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The burning behaviour of sofas during smoke propagation experiments

De Brandweeracademie is onderdeel van het Instituut Fysieke Veiligheid.

Instituut Fysieke Veiligheid
Brandweeracademie
Postbus 7010
6801 HA Arnhem
www.ifv.nl
info@ifv.nl
026 355 24 00

Colofon

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Contactpersoon:	ing. R.R. Hagen MPA
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Auteur:	M.L. Leene BA
Projectleider:	ing. H.L. de Witte
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Introduction

From the 24th of June till the 5th of July, the Fire Service Academy of the Institute for Safety (IFV) has conducted smoke propagation experiments in a residential building, located in the town of Oudewater in the Netherlands. Nineteen experiments have been carried out, using the type of sofa that is most frequently sold in the Netherlands. The sofa was used as the fire load during the experiments that focused on smoke propagation.

The research focused mainly on smoke propagation but the results of the experiments also provided interesting insights into the combustion of the sofas. This report describes the effect of the different variables on the mass loss of the sofa and the peak heat release rate.

As a part of the research about the fire safety of upholstered furniture and matrasses in the domestic area (Federation of the European Union Fire Officer Associations 2017), the behaviour of (the most frequently sold) upholstered furniture (sofas) and matrasses was studied by performing impression tests in 2016 (Fire Service Academy 2017). This report about the fire and smoke behaviour of the sofas during the experiments on smoke propagation, is a follow-up to these impression tests.

Background

Smoke propagation in residential buildings with indoor corridors appears to proceed differently than could be expected, based on fire protection facilities within buildings according to the Dutch building regulations. Often, fires in residential buildings with indoor corridors lead to rapid smoke propagation throughout (different parts of) the building. Caused by a rapid development of the fire, smoke can spread to other floors by shafts, cracks and ventilation channels. Also, there is a difference between measures being taken to prevent smoke propagation, according to the objectives of fire safety regulations and their actual effect. Often the objectives of fire safety regulations are not achieved in practice, in case of smoke propagation (Brandweeracademie & Brandweer Nederland, 2017).

Often both self-reliant and less- or non-self-reliant people live in residential buildings with indoor corridors. Especially the less- or non-self-reliant people are at risk in case of a fire and smoke propagation. They have problems with escaping quickly and without help from others. Smoke that has spread can cause inhalation problems and block escape routes, preventing people from escaping. Often, large-scale evacuation is needed in case of a fire in a residential building, because of smoke propagation throughout the building. The situation described above can lead to an enormous and acute incident and an almost impossible task for the fire service.

Research objective

Little is known about the effects and effectiveness of different methods for evacuation and firefighting against smoke propagation. By doing experiments, the Fire Service Academy of the IFV wanted to gain insight into smoke propagation, the ability to escape and the survivability during the fire, and firefighting in a residential building with indoor corridors. The experiments allowed us to examine the actual effects of specific fire prevention measures in buildings on smoke propagation and fire development. The results of these experiments can lead to a substantiated policy concerning fire safety and methods of action for the fire service in case of fires in these types of buildings.

1 Research method

1.1 The fire scenario

The scenario that is central to this research, is a fire that starts in an object in the living room of an apartment in a residential building with indoor corridors, during the night (i.e. an imitated nocturnal situation). This scenario is based on a previous study done by the Fire Service Academy of the Institute for Safety (Fire Service Academy, 2015). This scenario was also useful to gain insight into fire development, smoke propagation when applying different variables and the effect of various methods used by the fire service.

The decision to use a sofa as the object in which the fire originated, was based on research conducted by the Institute for Safety/Fire Service Academy and others over the last years. The research of the Fire Service Academy shows that fatal residential fires in the Netherlands and Europe often (25%) start in upholstered furniture and mattresses in the living room or (living-/) bedroom (Brandweeracademie, 2018). To be able to make reliable comparisons, one object (a sofa) was chosen that is representative of a common housing interior. The choice not to put other furniture or combustible material in the room was made because we know that – in recent years – more and more fires are limited to the object of origin, because of a lack of oxygen in the compartment. Therefore, a single sofa is the only combustible object in the room, creating a scenario in which no other object can ignite (Brandweeracademie, 2018; Fire Service Academy, 2015).

The fire load of the sofa (fuel for the fire) consists mostly of polyurethane foam. It is to be expected that toxic and irritating smoke gasses will be generated by the fire, as well as large amounts of soot. How much soot will be produced, depends on the amount of burned material (which results in mass loss), on the conditions in the fire room during the experiments and on the different tactics used by the fire service.

1.2 Characteristics of residential buildings

There are three main types of residential buildings: portico apartments (with a single staircase to which the individual front doors open), gallery flats (with an open or closed gallery) and apartments with an indoor corridor. The building in which the smoke propagation experiments were held, is a former residential care complex, located in Oudewater in the province of Utrecht. It is a building of the third type (apartments with indoor corridor), of which the indoor corridors are an important feature in relation to fire safety. Over the last years several practical examples showed risks, related to fire safety and smoke propagation in this type of building. Relatively small fires can produce a lot of smoke which can spread through the indoor corridor and throughout the building. The escape route of the residents is also located inside the building, which means that it may be filled with smoke during a fire. The front doors of each apartment within the building open to an indoor corridor, which leads to staircases on both sides of the corridor. Therefore, it is possible that in case of a fire in an apartment, smoke can spread through the indoor corridors, throughout the building. The building in Oudewater has four floors, which all have indoor corridors. Figure 1.1 shows a photograph of the building.

Figure 1.1: Residential building in Oudewater in which the experiments took place

In the part of the building that has been used for the experiments (situated on the first floor), apartments with the front door opening onto the indoor corridor are located on both sides of the corridor. Each apartment within the building – all previously used to house one person and consisting of a small hallway and one room – has a second door opening to a balcony on the opposite side of the front door. This layout is representative for many residential buildings in the Netherlands, although the amount of rooms and room size per apartment can vary. After entering an apartment through the front door, a small hallway leads directly to the main combined living and sleeping room. Figure 1.2 shows the floor plan and the two rooms where the experiments took place (fire rooms).

Figure 1.2: Map of the first floor, with fire rooms

Figure 1.3 below shows the indoor corridor on the first floor.

Figure 1.3 Indoor corridor on the first floor

1.3 Fire rooms

The experiments took place in the living/bedroom of two apartments, hereafter referred to as fire rooms; the fires were started here. The rooms were carefully selected to obtain reliable and comparable results. The structure of the rooms, as well as the building itself, were intact, and fire safety measures according to the building regulations from 2012 were in place. The two fire rooms were identical in terms of layout. The rooms were used alternately: the first experiment (in the morning) took place in one fire room and the second experiment (in the afternoon) in the other. This was done to minimize the chance that the results of the afternoon experiments were affected by heat or other remains from the previous experiment. Figure 1.4 shows one of the fire rooms before preparation.

Figure 1.4 Picture of one of the fire rooms

1.4 Preparation for practical research

1.4.1 Preparation of the fire rooms

Before the experiments took place, the two fire rooms were emptied and all flammable material removed, in order to create the same starting situation in each room and to make sure no other combustible material would influence the results of the experiments.

The sofa was put in a corner of the room, against the wall of the bathroom and the adjacent apartment. This was done to ensure a quicker spread of the fire, as compared to that of a fire starting in an object standing in the middle of the room. The sofa was placed on top of a scale, to measure the mass loss of the fire load during the fire. During the fire development, the mass loss of the sofa was measured over time, resulting in a fire growth curve of the peak heat release rate. The scale was calibrated in advance to be able to determine the mass loss of the sofa for each scenario. The mass of the sofa before ignition of the fire was circa 86 kilograms (kg); this is the 'starting weight'. Measurements of the mass loss rate and measurements of smoke gasses during each test provide insight in the release of various smoke gasses and other products of combustion over time. The prepared fire rooms are shown in figure 1.5.

Figure 1.5 Prepared fire room with the fire load in place

1.4.2 Deployment tactics and other variables

During two weeks, nineteen experiments took place. Each day an offensive and a defensive interior (fire fighting) attack were conducted, except for the baseline measurements in which no deployment tactic was applied. For each experiment, the fire was ignited in the right corner of the seating of the sofa, close to the backrest.

The experiments were divided into two timeslots. During the first phase the influence of the presence or absence of fire protection measurements was determined, as well as their efficiency. The measurements that were used where: a standard smoke resisting door, a smoke resistant separation/door and a mobile water mist system. In two scenario's the mobile water mist system and the separation were both used.
Each scenario within this phase lasted for 20 minutes after the fire was ignited. These 20 minutes were based on the time it takes to detect and report a fire, including the time needed by the fire service to arrive and prepare for deployment.

The second phase started after 20 minutes, following immediately after the first phase. In second phase, the effect of the deployment tactics of the fire service on smoke propagation were studied. As has been mentioned above, two different deployment tactics were used. The first tactic was the offensive interior attack, which means that the fire was attacked in the compartment where it started. This implied that the front door was opened by a member of the fire service (or it was already opened) who entered the apartment with a fire hose and extinguish the fire. The second tactic was the defensive interior attack. This attack is deployed to prevent the fire and smoke from propagating outside the compartment by maintaining or resorting the fire-resistant separation/wall, in this case a door. The fire service first closed the front door of the fire room – which had been left open by escaping residents (i.e. a member of the crew), in case of a scenario with an open door – and evacuated other (virtual) residents, before attacking the fire. Two other tactics, the offensive exterior attack and the defensive exterior attack were not applied in the experiments.

Another variable was the ventilation profile of the apartment as part of the residential building. The front door opened or closed were the two different scenarios for the ventilation profile, except for the scenario maximum ventilation[1] (Fire Service Academy, 2015). These scenarios are further explained in the following chapter of this report. In the first scenario, the front door was opened by 'an escaping resident', represented by a member of the crew. This was done 5 minutes after the ignition of the fire. In the scenario 'door open', the front door was left open during the time the experiment lasted. The fire was ignited at t=0. In the second scenario ('door closed') the front door was opened 5 minutes after the ignition of the fire and closed 0.5 minutes after opening it (t=5.5 minutes). The door remained closed until the fire fighters entered the fire room. Each experiment continued for 55 minutes.

In order to achieve reliable results, each scenario and deployment tactic was performed according to a predetermined protocol. In addition, each scenario was executed twice, before the start of the second phase (deployment by the fire fighters).

In the appendix, an overview of all experiments and scenarios is shown.

[1] The importance of the position of the front door is based on previous fire experiments in Zutphen and observations during fires in residential building in daily practice.

2 Burning behaviour during the tests

In this chapter, a description of each experiment, including the scenario and the applied deployment tactic are being discussed, as well as the effect on the mass loss of the sofa and the peak heat release rate. The peak heat release rate is estimated based on the peak mass loss rate. The mass loss rate is multiplied by the net heat of combustion of polyurethane for the used sofa, this is 25 MJ/kg and wood for the organic fire load this is 17.5 MJ/kg (SFPE, 2016, pt. table a.31 & a.32). The mass loss rate of the sofa during the fire was measured with a scale. The total weight loss measured by the scale was compared with pictures of the sofa after the fire. During a few tests the scale did not give reliable results. For instance, because water from the water mist system added weight to the sofa. The mass of the parts that were burned away were determined by looking at the sofas.

The sofa consists of many different materials which all have a different net heat of combustion. In order to get a first estimation of the peak heat release, the values in this report are only based on the combustion of polyurethane.

2.1 Scenarios with the door of the fire room opened

2.1.1 Baseline measurements

On the first experiment day, baseline measurements were conducted in order to be able to compare the results of the different scenarios. In addition, the baseline measurement can give insights into the effects of deployment tactics of the fire service, compared to ‘doing nothing’. For conducting the baseline scenario, the front door of the fire room was opened 5 minutes after the ignition of the fire and remained open during the experiment. No deployment tactic was used, so as measure the fire and smoke development without any intervention. The mass loss of the sofa was 17-18 kg. The peak heat release rate was approximately 1.3-2.0 MW (Megawatt). The peak heat release rate is calculated by mass loss rate multiplied by the net combustion value of polyurethane. This is a first estimation, purely based on the combustion of polyurethane. Pictures of the sofa are shown in figure 2.1.[2]

[2] All pictures are taken by the fire fighters after deployment.

Figure 2.1 Pictures of the sofa after the first baseline measurement

Another baseline measurement took place during the second experiment week.
Again, the front door was opened and there was no deployment by the fire service that could influence the growth of the fire during the experiment. The mass loss of the sofa was circa 28-29 kg. The peak heat release rate was 2.8-3.5 MW. Figure 2.2 shows the remains of the sofa.

Figure 2.2 Pictures of the sofa after the second baseline measurement

2.1.2 Other scenarios with the door of the fire room opened

As has been mentioned in the previous chapter, two other experiments were conducted with the front door opened, one with a defensive interior attack, the other with an offensive interior attack. First the defensive interior attack will be described.

In each scenario with an open door and deployment by the fire service, the door was opened 5 minutes after the ignition of the fire, when the member of the crew who had ignited the fire left the fire room. The door was closed by the attack crew 20 minutes after the start of the fire. The fire room was entered by the crew, 37,5 minutes after the start of the fire. It has not been recorded for the defensive scenarios when the fire was extinguished, because the exact time was unknown when the fire was extinguished before the crew entered the room. The mass loss of the sofa was approximately 18-19 kg. The peak heat release rate was approximately 1.5-2.0 MW. The second scenario led to more rapid fire progress, compared to the first experiment of the day. The pictures in figure 2.3 show that the sofa is more combusted, resulting in a lower weight of its remains.

Figure 2.3 Pictures door open, defensive interior tactic

During the experiment with the door open and an offensive interior attack, the mass loss of the sofa was 15-25 kg. Due to failure of the scale no reliable data of the mass loss rate is available. The mass loss over time is estimated on the pictures and scale measurements before and after. The pictures in figure 2.4 show the remains of the sofa in the fire room and after it has been removed and taken outside.

Figure 2.4 Pictures door open, offensive interior tactic

In the scenarios with the front door open, all sofas were mostly burnt. Table 2.5 gives an overview of the mass loss and peak heat release rate.

Table 2.5 Overview of the mass loss and peak heat release rate during the scenarios with the door of the fire room opened

Day	Test	Measures	Mass loss [kg]	Peak heat release rate [MW]
1	1	Baseline + front door opened	17 – 18	1.3 – 2.0
2	3	Front door opened	18 – 19	1.5 – 2.0
3	5	Front door opened	15 – 25 *	-
9	17	Baseline + front door opened	28 – 29	2.8 – 3.5

*no peak heat release rate known due to failure of the scale measurements

2.2 Scenarios with the door of the fire room closed

2.2.1 Scenarios with a standard front door closed

Two scenarios have been conducted in order to measure the effect of a closed standard front door on the fire spread and – most important – the effect on the smoke propagation. In the first scenario, the front door was opened and closed again by 'an escaping resident', represented by a member of the crew. This was done 5 minutes after the ignition of the fire. After t=5,5 the door was closed until the crew started the offensive interior attack. The front door was opened by the fire fighters 21,5 minutes after the ignition of the fire. After 22 minutes the fire fighters reported 'fire out'. The mass loss of the sofa was approximately 5-10 kg. Figure 2.6 shows pictures of the sofa after this experiment.

Figure 2.6 Pictures door closed, offensive interior attack

The scenario ‘door closed’ with a defensive interior tactic resulted in a mass loss of approximately 6-8 kg. Figure 2.7 shows the pictures of the sofa that were taken after this experiment.

Figure 2.7 Pictures of the sofa after defensive interior tactic with door closed

One of the experiment days, an experiment from the first day had to be repeated, because at the time the measurements of temperatures had failed. As this did not affect the combustion of the sofa, the pictures taken after the initial experiment are shown in this report (figure 2.8). The scenario with the offensive interior attack was repeated with the front door closed. The mass loss was approximately 8-9 kg and the peak heat release rate 1.2-1.6 MW.

Figure 2.8 Pictures of the sofa after offensive interior attack with door closed

2.2.2 Scenarios with a smoke-resistant separation and the door of the fire room closed

One of the experiment days, a smoke-resistant separation/door was used. Both experiments of that day took place with the front door closed (except for its opening the door at t=5), in order to test the effectiveness of the separation. During the first experiment an offensive interior attack was carried out, starting 21,5 minutes after the fire was ignited. The fire was extinguished in circa 24 minutes after its ignition. The mass loss of the sofa was approximately 7-8 kg, and the peak heat release rate approximately 0.-1.3 MW. Figure 2.9

shows a picture of the sofa, taken after this experiment with a smoke-resistant door and an offensive interior attack.

Figure 2.9 Effect of smoke-resistant separation, offensive interior attack

During the other experiment, a defensive interior attack was used. 35 minutes after the start of the fire, the crew entered the room and extinguished the fire. The mass loss of the sofa was approximately 6-7 kg, and the peak heat release rate 0.9 - 1.3 MW. Figure 2.10 shows pictures of the sofa, taken after this experiment.

Figure 2.10 Effect of smoke-resistant separation, defensive interior attack

2.2.3 Overview scenarios with a closed door

In comparison to the experiments with an open door, the sofas are less combusted with the door closed. Table 2.11 provides an overview of the different scenarios with the front door closed.

Table 2.11 Overview scenarios with the door of the fire room closed

Day	Test	Measures	Mass loss [kg]	Peak heat release rate [MW]
2	2	Front door closed	5 – 10 *	-
3	4	Front door closed	6 – 8 *	-
7	12	Smoke RS + front door closed	7 – 8	0.9 – 1.3
	13	Smoke RS + front door closed	6 – 7	0.9 – 1.3
9	16	Front door closed	8 – 9	1.2 – 1.6

*no peak heat release rate known due to failure of the scale measurements

2.3 Scenarios with a maximum ventilation

The scenario with a maximum ventilation was executed with the front door of the fire room opened, as well as the door to the balcony on the opposite side of the room. These open doors let more oxygen into the room, which influenced the growth of the fire and the combustion of the sofa.

An offensive interior attack was applied during the first experiment. The balcony door was opened at the moment the fire was ignited. After 5 minutes the front door was opened as well, and remained open during the 50 minutes the experiment lasted. 21,5 minutes after the ignition, fire fighters entered the room and started to extinguish the fire. The signal 'fire out' was reported circa 1,5 minutes later. The mass loss of the sofa was 51-52 kg; the peak heat release rate was approximately 2.5-3.5 MW. Figure 2.12 shows the remains of the sofa after this experiment.

Figure 2.12 Maximum ventilation, offensive interior tactic

During the second experiment of the day, a defensive interior attack was carried out. The balcony door was open from the start, while the front door was opened five minutes after the ignition of the fire; it remained open until the end of the experiment. The fire fighters entered the fire room after 20 minutes and then closed the front door and the balcony door. 35 minutes after ignition, the fire fighters entered the fire room again and extinguished the fire. The mass loss was approximately 59-60 kg and the peak heat release rate 2.5-3.5 MW. Figure 2.13 shows the remains of the sofa after this experiment.

Figure 2.13 Maximum ventilation, defensive interior tactic

It is clear from figures 2.12 and 2.13, the sofas were almost completely combusted during both experiments with maximum of ventilation, resulting in a greater mass loss and higher peak heat release rates. Table 2.14 provides an overview of the results.

Table 2.14 Overview of the scenarios with a maximum ventilation

Day	Test	Measures	Mass loss [kg]	Peak heat release rate [MW]
10	18	Maximum ventilation + front door and balcony door opened	51 – 52	2.5 – 3.5
	19	Maximum ventilation + front door and balcony door opened	59 – 60	2.5 – 3.5

2.4 Scenarios with a mobile water mist system

During six experiments, a mobile water mist system was used. This is a standalone application and acts as an automatic suppression system that activates itself on by a smoke and temperature detector. The effect of the mobile water mist system on the fire and smoke development was tested.

No mass loss rate (and therefore also no peak heat release rate) is known for the scenarios with a mobile water mist system, because the measurements of the mass loss rate where affected by mist of the water of the water mist system. The total mass loss is estimated on the pictures and scale measurements before and after.

In the scenario of the first experiment of the day the door was closed and an offensive interior attack was carried out. 21,5 minutes after the start of the fire the crew entered the fire room through the front door and started to extinguish the fire; 30 seconds later, it was extinguished. The mass loss of the sofa after the experiment was approximately 1-5 kg. The pictures in figure 2.15 show the sofa after the experiment.

Figure 2.15 Effect mobile water mist system, offensive interior attack, door closed

In the second experiment of the day, again a mobile water mist system was used and a defensive interior attack tactic was carried out. The front door was opened 5 minutes after the ignition of the fire. 35 minutes after the start of the fire a fire hose was used to extinguish the fire. The mass loss of the sofa was approximately 10-20 kg. Figure 2.16 shows the pictures of the sofa that were taken after this experiment.

Figure 2.16 Effect mobile water mist system, defensive interior tactic, door open

On the fifth experiment day, a mobile water mist system was used again. During the first test, the front door was closed and a defensive interior attack carried out. The mobile water mist system activated itself in approximately 2 minutes after the fire was ignited. 35 minutes after the igniting the fire the crew entered the fire room. The mass loss of the sofa was approximately 1-5 kg. Figure 2.17 shows the pictures of the sofa after this experiment.

Figure 2.17: Effect mobile water mist system, defensive interior tactic, door closed

An offensive interior attack was deployed during the second experiment of the day. The front door was open. The mass loss of the sofa was approximately 10-20 kg. In figure 2.18 the pictures of the sofa taken after this experiment are shown.

Figure 2.18 Effect mobile water mist system, offensive interior tactic, door open

On the sixth day, a smoke-resistant separation was used, as well as a mobile water mist system. During both experiments, the front door was closed to be able to test the effectiveness of the combination of the smoke-resistant separation and the water mist system.

In the first experiment the deployment tactic was offensive. 21,5 minutes after the ignition of the fire, the fire fighters entered the fire room through the front door and started their offensive attack, resulting after 30 seconds in the extinguishment of the fire. The mass loss of the sofa was approximately 1-3 kg. Figure 2.19 shows the pictures of the sofa.

Figure 2.19 Effect smoke-resistant separation and mobile water mist system, offensive interior tactic

In the second experiment of the day a defensive attack was carried out. The mass loss of the sofa was approximately 1-5 kg. Figure 2.20 shows the pictures of the sofa, taken after this experiment.

Figure 2.20 Effect smoke-resistant separation and mobile water mist system, defensive interior tactic

Table 2.21 provides an overview of the scenarios in which the mobile water mist system was used. No mass loss rate is known, because the measurements of the mass loss rate where affected by mist of the water of the water mist system. The mass loss over time is estimated on the pictures and scale measurements before and after.

Table 2.21 Overview of the scenarios with the mobile water mist system

Day	Test	Measures	Mass loss [kg]	Peak heat release rate [MW]
4	6	Mobile water mist + front door closed	1 – 5 *	-
	7	Mobile water mist + front door opened	10 – 20 *	-
5	8	Mobile water mist + front door closed	1 – 5 *	-
	9	Mobile water mist + front door opened	10 – 20 *	-
6	10	Mobile water mist + smoke RS + front door closed	1 – 3 *	-
	11	Mobile water mist + smoke RS + front door closed	1 – 5 *	-

* no peak heat release rate known due to weight measurements affected by the water mist system

2.5 Scenarios with an organic fire load

In addition to the experiments with a sofa as fire load, in two experiments an organic fire load, consisting of dried wood was used. The dried wood was used as an imitation of an old sofa of approximately 1980. In these experiments, the organic fire load (and smoke development) was compared to the 'modern' sofa. The organic fire load was placed in the same corner of the fire room as the sofa in the previous experiments. The pieces of wood were stacked according to a predetermined pattern. Except for the fire load, the deployment tactics and scenarios were the same as in the experiments discussed earlier in this report.

First, the scenario with a closed front door and an offensive interior attack was used. The starting weight of the organic fire load was circa 21.7 kg. After 21,5 minutes the fire fighters entered the fire room and in less than 1 minute the fire was extinguished. The mass loss of the organic fire load was approximately 5-6 kg, and the peak heat release rate 0.1-0.2 MW. The pictures of the remains of the organic fire load are shown in figure 2.22.

Figure 2.22 Effect of organic fire load, offensive interior tactic

During the second experiment of the day, the front door was open and a defensive interior attack was carried out. The starting weight of the organic fire load was 22.1 kg. The mass loss of the organic fire load was approximately 11-12 kg; the peak heat release rate was approximately 0.2-0.35 MW. The pictures of the remains of the organic fire load are shown in figure 2.23.

Figure 2.23 Effect organic fire load, defensive interior tactic

Table 2.24 provides an overview of the results of the two experiments with an organic fire load.

Table 2.24 Overview of the experiments with an organic fire load

Day	Test	Measures	Mass loss [kg]	Peak heat release rate [MW]
8	14	Organic fire Load + front door closed	5 – 6	0.1 – 0.2
	15	Organic fire load + front door opened	11 – 12	0.2 – 0.35

3 Summary

In table 3.1 an overview is of all experiment is shown, including the mass loss and the peak heat release rate for the different scenarios.

Table 3.1 Overview of experiments and results

Day	Objective experiment day	Front door open/closed	Smoke resistant separation	System	Tactics	Mass loss (kg)	Peak heat release rate (MW)
1	Baseline measurement	Open	No	No	No deployment	17-18	1.3-2.0
2	Effect door	Closed	No	No	Offensive	5-10*	-
		Open	No	No	Defensive	18-19	1.5-2.0
3	Effect door 2	Closed	No	No	Defensive	6-8*	-
		Open	No	No	Offensive	15-25*	-
4	Effect water mist system	Closed	No	Yes	Offensive	1-5*	-
		Open	No	Yes	Defensive	10-20*	-
5	Effect water mist system 2	Closed	No	Yes	Defensive	1-5*	-
		Open	No	Yes	Offensive	10-20*	-
6	Smoke resistant separation + water mist system	Closed	Yes	No	Offensive	1-3*	-
		Closed	Yes	No	Defensive	1-5*	-
7	Effect smoke resistant separation	Closed	Yes	No	Offensive	7-8	0.9-1.3
		Closed	Yes	No	Defensive	6-7	0.9-1.3
8	Organic fire load	Closed	No	No	Defensive	5-6	0.1-0.2
		Open	No	No	Offensive	11-12	0.2-0.35
9	Spare test and baseline	Closed	No	No	Offensive	8-9	1.2-1.6
		Open	No	No	No deployment	28-29	2.8-3.5
10	Maximum ventilation	Open	No	No	Offensive	51-52	2.5-3.5
		Open	No	No	Defensive	59-60	2.5-3.5

* no peak heat release rate known for this scenario due to failure of the scale measurements or use of the water mist system

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Appendix: An overview of the experiments

Day	Objective test day	Test	Effect prevention facilities on smoke propagation			Effect deployment tactics on smoke propagation
			Door to escape route open/closed	Smoke-resistant separation	Sprin-kler	Tactics
1	Day for media and VIPS	1	Open	No	No	No deployment (baseline measurement)
2	Effect door	2	Closed	No	No	Offensive interior
		3	Open	No	No	Defensive interior
3	Effect door 2	4	Closed	No	No	Defensive interior
		5	Open	No	No	Offensive interior
4	Effect water mist system	6	Closed	No	yes	Offensive interior
		7	Open	No	yes	Defensive interior
5	Effect water mist system	8	Closed	No	Yes	Defensive interior
		9	Open	No	Yes	Offensive interior
6	Effect smoke-resistant separation + sprinkler	10	Closed	Yes	Yes	Offensive interior
		11	Closed	Yes	Yes	Defensive interior
7	Effect smoke-resistant separation	12	Closed	Yes	No	Offensive interior
		13	Closed	Yes	No	Defensive interior
8	Organic fire load[3]	14	Closed	No	No	Defensive interior
		15	Open	No	No	Offensive interior
9	Spare test and baseline measurement	16	Closed	No	No	Offensive interior
		17	Open	No	No	No deployment
10	Maximum ventilation	18	Open	No	No	Offensive interior
		19	Open	No	No	Defensive interior

[3] A test in which the fire load (dried wood) of a sofa of approximately 1980 will be compared to the fire load (and smoke development) of a modern sofa. dried wood was used as an imitation of an old sofa of approximately 1980