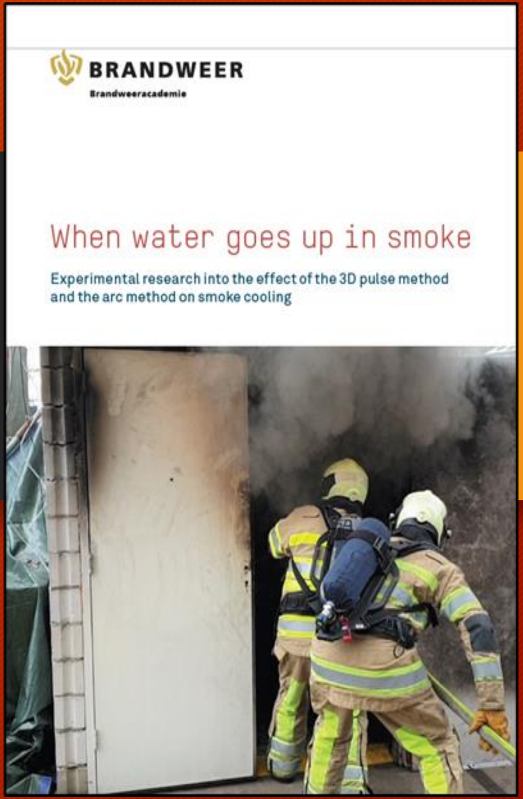
Fire Service Brandweer Academy (2021). Experimental research into the effect of the 3D pulse method and the arc (surface cooling) method on smoke cooling Arnhem: IFV.



3D Gas Cooling or Surface Cooling?

A Compartment Fire Discussion Paper for 2024 based on Brandweeracademie Research

EuroFirefighter.com

Gas Cooling or Surface Cooling?

There is ongoing discussion within Europe and the USA around methods of applying water to best effect, when approaching compartment fires, for both gas cooling and surface cooling purpose. It is recognised over the past years that 3D gas cooling has been difficult to teach, and adequate skill levels are challenging to maintain without regular training exposures.

In contrast, the methods associated with boundary surface (walls and ceiling) cooling are considered far easier to teach but also demonstrate greater cooling capacity when controlling the fire environment, both on the approach route and within the fire compartment itself. The following research is an example of how application methods are changing, and firefighter safety is seen to be increased.

Compartment Firefighting Review

‘3D Gas Cooling is rarely performed correctly’

‘Opinions differ when it comes to the question of how to approach the seat of a fire that cannot be reached directly with the extinguishing agent, making it necessary for firefighters to progress through hot smoke. In the Netherlands, the '3D pulse method' (Appendix 1) is used as a smoke cooling technique. Instructors have noticed that this method is difficult to learn, requires a lot of practice and training and is rarely performed correctly.

There is also evidence that the pulse method is seldom applied in practice. The general impression among the fire service community is that it is too complicated and should be simplified. Previous field experiments with smoke cooling showed that the 3D pulse method can jeopardize the fire attack team since, although the smoke gases are cooled locally, they can heat up again behind the fire attack team. This can cause the team members to become trapped, as it were’

‘Arc’ surface cooling offers greater effect

Easier to teach and use correctly and more effective

‘More information on other possible smoke cooling methods which are also effective, and which are easier to learn is also required. Consequently, this research compares the 3D pulse method used in the Netherlands to the arc method (Surface Cooling) commonly used in the United States of America.

These methods are compared for both high pressure and low-pressure systems. Because some Dutch fire brigades are equipped with CAFS ‘OneSeven’ (Compressed Air Foam System), where foam is applied to the walls and ceiling, this extinguishing system has been included in this research as well. The effectiveness of the door procedure (Appendix 1) was also investigated’.

UK Water Stream Dispersion and Direct Attack

The principles involved in boundary or surface cooling, effective water dispersion onto walls and ceilings, and direct attack at the fire base using trimmed or solid straight streams is a strategy that disappeared in the UK during the late 1990s. However, National Guidance is demonstrating support for such a firefighting approach, and the ‘Arc’ methodology explained in the Dutch Brandweer research is about to make a return as an alternative approach in the UK fire service.

This is also quite timely, as UK rising fire main standards are considering updates to reflect the tactical need for twin outlets at every floor level (in support of firefighter physiology and tactical requirements for safety jets), 150mm mains, and solid stream branch nozzles at height demonstrating more appropriate ‘K’ Factors, but still using 51mm hose as per BDAG 2004.

Purpose-built test structure

The experiments were carried out in purpose-built structure at the Troned training centre for professional emergency services at Twente Airport in the Netherlands.

The L-shaped building has a 20-metre long, 2.5 metre high and 2-metre-wide corridor. The corridor is constructed of sand-lime bricks (walls) and concrete hollow-core slabs (roof). Halfway down the corridor there is a safety door to the outside. The short part of the L is a modified steel shipping container in which the fuel was placed. This fire room, the total dimensions of which are 2.4 x 2.4 metres, has four doors and a sliding hatch (approx. 0.4 x 0.6 m) for ventilation. A 50-cm draft stop was installed over the doors of the corridor.

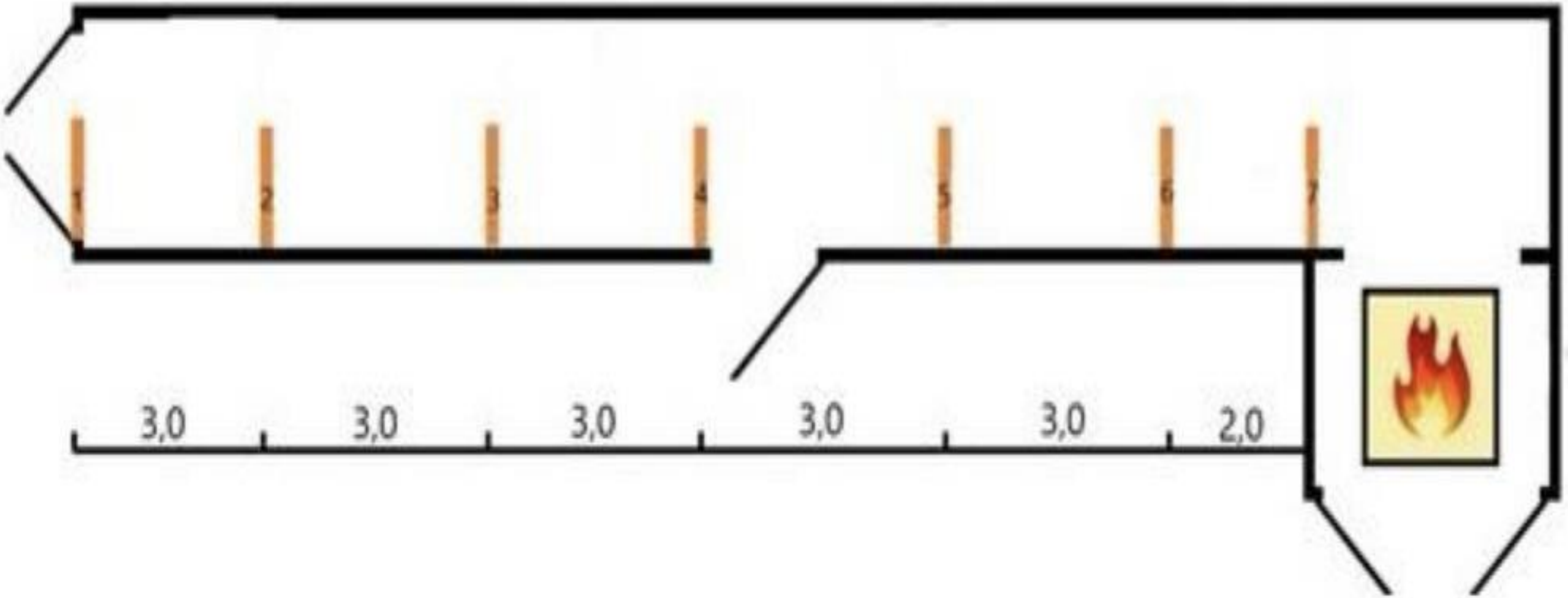


Figure 1.4 Locations of thresholds in the test location

30 metre residential corridors in UK buildings

Require an efficient and safer approach

I have written for years about wind driven corridor fires, and how firefighters may be exposed to great risk as fire intensity and velocity is doubled by a > 20-mph wind. Multiples of firefighters have been killed by such fires (all reported in my books) including eight firefighters in Leningrad (St.Petersburgh) in 1991 (Fog Attack p192-3).

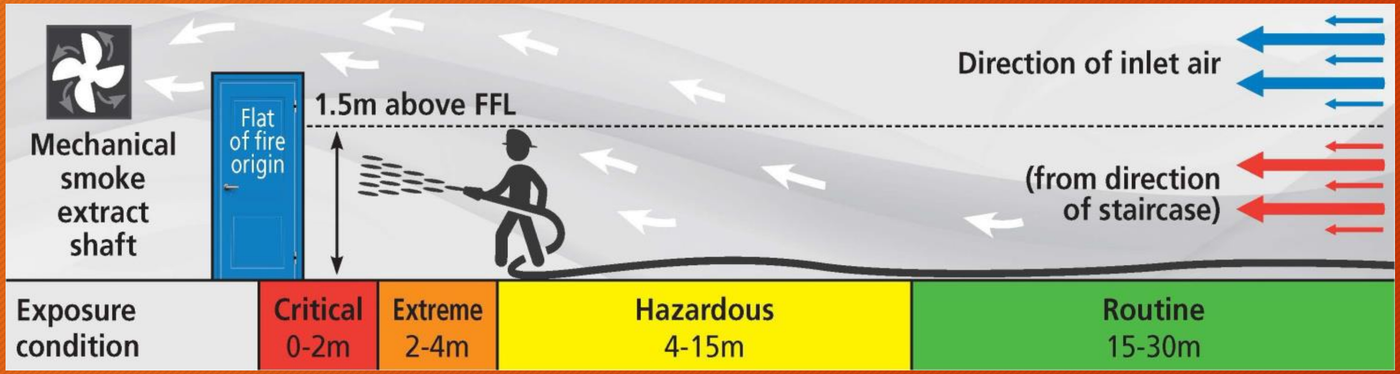
In 2001 four firefighters in Kent (UK) were almost overcome by the speed of a 22-mph wind driven fire chasing them along a corridor. The fire went on to burn though three 30-minute fire doors in less than 10 minutes.

It is here, in the 30-metre residential corridors faced by UK firefighters, where high-flow surface cooling (wall-ceiling-wall) stream applications will outperform 3D gas cooling methods of approach.

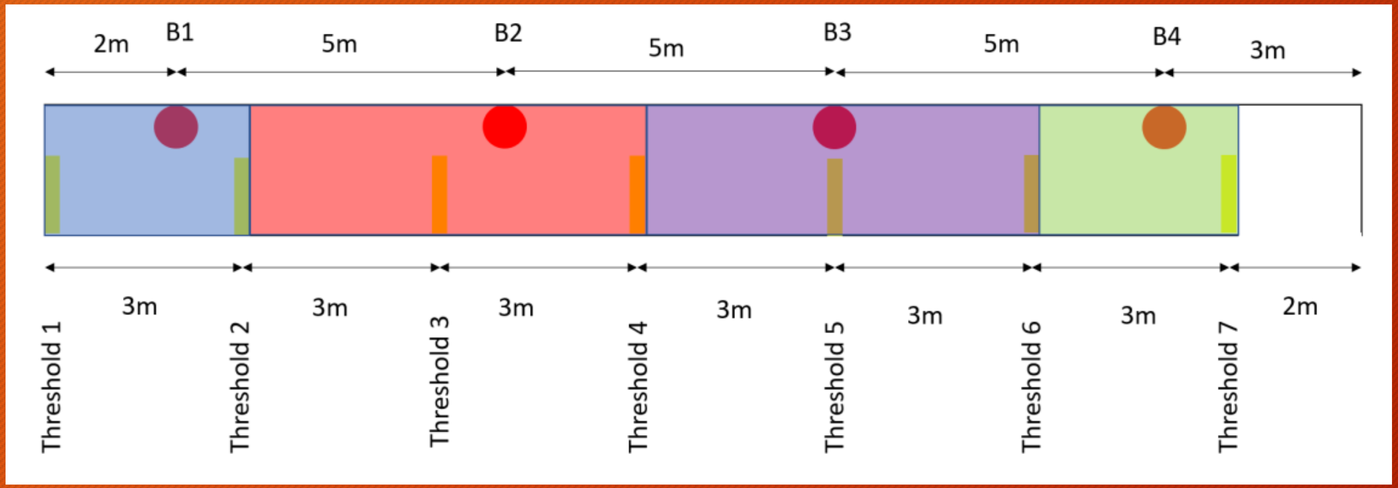
The UK Smoke Control Guide in comparison

Firefighter Safety as Maximum permissible radiation load

SCA Guide UK



Dutch Research



There are no standard methods for determining the safety conditions for fire service personnel as there are for casualties. The radiation part of the FED heat method was used to develop a formula for determining exposure(Appendix 8 Safety of fire service personnel).

This formula is based on the exposure to heat radiation according to the following tolerance (Brandweeracademie, 2016):

- Maximum radiation load of 3 kW/m2 for 20 minutes
- Maximum radiation load of 4.6 kW/m2 for 5 minutes

A FED of 1.0 is reached for both tolerances with the developed formula. The radiation measured at a height of 1.5 m was used to determine the actual exposure. This height can be considered the maximum height (top of the helmet) when progressing through the corridor in a crouched position.

6-8 MW Baseline fire for all tests

One base scenario was applied to all experiments:

A major fire in a living room (6 – 8 MW) where the door from the fire room to the corridor is open, smoke is flowing into the adjoining corridor and the front door to the residence is open; no fire attack.

This base scenario (the baseline measurement) was carried out twice (experiments 18 and 19, see table 1.2). The fire attack team was deployed during the other experiments, and they used different fire extinguishing systems and attack methods (see section 1.4 of the report (linked in this presentation).

Table 1.1 Fire extinguishing systems that were the subject of the research

Fire extinguishing system	Brand / type of extinguishing agent	Average flow rate, measured prior to the experiments	Pump pressure	Nozzle type
HP	Water	119 l/min	33 bar high pressure	Akron trigger
LP 250	Water	252 l/min	10 bar	TFT F06
LP 450	Water	433 l/min	12 bar	TFT F06
CAFS OneSeven	A-class OneSeven Addition as a percentage: 0.3%	130 l/min	9 bar low pressure 8 bar air pressure	TFT G-force fliptip

3D pulse method

The fire attack team started at the first threshold in the corridor and discharged a three-second pulse from there. The team then progressed to the next thresholds. Whenever the next threshold was reached, the team reported this to the control room to enable the progress to be recorded. A three-second pulse was discharged at each threshold, except at threshold 7. Once threshold 7 was reached, this was also reported to the control room.

Arc method

The fire attack team started at the first threshold in the corridor. The nozzle operator opened the nozzle and started making the arc pattern. While making this pattern, the team continued progressing to the seat of the fire.

Extinguishing the seat of the fire

When threshold 7 was reached, the team started extinguishing the seat of the fire in accordance with the teaching and study material. When a knock-down[3] was reached, this was reported for recording.

3D Gas Cooling .v. Surface cooling Arc method

Cooling effect in a 20-metre corridor towards the fire

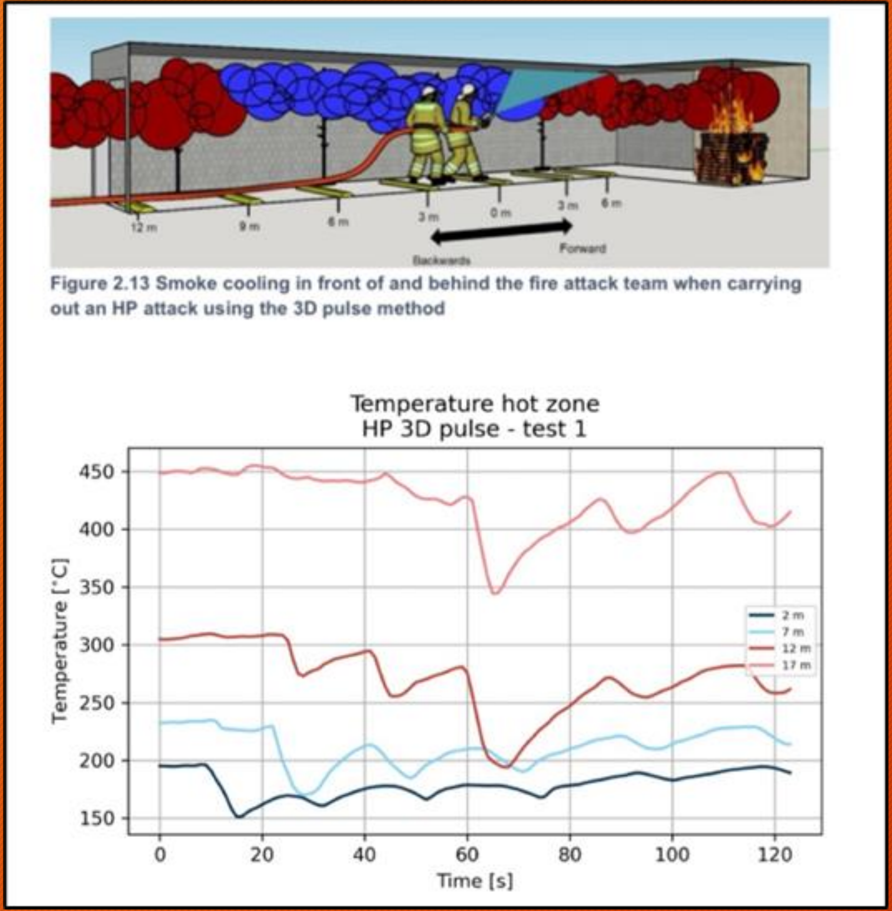


Figure 2.13 Smoke cooling in front of and behind the fire attack team when carrying out an HP attack using the 3D pulse method

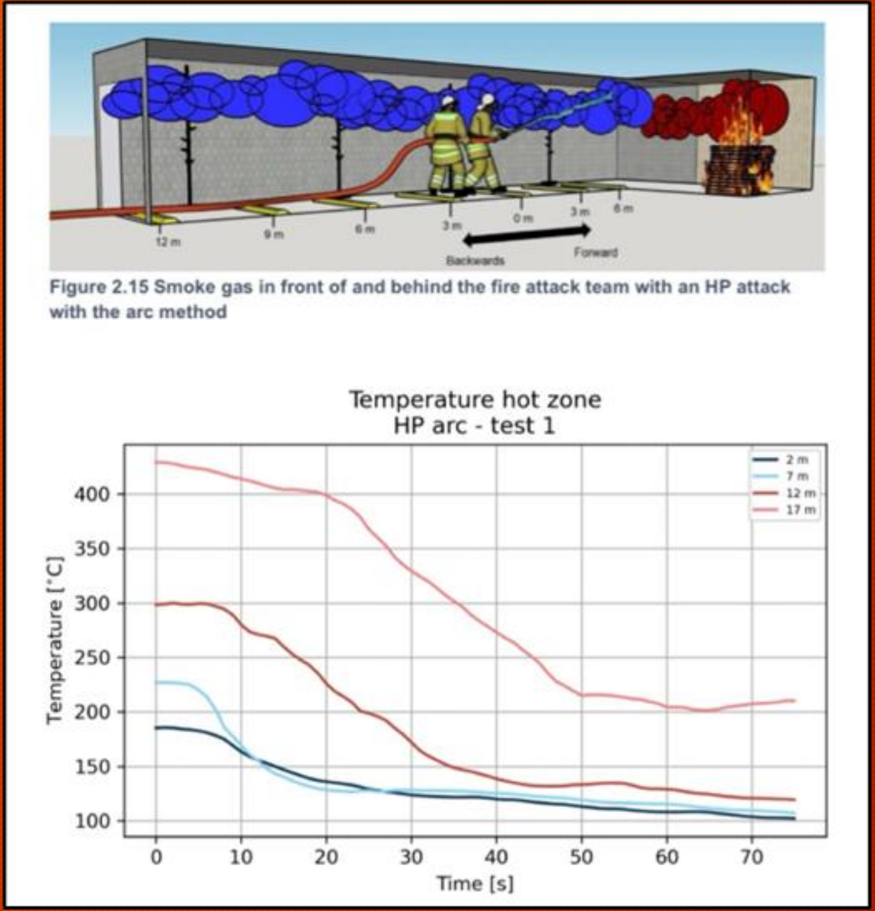


Figure 2.15 Smoke gas in front of and behind the fire attack team with an HP attack with the arc method

'The research focused exclusively on smoke cooling methods using low pressure, high pressure and CAFS OneSeven. The 3D pulse method for smoke cooling as contained in the teaching and study material was carried out during the field experiments and compared to the arc method. The arc method is an American method which has led to good results there'.

EuroFirefighter.com

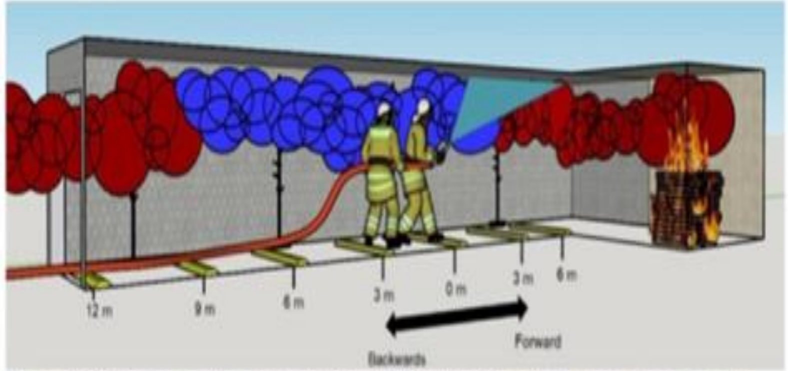
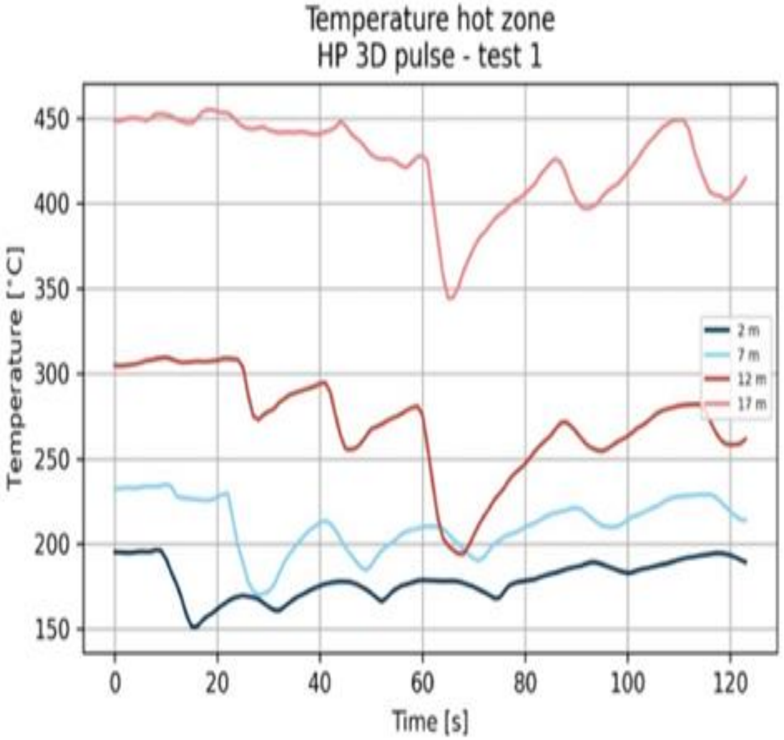


Figure 2.13 Smoke cooling in front of and behind the fire attack team when carrying out an HP attack using the 3D pulse method



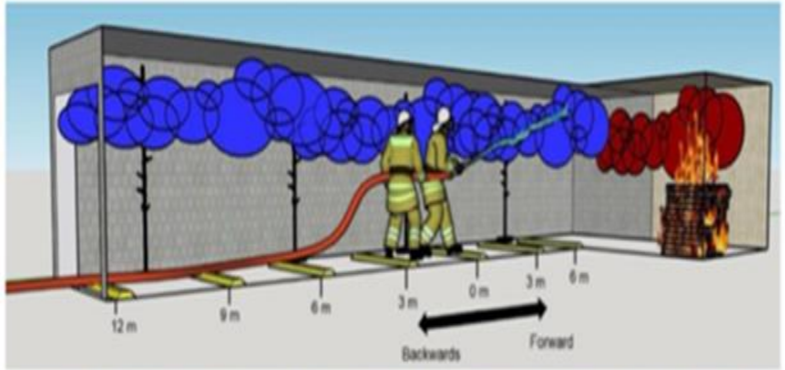
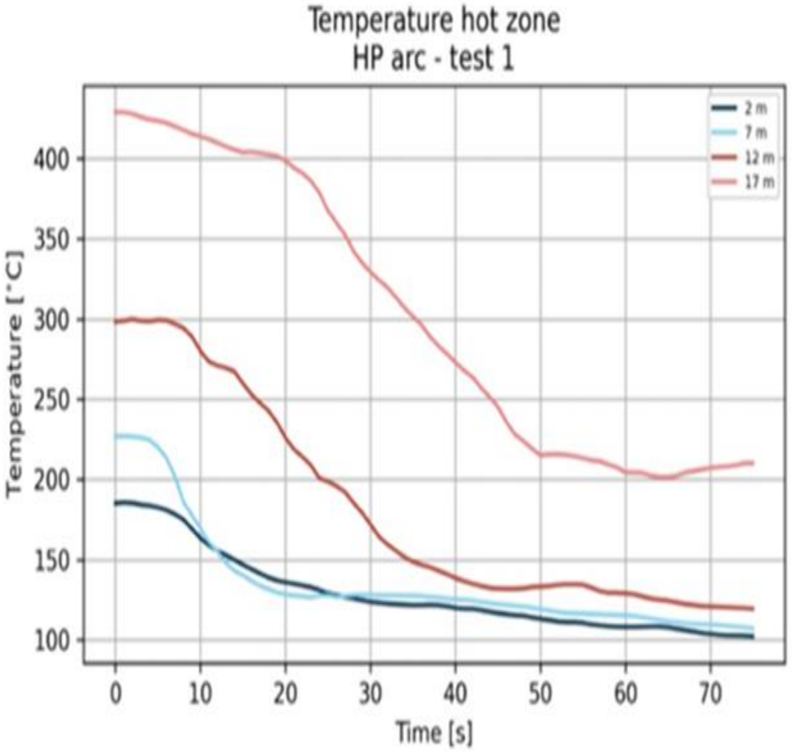


Figure 2.15 Smoke gas in front of and behind the fire attack team with an HP attack with the arc method



'The purpose of this research is to determine how, and to what extent, different smoke cooling methods (the 3D pulse method and arc method) affect conditions in a space containing a hot smoke layer (i.e. decrease temperature and energy), the seat of the fire, the safety of firefighters and any casualties while progressing to the seat of a fire in a dynamic smoke layer'

EuroFirefighter.com

3.2 Answering the main question

The main research question was:

When using either the 3D pulse method or the arc method, to which extent are smoke gases cooled and what are the effects on the seat of the fire and on the safety of firefighters and casualties when firefighters progress to the seat of the fire in a dynamic smoke layer?

Since both methods cool the smoke gases, implementing smoke cooling is always better than not attacking at all. The results of the arc method are more positive than those of the 3D pulse method, both as regards cooling up to the height and along length of the corridor, and as regards forwards and backwards cooling. The results of the arc method are also more consistent which seems to indicate that this method is easier to carry out.

The reach of forwards and backwards cooling when applying the arc method was better than that of the 3D pulse method. The time needed for the attack is also shorter when using the arc method (at least with the current test design).

All extinguishing systems and attack methods have a cooling effect on the fire room while progressing. The average scores of subjective perception of thermoregulation, discomfort and effort show that the experiments were not unduly strenuous for the teams. The attacks with LD 450 were reported to produce the most discomfort. No unsafe situations for fire service personnel arose during the experiments.

The use of the methods and extinguishing systems researched for smoke cooling did however worsen the conditions for potential casualties. This might lead to life-threatening or fatal situations for vulnerable and highly vulnerable people. In general, the arc method worsened these conditions less than the 3D pulse method, specifically in the front section of the corridor. There are significant differences between the two tests for the individual extinguishing systems in terms of survivability, indicating that the nozzle operator has a major influence on these conditions.

The analysis of the film footage has shown that, although the 3D method is the standard method taught, the arc method is easier to perform according to protocol and is less dependent on the nozzle operator.

Based on this research, it can be concluded that both the arc method and the 3D method are effective methods to cool smoke gases, but that the arc method provides more cooling, and is easier to learn and carry out.

Table 2.8 Scores for subjective perception of thermoregulation, pain and effort

Fire extinguishing system	Thermal sensation	Thermal comfort	Skin moisture	Sensation of pain	Effort perceived
HP 3D pulse method	Not hot, not cold	Neutral	Slightly moist	No pain	Extremely light
HP arc method	Slightly warm	-	Quite moist	No pain	Somewhat strong
LP 250 3D pulse method	Slightly warm	Slightly uncomfortable	Moist	No pain	Somewhat strong
LP 250 arc method	Slightly warm	Slightly uncomfortable	Moist	No pain	Very light
LP 450 3D pulse method	Hot	-	Moist	No pain	Between light and somewhat strong
LP 450 arc method	Not hot, not cold	Neutral	Moist	No pain	Somewhat strong
CAFS OneSeven arc method	Not hot, not cold	Neutral	Moist	No pain	Between extremely light and very light

Table 2.9 Attack durations until the seat of the fire was reached and water consumption

Extinguishing method	Attack time in seconds until the seat of the fire was reached	Water consumption in litres
HP 3D pulse method	90	40
HP arc method	66	135
LP 250 3D pulse method	102	70
LP 250 arc method	62	275
LP 450 3D pulse method	88	130
LP 450 arc method	78	550
CAFS OneSeven arc method	80	175

Firefighting water – 10 MW fire

	Brandweeracademie Dutch Fire Service	UK 7974-5:2014 UK Fire Service
10 MW (Qmax) Apartment Fire with 40-50% Firefighting Effectiveness	**450 L/min**	**488 L/min**
10 MW (Qmax) Apartment Fire with 40-50% Firefighting Effectiveness		0.36 x 3.6 x 1/0.3 x 8.133 x 0.15 = 5.27 MW 0.64 x 2.6 x 8.133 x 0.35 = 4.73 MW Total = **10 MW** @ 50% FF Efficiency **Requires 488 L/min (8.133L/s)**
10 MW (Qmax) Fire with 100% Firefighting Effectiveness	**225 L/min**	24.42 x 10 = **244 L/min**

When water goes up in smoke

Research into the effect of the 3D pulse method and the arc (surface cooling) method on smoke cooling

Fire Service Brandweer Academy (2021). Experimental research into the effect of the 3D pulse method and the arc (surface cooling) method on smoke cooling Arnhem: IFV.

‘When water goes up in smoke’

Experimental research into the effect of the 3D pulse method and the arc method on smoke cooling 2021

https://nipv.nl/wp-content/uploads/2022/04/20211207-BA-When-water-goes-up-in-smoke.pdf

‘Smoke cooling and nozzle techniques’

A Literature Study 2022

https://nipv.nl/wp-content/uploads/2022/10/20220925-NIPV-Smoke-cooling-and-nozzle-techniques.pdf