TECHNIQUES FOR THE OFFENSIVE EXTERIOR ATTACK IN FIGHTING VENTILATION CONTROLLED STRUCTURE FIRES

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ABSTRACT

This article gives a brief overview of four sets of experiments that were carried out to study the applicability of techniques to fight ventilation controlled structure fires from the exterior of the building, according to the newly developed "Offensive Exterior Attack Tactic". Five fire fighting techniques (fognails (FN), cold cutting extinguisher (CCE), spray distribution nozzle (SDN), CAFS OneSeven, and Low Pressure Attack Line (LPAL)) were studied in three different confined building types (industrial and domestic building). The aim of the research program was to find out if the techniques were able to meet the objectives of the offensive exterior attack (extinguish the fire from outside, create tenable environment for casualties inside, or create a safe entry for fire fighters for an offensive interior attack). The results show that all techniques were capable of extinguishing the fire and create a safe entry when they were applied from the exterior of the room where the seat of the fire was located. In a building consisting of two rooms, only LPAL and CAFS (one time) were able to create a persisting knock down during the attack. In a four-room building none of the techniques was able to create a safe pathway to the fire room or a knockdown of the fire. It was shown that temperature is not the most important parameter determining tenability for possible casualties inside. CO concentration and radiation were in fact the determining factors for tenability. The exterior attack did not create a tenable situation, however, due to the natural behaviour of the fire, depending on the position of the casualty, some techniques showed a minor improvement with respect to no attack at all, which is the alternative.
The main conclusion is that the offensive exterior attack should be made into the room where the seat of the fire is located or as close to that as possible. Therefore it is of great importance to perform a thorough size up and find the fire room before attack is made. Future development of the offensive exterior attack may therefore be more in improving size-up than in optimizing techniques for attacking the fire. Possibilities and limitations of every technique were found. The results of the experiments are used for education and training of fire fighters in the Netherlands.

INTRODUCTION

In the Netherlands, after three fire fighters died in a fire in a boathouse[1], a new concept of firefighting tactics was developed. This new concept, called the Quadrant Model[2], provides four tactics to approach structure fires and is intended to improve fire fighter safety. For each tactic different (existing) techniques are expected to be applicable or should be developed. Therefore, the Netherlands Fire Service Academy started a major research program to obtain more understanding of the (im)possibilities of these four tactics, and to find innovative techniques to perform them. A start was made with the offensive exterior attack, because this is a new tactic, and fire fighters do not have the appropriate techniques to apply the tactic in real structure fires. The objectives of the offensive exterior attack are (while fire fighters stay outside the building): either extinguish the fire or to create proper conditions to enter the structure safely and / or to improve the tenability for casualties.
In order to find out the effects and the applicability of some (existing or new) fire fighting techniques, a research program was started consisting of four sets of experiments. Real scale experiments were conducted to find ways to attack a structure fire from the outside.

The research questions that had to be answered were: to which extend it is possible, applying the chosen techniques, from the outside of the building to:

1. extinguish the fire inside the structure;
2. cool down the smoke gasses to create a safe entry to perform an offensive interior attack;
3. create or maintain a tenable environment for a potential casualty inside;
4. maintain this safe or tenable situation after the offensive exterior attack was ended?

The experiments were carried out in collaboration with and involving more than a hundred fire fighters. Professionalism and Science were in this way maximally combined, and acceptance of the results of the experiments maximized. This article gives an overview of the results of four sets of experiments. A more extensive report of the separate experiments will be given in other publications[3,4,5,6]. The amount of data we collected is that big, that it is impossible to show all details in one publication. Since we like to share the overall results and conclusion of the experiments first, in this article we give only typical figures of our results.

METHODOLOGY

General

Four sets of experiments were carried out in three different building configurations and fuel loads. Table 1 shows the specifications of the different buildings and fuel loads. Figure 1 shows maps of the building configurations. In these buildings ventilation controlled fires were set by closing and opening doors until the fire reached the state where temperature was high enough (see Table 1) and the smoke layer was dense and uniform. At that time the door was closed and when the temperature reached a stable level the experiment was started.

Table 1. Experimental configurations

Experiment set #	Type of building and # of rooms	Building area and height (A (m^2); h (m))	Fuel Load (MJ)	Start temperature (°C)	Stopcriterion
1	Industrial; 1 space 1 room	150	9728 MJ 512 kg pinewood eq. (32 pallets)	430°C on thermocouple 5	150°C on thermocouple 6
2	Industrial; 1 space 1 room	150	21950 MJ 874 kg pinewood eq. 170 kg particle board Approx. 6-9 MW	400°C on thermocouple 5	150°C on thermocouple 15 or maximum time of 20 mins.
3	Industrial; connected steel containers 4 rooms	70 Room 1: 12,6 Room 2: 11,1 Room 3: 18,3 Room 4: 27,5 Height 2,3	3200 MJ 9 pallets 167 kg pinewood eq. 9 kg PUR foam on 4 m^2	550°C on thermocouple 11 Smoke layer uniformly ficititious	In every room 150°C or three attemps during 30 sec.
4	Industrial; connected steel containers 2 rooms	70 Fire room: 27,5 Adjecent room: 18,3 Height 2,3	5800 MJ 8 pallets 180 kg pinewood eq. 9 kg PUR foam pillow 107 kg particle board	500°C on thermocouple 11. Smoke layer uniformly ficititious	150°C in fire room or after max. 10 mins

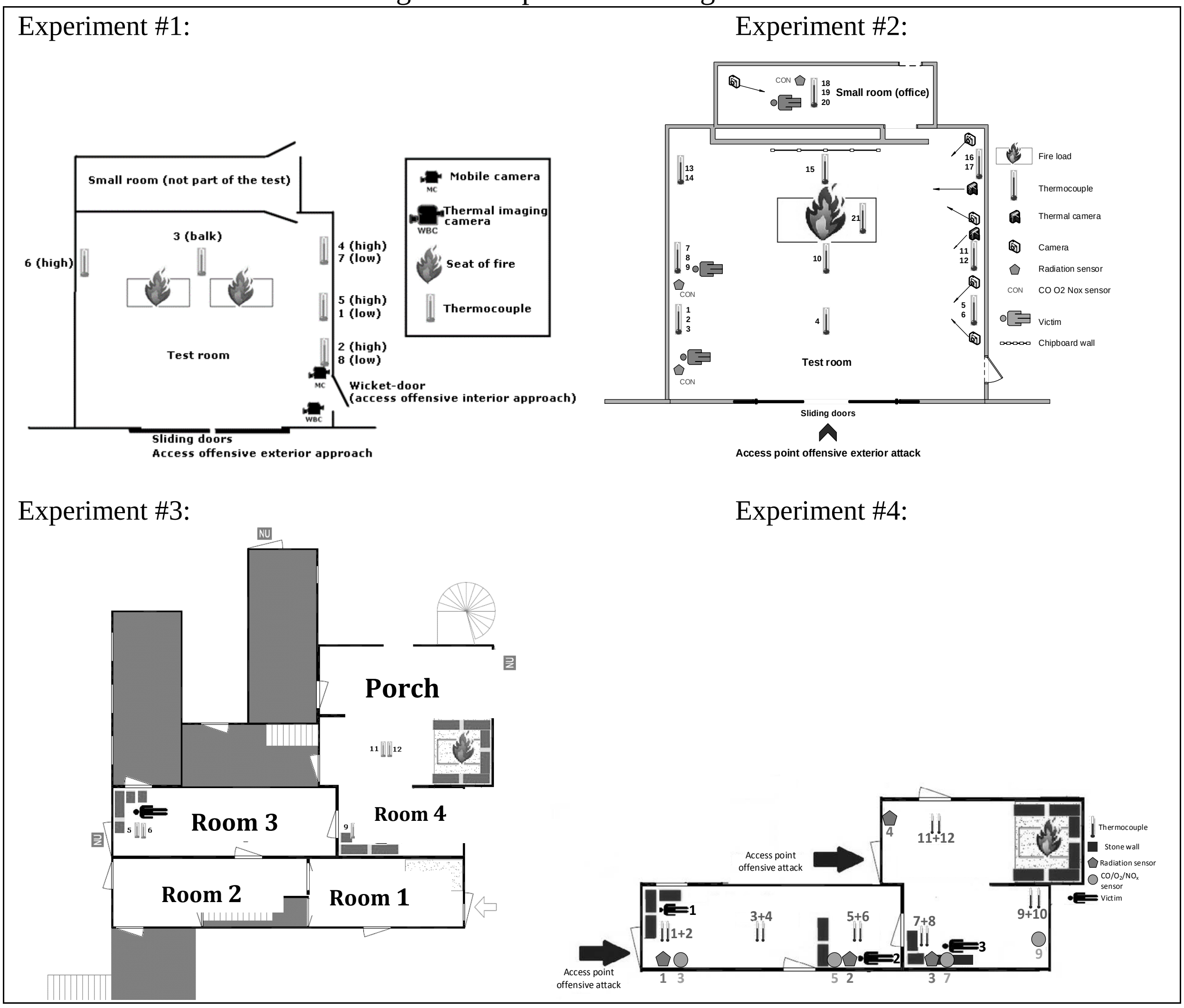
Five selected techniques were investigated to find out their capability for application as an offensive exterior attack technique: Cold cutting extinguisher (CCE), fognails (FN), spray distribution nozzle (SDN), CAFS One Seven (CAFS) and the commonly used Low Pressure Attack Line (LPAL). The techniques, the application technique and their specifications are listed in Table 3. The attack was in all experiments made through a premade hole in the front door.

In two sets of experiments only temperature was recorded (experiment 1 and 3). In the other two sets of experiments (2 and 4) also heat radiation levels, carbon monoxide, nitrogen oxide and oxygen concentrations were recorded, in order to determine tenability for assumed casualties inside the building. In all experiments the situation inside the building was recorded using normal cameras and thermal imaging cameras. In the latter experiments (2 and 4) a zero measurement was obducted in order to compare the effect of the technique with the situation when no intervention would be made. This zero measurement can also be seen as a new technique: anti-ventilation.

The specifications of the sensors are listed in Table 4. The location of the sensors in the buildings and rooms are shown in Figure 1. The experiments were ended when the criterion for successful external attack was reached.

This criterion was set as the moment at which the temperature at a predetermined thermocouple decreased below 150°C. Even if the fire was observed to show a knockdown (flames were gone), the attack was continued until this criterion was reached.

Figure 1. Experiment configurations



In experiment 2 and 4 also tenability was determined at 50 cm above floor level to find out if, using the techniques, tenability would improve or not. Parameters for tenability are given in Table 2.

Table 2. Tenability limits

Parameter	Limit
Temperature	T >= 120°C
Radiation	>= 6 kWm-2
Oxygen concentration	<= 6%
Caron monoxide concentration	>= 8000 ppm
Nitrogen oxide concentration	> 150 ppm

In experiment sets 1 and 3 the experiments were repeated five times. Since reproducibility turned out to be excellent, in experiment 2 and 4 we only repeated the experiment once. After the experiments were ended, the building was reconditioned in order to achieve the same starting conditions for all experiments and achieve maximum reproducibility.

Table 3. The applied techniques and their specifications

Applied technique	Type of extinguishment	Spray nozzle	Flow rate and angle of cone	Applied pump pressure	Dynamic pressure
CCE	Water[1]	Cobra lance	60 l/min narrow-angle cone[2]	290 bar	260 bar
SDN	Water	No nozzle, but valve is present on spray distribution nozzle.	380 l/min.[3]	9,5 bar low pressure	7 bar on spray nozzle
FN	Water	Offensive	70 l/min	10 bar	7 bar
CAFS	A-class OneSeven from Schmitz Mix of 0,3% foam solution	Standard DLS-nozzle (connected to 75mm discharge valve)	133 l/min straight stream[4]	8 bar	7 bar
LPAL	Water	TFT F06	430 l/min 15-25°	8 bar	7 bar
HPL	Water	Akron 1711	125 l/min 30º	35 bar	7 bar

Experiments set #1[3]

In this set of experiments the temperature decrease was recorded following an attack with CCE, SDN, FN, LPAL and HPL from outside the building through a hole in the door, and compared with an offensive internal attack using HPL. Note that in this experiment set it was possible to reach the fire with the streams. HPL is currently the common way to attack the fire using the offensive internal attack tactic. The experiments were carried out in an industrial building (insulated walls, configuration 1 in Table 1). Time was measured until the temperature became lower than 150°C measured in the smoke layer, or when the fire was extinguished.
In this set of experiments only temperature and camera recordings were made to record the effect of the external attack. The experiments were repeated five times.

Experiments set #2

This set of experiments was a repetition of the first set. We changed one aspect of the scenario being that in this scenario it was not possible to reach the seat of the fire with the streams, because it will now always be possible to touch the fire in realistic scenarios. The experiments were carried out in an industrial building (insulated walls, configuration 1 in Table 1). In this situation the seat of the fire was

[1] An abrasive is used for cutting through material.
[2] Exact angle of cone is unknown.
[3] Angle of cone is unknown, the SDN produces water mist in a round shape (circle).
[4] For the CAFS nozzle it is not possible to adjust the angle of the cone. The nozzle produces a straight stream.

in the rear of the room directly behind the point of external attack and was protected from direct contact with hose streams.
Time was measured until the temperature became lower than 150°C measured in the smoke layer, or when the fire was extinguished. In the scenario a first engine was able to attack using 2 LPAL, 2 FN, 1 CCE, 1CAFS or 1 SDN. If the end criterion was not reached after 10 minutes, a second engine was supposed to be at the scene, and the attack power could be doubled. The experiment was ended after 20 minutes of attack when the stop criterion was still not reached.
This time we were also able to measure tenability parameters at 50 cm above the floor, at three different locations within the building, representing probable positions of casualties. Two of them were in the large fire room, and one was in the small office room in the rear of the building.
Tenability, smoke gas layer temperature and effect on knock down and time to re-ignition were determined for every technique. After the attack a door was opened in order to simulate entrance of the building by crews to finish the fire extinguishment by an offensive inside attack. The fire development was recorded using camera's. All experiments were repeated once.

Experiments set #3

This set of experiments was conducted in a small business or industrial building or domestic building consisting of four rooms. The aim of this set was to find out whether it is possible to influence a fire in a room farthest away from the point of intervention, This type of building was simulated by four connected steel containers (configuration 2 in Table 1). The doors between the rooms were open at the time of intervention. In these experiments the HPL and PPV (positive pressure ventilation) were additionally studied as an optional technique. For the PPV experiments a small window in the fire room was opened in order to create an exhaust for the smoke. Different from the other set of experiments, in this set HPL and LPAL were not applied as a continuous stream, but two pulses of about 2-3 seconds were given. This was done three times in 60 seconds, separated by a break in which the door was closed. Every technique was applied for 60 seconds since it was assumed that this should be long enough to create a safe environment inside. Temperatures were recorded in every room 50 cm above the floor and 50 cm below the ceiling. The experiment ended if in the fire room (room #4) temperature was below 150°C. The experiments were repeated five times.

Experiments set #4

These experiments were carried out in the same building as set #3 (steel containers, configuration 3 in Table 1) but this time the building comprised only 2 rooms. This type of building was used in order to find out if the techniques would work in a building where the fire is located in a room not directly behind the front door, but when the fire would be separated by only one room from the point of external attack. In this configuration two subsets of experiments were done. The attack was made from the outside of the:

- fire room, directly into the fire room through a hole in the door;
- room adjacent to the fire room, also through a hole in the door of this room.

In both situations the experiment was ended when the temperature in the fire room decreased below 150°C or when the fire was extinguished. Temperatures and tenability parameters were recorded in both rooms.

Tenability, smoke gas layer temperature (a temperature of <150°C was assumed to be a safe temperature to enter the building and finish the extinguishment) and effect on knock down and time to re-ignition were determined for every technique. After the attack a door was opened in order to simulate entrance of the building by crews to finish the fire extinguishment by an offensive inside attack. The fire development was recorded using camera's. The experiments were repeated once.

Table 4. Specifications of the applied sensors: thermocouples, radiation sensor and gas analysis

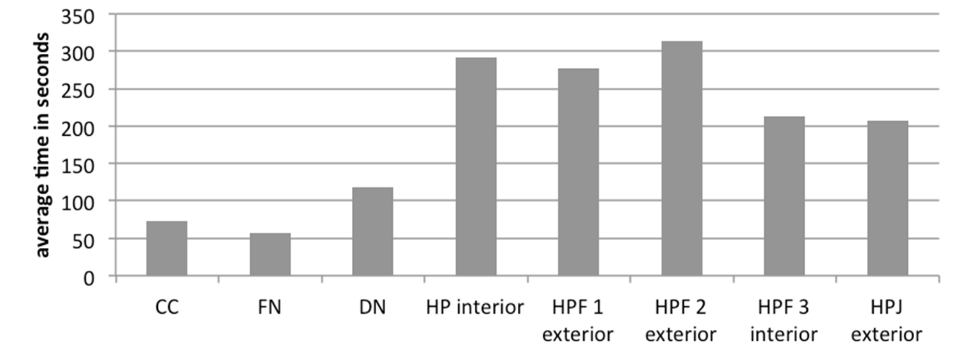
Thermocouples	**Characteristics**
Type	K-270 L221152-034 K (chromel / alumel) standard NF EN 60584-2
Max. temperature	1150 °C
Sensitivity	-40 to 333 °C: ± 2,5 °C; from 333 °C to 1200 °C ± 0,0075 x T °C.
Availability of data	The thermocouples were connected to a data logger with a measurement program. Therewith all temperatures were directly available and visible.
Radiation Sensor	
Brand	Hukseflux thermal sensors
Type	SGB 01 water-cooled heatflux sensor, type 50 (working range)
Number of sensors	5
Range	0 – 200 kW/m^2, range .50 50-75 kW/m^2
Cooling water	10 – 30 °C, barrel 30 liters
Respons time	<250 ms (63%)
Elect. output	>5 mV
Data output	.txt, .xls
Measuring method	BRON – sensor - amplifier 200x – NI DAQ module - LABVIEW
Gas analysis (Carbon monoxide (CO), oxygen (CO_2) and nitrogen oxide (NO_x))	
Brand	Testo
Type	Testo 350 Portable Emission Analyzer
Number of sensors	3
Used sensors	CO (H_2), NO_2, NO, O_2
Probe type	Standard gas sampling probe 28 inch
Applied dilution	40x
Filters	Filter set 0554 3381 3x strainer ‘oblong’ (sonde, baseline measurement, dilution) 1x strainer ‘nonwoven’ (probe) 1x strainer ‘woven’ (condensator) 1x synthecanister (probe)

RESULTS

Experiments set #1

The results show a fair reproducibility, so it was allowed to take average temperature decrease per technique. Figure 2 shows the time until temperature decreased to 150°C in the smoke layer. With all techniques it was possible to create a knockdown. This was achieved within 50. With an internal attack using HPL it took significantly longer to achieve knockdown (about 400 seconds). The knockdown persisted when the attack was made with CCE, SDN and CAFS. With FN and HPL the fire flared up after some time. With all techniques eventually temperature decreased to 150°C. CCE and FN were significantly faster in decreasing temperature, within a 100 seconds temperature reached 150°C. SDN was also very fast. Attack using HPL was significantly slower, from outside as well as with interior attack. The temperature in the smoke layer did not increase after the building was entered, although using HPL the temperature remained significantly higher during the offensive interior attack.

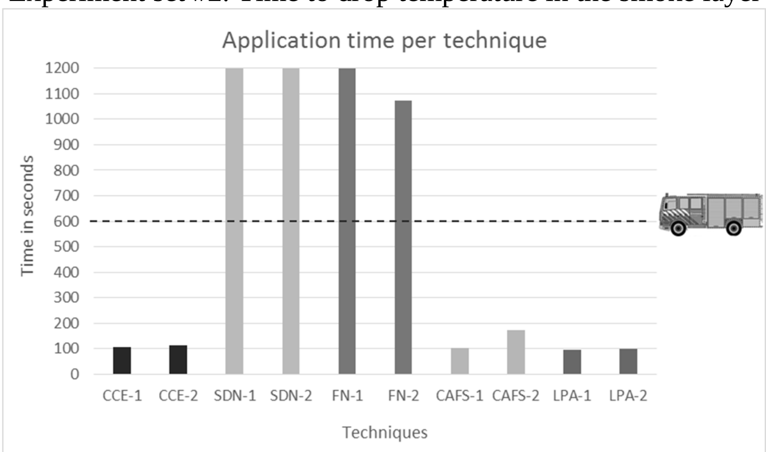
Figure 2. Experiments set #1: Time until temperature in the smoke layer decreased to 150°C



Experiments set #2

In first instance, all techniques were capable of achieving knockdown within 50 seconds. However none of the techniques was capable of extinguishing the fire completely. The differences between techniques were small, and in practical situations not relevant. This knockdown however did not always persist. Using the SDN and FN the fire flared up again during the attack. Figure 3 shows the time to drop the temperature in the smoke gas layer to 150ºC Using CCE, LPAL and CAFS it was possible to reduce temperature to 150°C with one set of equipment within 10 minutes. Actually temperature dropped below 150°C within 180 seconds. Using FN and SDN even with a second set of equipment it showed to be impossible to drop temperature in the smoke layer below 150°C.

Figure 3. Experiment set #2: Time to drop temperature in the smoke layer to 150°C



In this set of experiments also the effect on tenability at three different locations within the building was studied. The temperature, radiation, CO, O_2 and NO_x concentration were recorded at 50 cm above floor level. Tenability limits are set as hard limits although it is generally known that tenability depends on a lot of factors, and must be seen as a probability to survive or not. All parameters show a sudden (exponential) increase at the moment the attack starts., this was the case with all techniques we investigated. After some time the level of the tenability parameters decreased below the values recorded in the zero measurement. Overall it was observed that for the locations in the large fire room tenability parameters exceeded the (hard) limits for temperature, CO and radiation. Sometimes radiation even exceeded 20 kW/m^2, and CO concentration exceeded flammability limits. Note that this excess of the parameter might have been for a very short period after the start of the attack. In most cases afterwards it decreased below values recorded in the zero measurement. The results show that contrary to our expectations during offensive exterior attack tenability is not significantly improved, but does not really deteriorate either. The only one exception is the location in small office in the rear of the building. Tenability parameters did not exceed limits at this location. In Table 5 an overview of the results regarding tenability is presented.

Table 5. Effect on the tenability compared to the zero measurement. A positive marker refers to an improvement or sustainment of tenability, and a cross refers to no improvement

		CCE	SDN	FN	CAFS	LPAL
Sustaining or improving tenability of casualties	Fire room	✖	✖	✖	✖	✖
	Small office in rear	✓	✓	✓	✓	✓

After the offensive exterior attack it is always necessary to extinguish the fire applying an offensive interior attack. Therefore it is of interest to see what happens if fire fighters enter the building after the exterior attack. This was simulated in the experiments by opening a side door and record temperature. No matter which technique was applied the fire flared up immediately after opening the door. This flaring up prompts an increase in temperature up to 600 °C after about 90 seconds. Fire fighters therefore have only little time to enter the building, proceed to the fire seat and put out the fire definitely.

Experiments set #3

The fire room was separated from the point of attack (the front door) by three rooms. Temperatures at the start of the intervention were different for every room (room #1 about 150°C, room #2 about 200°C, room #3 about 350°C and the fire room #4: above 450°C). Figure 4 shows an overview of the effect on temperature for the four rooms and the techniques.
The temperature recordings show that temperature in the fire room hardly changed (maximum 15°C decrease in temperature), and no effect on the fire was observed with any technique, except PPV. With PPV the temperature actually increased after an initial decrease. This would be expected since more air is transported towards the fire. The start temperature in room #1 was already close to 150°C, which was the criterion for a safe environment.
All techniques were able to create a safe situation to enter the first room, PPV, CCE and CAFS performing the best. In room #2 HPL, SDN and FN cause no observable effect, LPAL and CAFS have a small effect, and only the CCE and PPV result in a substantial effect of more than 100°C cooling of the smoke layer, resulting in a temperature below 150°C which would be safe to enter. In room #3 only PPV shows any effect on temperature. The CCE apparently does not turn around the corner. It achieves only an effect straightforward. At 50 cm above the floor, temperatures increased slightly during the attack (10-30°C) but did not exceed the tenability limit of 120°C.

Experiments set #4

Two subsets of experiments were carried out in this two-room building. The experiments were repeated once. The results were fairly reproducible.

Subset #4-1: External attack through the door directly into fire room.
All techniques were able to achieve knockdown within 15 seconds. This knockdown persisted during the attack. Figure 5 shows the average temperature curves for every technique when applied directly into the fire room.

Figure 4. Experiment set #3: Overview of the effect of the different techniques in the rooms

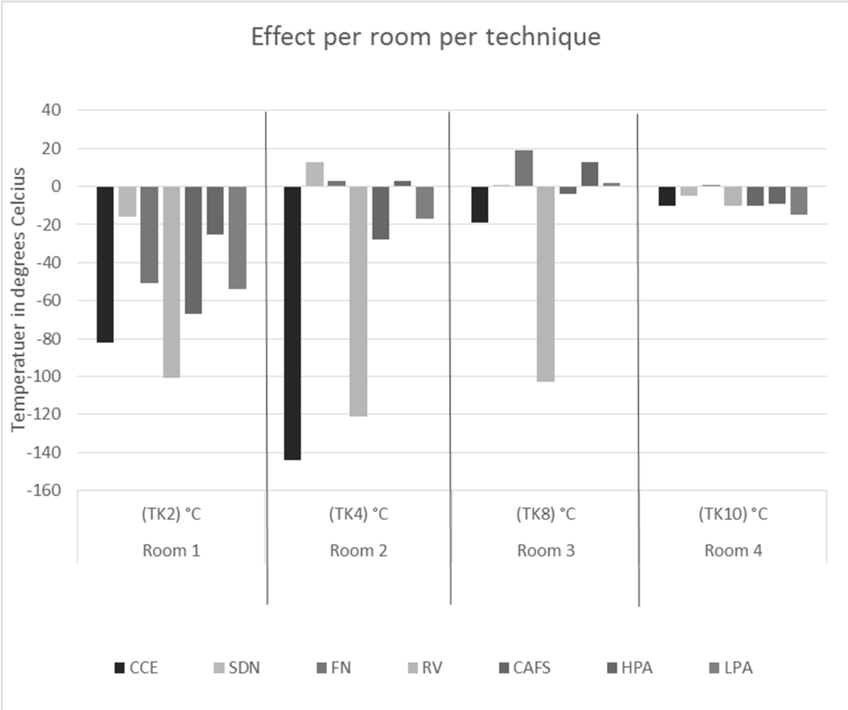
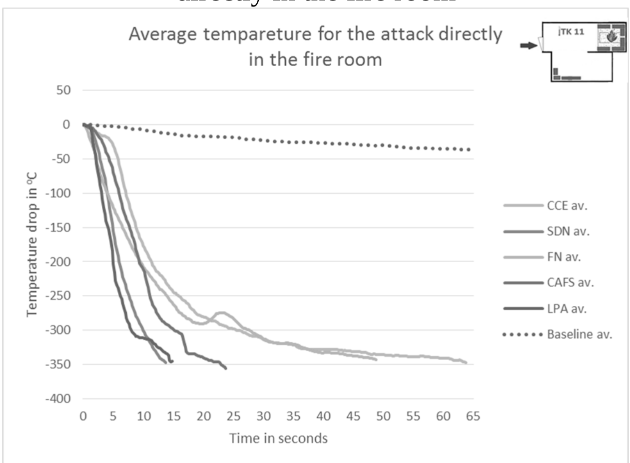


Figure 5. Experiment set #4: Average temperature (°C) versus time (S) recordings for the attack directly in the fire room



All techniques were able to decrease the temperature in the smoke layer to 150°C within 60 seconds, CCE and FN being the slowest techniques. As shown the effect with respect to the zero measurement was substantial. In the zero measurement, temperature remained roughly the same at about 500°C.
Looking at the data for tenability it was observed that, in agreement with experiment set #2, temperature, radiation and CO concentration peaked at floor level when the attack was started, and in most cases exceeded the tenability levels. During the zero measurement the temperature, CO concentration and radiation increased above the tenability level. The exterior attack resulted in an improvement of this tenability parameter: with any technique temperature was decreased below the tenability level. However, radiation also increased above the tenability level during the attack, except from FN and CAFS attack. CO concentration increased with any technique above tenability level.
After the exterior attack was ended we simulated entry by opening the front door to observe what would happen when fire fighters enter de building to finish the extinguishment of the fire. After attack with CAFS and LPAL the fire did not flare up, and temperature remained at about 100°C. After attack with

the other techniques, the fire did flare up and within 60-180 seconds temperature increased exponentially up to 700°C.

Subset #4-2: External attack through the door of the room adjacent to the fire room.
The experiments were repeated once. The results were fairly reproducible, however the two experiments with the FN, NK and CAFS differed from each other. All techniques were able to create a knockdown in first instance. However, this knockdown did not persist using CCE, SDN, FN and one time using CAFS. In these experiments, the fire flared up while the attack was still on going. Figure 6 shows average temperature versus time curves for the different techniques, including the zero measurement.
Only with LPAL it was possible to cool down the smoke gasses in the fire room to 150°C. With CAFS this was almost achieved, but the end temperature was about 180°C, although all techniques show an initial decrease of temperature. Surprisingly, the temperature curves for FN, CCE and SDN show almost the same behaviour as in the zero measurement, which means that the attack did not really influence natural fire behaviour. In the adjacent room itself the temperature always dropped down to under 150°C, so this room would be safe to enter.
Regarding the tenability data for this experiment (in this experiment set there were three locations) it was found that temperature, radiation and NO_x concentration during the zero measurement did not exceed the tenability levels. During the attack temperature levels were also not exceeded. The CO concentration exceeded the tenability limit in the zero measurement as well as the attack. For radiation a mixed picture is observed. Sometimes it was exceeded, sometimes it was not exceeded, also depending on the location of the casualty. We observed that, like in subset #1, the CO concentration and the radiation peaked almost immediately after the attack. In Table 6 an overview is given for the tenability. Table 6 an overview of the results regarding tenability is presented.

Figure 6. Experiment set #4: Temperature versus time (s) curves for exterior attack in room adjacent to the fire room

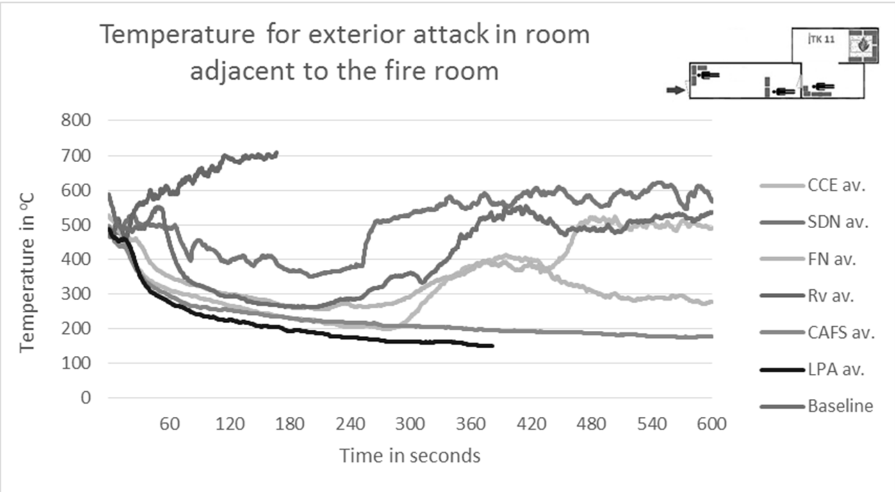


Table 6. Effect on tenability of the attack with different techniques. A positive marker refers to an improvement or sustainment of tenability, and a cross refers to no improvement

		CCE	SDN	FN	RV	CAFS	LPAL
Sustaining or improving tenability of casualties	Fire room (subset 4.1)	✔	✔	✔	d.n.a.	✔	✔
	Adjacent room (subset 4.2)	✖	✖	✖	✔	✖	✖

DISCUSSION

The results of these experiments are of course only valid for the configurations studied in this research, and strictly speaking they can not be generalized, except with common sense and caution. The manner of application of the techniques has a big influence on the results. In most reports we found in literature, the exact way of application is most of the time not described very accurately. In this article we did describe it in order to make repetition possible. In our case the application of the techniques was done by fire fighters who work with the techniques in practice and were well educated and trained on using the standard application of the techniques, thus achieving reproducibility. Taking into account all the above limitations however, we have observed certain trends, which probably also hold in other situations. These trends are written down in the conclusions.

Tenability limits are still under research by experts and subject of discussion among scientists. Also, they depend on various factors, like age and health of the casualty involved. We took the most actual values from literature, and set them as a hard criterion for tenability. Excess of this criterion will therefore not always result death of a casualty, but it is also not certain that a casualty will survive.

For this research program we had to introduce a criterion for safe entry. We chose, more or less arbitrarily, for 150°C. This temperature level was assumed to be safe to enter the building, because self ignition of the smoke layer is highly improbable. Although smoke gas can still ignite when between flammability levels when the temperature is lower than 150°C this was assumed equally improbable.

We observed that CO concentration and radiation levels increased exponentially and temporarily at some time (seconds) after the start of the attack. We did not expect this, and at first it was thought that this might have been an artefact, maybe caused by water droplets or steam on the radiation sensor, reflections of the water droplets in the smoke gasses. Therefore, in experiment set #4 we did some additional experiments. We measured radiation in the fire room without fire and smoke which was still 400°C. In this situation there was no increase of radiation measured during the attack, so steam and water droplets could be excluded. We think that the increase in radiation is caused by the lowering of and turbulence in the smoke gas layer caused by the attack. This is consistent with the observed increase in radiation and CO concentration in the zero measurement. Directly after closing the doors when the fire becomes ventilation controlled, it is expected that the smoke gas layer will also lower. However this increase in CO concentration and radiation is smaller also in this situation the smoke gas layer will lower.

CONCLUSIONS

Referring to the research questions 1-4 in the introduction we can draw the following general conclusions. Bear in mind that these conclusions are strictly spoken only applicable for the configurations studied in this research and should only be generalized with common sense and caution.

To which extent is it possible to extinguish the fire from the exterior of the structure applying the chosen techniques?

- If the exterior attack is made from the exterior of the structure directly or very close to the seat of the fire, all techniques are able to create a knockdown of the fire. However, it is always necessary to enter the building and extinguish the fire definitely by an offensive interior attack.
- After the exterior attack is finished and the building is entered, the fire might again flare up and temperature might increase exponentially, depending on fire load. There is about 60-300 seconds to reach the fire seat.
- When the attack is made from a room adjacent to the fire room, the effect on knockdown of the fire is less prominent. Only LPAL and CAFS (one of two times) were capable of creating a persisting knock down in the fire room. So in this situation “it depends”. The room where the attack is made itself can be made safe (temperature lower than 150°C).

- When the attack is made at a point where the fire room is separated from by more than one room, no effect is expected on the fire.
- When the seat of the fire might be deep inside the structure only the techniques which create long streams (LPAL, CCE and CAFS) affect the fire.

To which extent is it possible to cool down the smoke gasses to 150°C applying the chosen techniques from the exterior of a building?

- When the attack is not made directly into the fire room, this room can be cooled down by an exterior attack. However this attack probably will not cool down the fire room.
- When the attack is made directly into the fire room all techniques are able to cool down the smoke gasses to 150°C. After the attack is finished there is sufficient time to enter the room and extinguish the fire.
- When the attack is made in a large fire room and the fire is far away from the point of intervention, only CCE, CAFS and LPAL (these techniques possess a long stream) were capable of reducing temperature to 150°C. After opening the door temperature increased exponentially however after about 2 minutes.

To which extent is it possible to improve or maintain tenability inside de structure applying the chosen techniques ?

- Generally spoken temperature is not the most important tenability parameter to be affected.
- CO concentration and radiation levels increase exponentially and exceed tenability levels directly after the start of the attack. However this would also happen without the attack due to natural fire development in a ventilation controlled fire
- Tenability will not deteriorate because of the exterior attack, there might be a slight improvement, but generally there is no substantial improvement.

To which extent will the situation created by the offensive exterior attack be maintained after the attack is finished?

- Generally fires are not completely extinguished after the exterior attack. After some time, depending on the technique, the fire will flare up, and temperatures will increase exponentially. There is little but sufficient time to finish the fire.

The overall conclusion is that an offensive exterior attack has a good chance of meeting the objectives when it is made from the exterior of the fire room close to the seat of the fire. In other situations it depends. Therefore, it can be concluded that a thorough exterior reconnaissance (size-up) should be made to find the best location to start the offensive exterior attack. When this is possible, it does not matter which technique is applied to meet the objective. If this is not possible, techniques which create long streams and high volumes of cooling media have the best chances. When the attack is made into another room than the fire room, a possible tactic would be to make the building safe room-by-room.

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