This could be explained by a limited connection between theory and practice or by a lack of refreshment of knowledge (forgetting). Nils shared some examples of the use of FSE in preventative activities and fire investigations, which contributed to one of the main goals of the Exchange: sharing ideas about how to combine theory and practice.

Figure 3.2 Nils Johansson during his presentation on fire dynamics

Nils continued his presentation on another topic: how to study wind effect with an easy analytical method. He based his talk on the paper about this method. To introduce the subject, he first addressed why this method had been developed. He stated that the influence of external conditions like wind is only occasionally accounted for in fire safety engineering. However, the effect of wind on the smoke control system could be large. To achieve a new method to take wind effect into account when using ventilation, fire safety engineering and wind engineering needed to be combined. Wind speed, the shape of the building and wind directions are all included into this new analytical method. The method showed, among other things, that the most beneficial position of the make-up air is on the windward side of the building. It can be concluded that the influence of wind on the exterior and interior of a building is complex, that the simplifications included in the analytical method might be too large for it to be useful and that further evaluation of the method is needed.

3.2 Tuesday 12 November 2019

On the second day of the Exchange, the sessions with presentations followed by discussions continued. In the morning, a presentation was given on the FSE simulations from the Oudewater experiments, and learning from real incidents and a specific case of smoke explosion were discussed, as well as fires in modern vehicles. After lunch, the Fire Impact Tool was explained and a study on search and rescue was discussed, just as various other remaining topics.

3.2.1 Session 4, FSE simulations from the experiments in Oudewater

Lieuwe de Witte shared the first results of the FSE simulations from the Oudewater experiments. First, he explained the set-up of the experiments, for which 25 identical sofas were used. There were two airtight fire rooms, and some back-up rooms. One of the research questions was: What is the effect on smoke propagation of opening doors? Simulations were run for hot layer and cold layer scenario's on temperature, while taking the effect of opening doors into account. In all scenario's the heat release rate (HRR) was

calculated. Whether the door was closed or open, there was always a lot of smoke, partly due to the synthetical material from which the sofas were made. Due to pressure, smoke also appeared through cracks, toilets and electrical sockets in other rooms on or other floors. Karel Lambert suggested that a smoke stopper could be a solution or sending more fire fighters, as happens in the United States.

3.2.2 Session 5, Learning from real incidents and the IFE database

In the next presentation Adam Course, crew manager of the Avon Fire & Rescue Service in the United Kingdom and the driving force behind the IFE database, talked about learning from real accidents and smoke explosions in order to raise awareness about the topic. Smoke explosions are seen as a relatively new phenomena. Course emphasised that it is very important to have a good understanding of the construction of buildings, as very often, there are many defects in buildings. According to the database, there are more wildfires, even in the northern countries. Fires in nightclubs also get more attention. Adam supported his talk with video's about real incidents in the UK. There are many fires that have a similar cause, but relevant information is not shared very frequently among fire brigades. To enable a better sharing of relevant information about fire incidents, the IFE database was created, that lists many real incidents from all around the world. For every incident, you can find reports, videos and other relevant information. At the end of his talk, Adam made an appeal to submit (English) reports and video's about fire incidents to the IFE database, so as to share and improve our tactics on firefighting.

Figure 3.3 Adam Course during his talk on learning from real incidents

3.2.3 Session 6, Fires in modern vehicles

Lotta Vylund, researcher at RISE, Sweden, presented on fires in modern vehicles and the risks of alternative fuels. She classified alternative fuels as liquified gasses, compressed gasses and batteries (Lithium-Ion). Risks of these alternative fuels include the possibility that jet flames and fires balls appear, that alternative fuels are toxic, flammable and difficult to extinguish and that these fuels could re-ignite. In addition, batteries can cause explosions. The questions are, if a sprinkler system can prevent this and we can stop the propagation. Vylund discussed the results of a study that had tackled these problems and shown that internal suppression systems have potential because they are able to stop the propagation.

Still, a lot of smoke remained. At RISE, experiments with safety valves in steel and composite tanks were also conducted. The tanks contained CNG, a compressed gas, which is commonly used as alternative fuel in Sweden. Safety valves worked for the steel tanks in all tests, and for the composite on three out of four times.

3.2.4 Session 7, Fire Impact Tool

After lunch, Vylund presented on the Fire Impact Tool, which helps responders to understand the impact of fire on the environment. In Sweden, local and national authorities are becoming increasingly responsible for the prevention of environmental damage caused by fires, but they do not have the expertise needed for making decisions during an incident. The goal of the project was to provide decision support information to responders about risks to the environment that are resulting in fires, and to expand the previous Enveco tool so it can be used for pre-planning and training. There are two analysis approaches. The first is the Environmental Risk Assessment (ERA), which estimates risk to the local environment. The other is the Lifecycle Assessment (LCA), which includes the impact beyond the local environment and compares impact in terms of emissions for global life. Output from the Fire Impact Tool showed results based on different variables, for example global warming, air pollution, water pollution and the impact on soil and surface water.
In a Swedish incident, a tractor was consumed by fire and 300 litres of diesel were burned or had leaked into the soil. 3000 litres of water were used by firefighters, of which nothing was collected afterwards. The result was that 150 cubic metres of soil had to be dug up and taken away. An researcher who used the Fire Impact Tool, estimated that only 11-19 cubic metres of soil would have had to be removed if no water had been used. From the following discussion at the Exchange, it appeared that the procedure of collecting soil and water after a car fire is not a common practice in other countries. Only Sweden collects soil and water, while Finland collects only water. Other countries where the environmental impact of firefighting does not seem to be a major topic, do not do this at all. One of the conclusions of the Fire Impact Tool project was that responders can formulate rules of thumbs for field operations from using the tool, for example, is it better to let it burn? In some cases, this does seem to be the case. The Fire Impact Tool also showed that the global impact of firefighting is indeed significant. All in all, the tool provides a framework for future improvements in training and pre-planning activities.

Figure 3.4 Lotta Vylund explaining the Fire Impact Tool

3.2.5 Session 8, Research on search & rescue

Karel Lambert, guest professor at Ghent University, gave a presentation about his research on search and rescue. Research questions included: How long does it take to search a room and how many firefighters are needed? The set-up consisted of four bedrooms and three office spaces with or without furniture, with or without victims and with or without hose lines. A total of 42 crews, consisting of two firefighter each, participated in the study. They were asked to stay low during their search. Participants were blindfolded and did not know if there were victims were inside and if so, how many. Search time, air consumption and increase in heart rate were measured, among other things. Results show that four minutes is sufficient for search and rescue in bedrooms. Also, search time does not increase linearly with surface. When taking a nozzle, 56% more time/m^3 and 97% more air/m^3 was used. These results suggest that bringing a hose makes the work heavier. However, it is important to keep in mind that bringing a hose can improve safety, for example for protection and so as not to get lost. With respect to search time in general, a large standard deviation can be noticed. Future research could focus on search and rescue for a whole apartment (not just a single room), with or without hoses or in a hybrid form. Another study could be devoted to the principles of “staying low” or “standing up”. A suggestion from the participants was the use of thermal imaging camera’s. A possible collaboration between the Fire Service Academy of the IFV and Belgium was proposed.

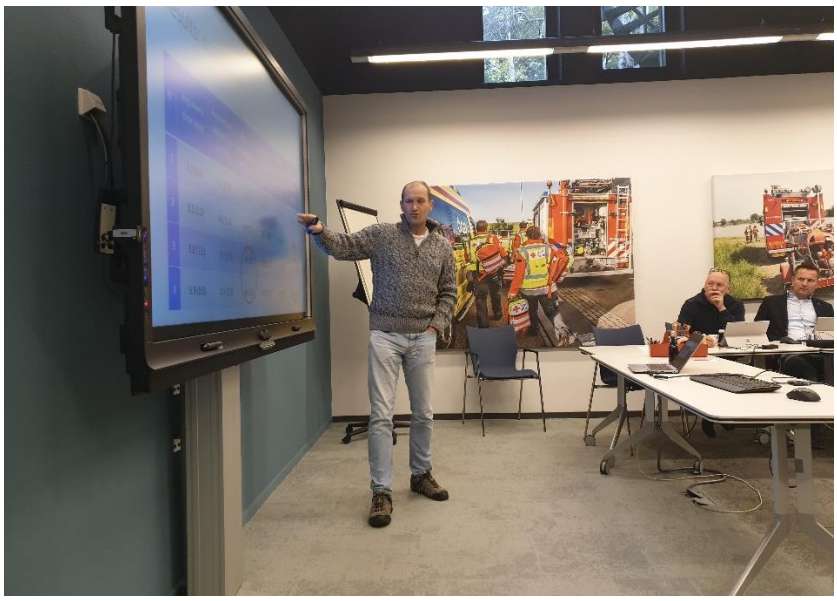

Figure 3.4 Karel Lambert showing the results of the research on search and rescue

3.2.6 Session 9, Remaining topics

The last session was reserved for remaining topics. Jarno Ruusunen, researcher at the Emergency Services Academy Finland, presented on the Wild Fire project and on door management in Finland. Afterwards, the Exchange ended by summarizing and evaluating the experiences gained.

4 List of Participants

Country	Participant
Austria	Daniel Bernhard
Belgium	Karel Lambert
Belgium	Michiel de Paepe
Catalonia	Daniel Garcés Sánchez
Denmark	Flemming Hoffman Pedersen
Denmark	Martin Thomsen
Finland	Jarno Ruusunen
Hungary	Zoltán Karacs
Hungary	Kund Vilmos Karvai
Italy	Paolo Covelli
Lithuania	Tomaš Veliseičik
Netherlands **(Host)**	Ricardo Weewer
Netherlands **(Host)**	Rosanne Fikke
Netherlands	Folkert van der Ploeg
Netherlands	Lieuwe de Witte
Netherlands	Maurice de Beer
Netherlands	Peter Krom
Netherlands	René de Feijter
Netherlands	René Tonis
Netherlands	Rijk van den Dikkenberg
Netherlands	Ruud van Herpen
Netherlands	Siemco Baaij
Netherlands	Ruud van Liempd
Netherlands	Hans Hazebroek

Netherlands	Kitty van Rossum
Sweden	Nils Johansson
Sweden	Lotta Vylund
United Kingdom	Adam Course
Ukraine	Dmytro Kolbylkin

5 Program

TIMETABLE November 2019

Exchange of Experts

11 - 15 November 2019

Arnhem (Netherlands)

Arnhem, The Netherlands

Date	Hour	Item	Remarks
Monday	**11/11**	**Exchange of Experts: sessions**	dress code: casual
	08.00-12.00 h	Arrival and transfer to IFV	
	12.00-13.00 h	Lunch	
	13.00 h	Welcome to the participants (Ricardo Weewer; professor IFV) Short introductions	IFV
	13.30 h	Lieuwe de Witte: Smoke cooling / inertisation experiments	
	14.30 h	Coffee break/ group photo	
	14.45 h	Rijk van den Dikkenberg: Smoke cooling experiments	
	15.45 h	Coffee break	
	16.00 h	Nils Johansson: use of FSE in the fire service Nils Johansson: simple method to take wind effect into account when using natural ventilation	
	17.00 h	Depart to hotel and check-in	Hotel
	19.30 h	Dinner at Hotel	
Tuesday	**12/11**	**Exchange of Experts: sessions**	dress code: casual
	08.00 h	Breakfast	Hotel
	08.30 h	Transfer Hotel - IFV	
	09.00 h	Lieuwe de Witte: FSE simulations experiments Oudewater	IFV
	10.15 h	Coffee break	
	10.30 h	Adam Course: Learning from real incidents and case study of a smoke explosion	
	11.30 h	Lotta Vylund: Fires in Modern Vehicles	
	12.15 h	Lunch	
	13.15 h	Lotta Vylund: Fire Impact tool	
	14.00 h	Karel Lambert: Research on search & rescue	
	14.45 h	Coffee break	
	15.00 h	Remaining topics	

	16.00 h	Wrap up	
	17.00 h	Return to hotel	Hotel
	18.30 h	Dinner with FSS Speakers	dress code: smart casual
Wednes day	**13/11**	**FSS Congress https://www.ifv.nl/congressen/Paginas/Congres-Fire-Safety-and-Science-2019.aspx**	dress code: smart casual
	19.00 h	Network Dinner	IFV
	20.30 h	Return to hotel	Hotel
Thursday	**14/11**	**FSS Congress https://www.ifv.nl/congressen/Paginas/Congres-Fire-Safety-and-Science-2019.aspx**	dress code: smart casual
	17.30 h	Return to hotel	Hotel
	19.00 h	Dinner at Hotel	
Friday	**15/11**	**Facultatively Visit Troned / Travel day**	dress code: casual
Choice	08.00 h	Breakfast	Hotel
	08.30 h	Transfer Hotel - Troned	
	10.00	Welcome by Ymco Attema (host Troned)	Troned
		Visit Safety Campus	
		Visit Fire Investigation Lab	
		Visit Fire Lab and instruction area	
	±15.00	Travel to Schiphol Airport	