How long does search & rescue take?

1 Introduction

For some years now, the fire service has been studying fire behavior more closely. Up until 10 years ago, knowledge of fire behavior consisted of flashover and backdraft. A fire development curve was taught in training, but there was no real understanding of the time frame of this curve. Firefighters often did not know whether the time for flashover to occur was 3 minutes, 30 minutes or 3 hours.

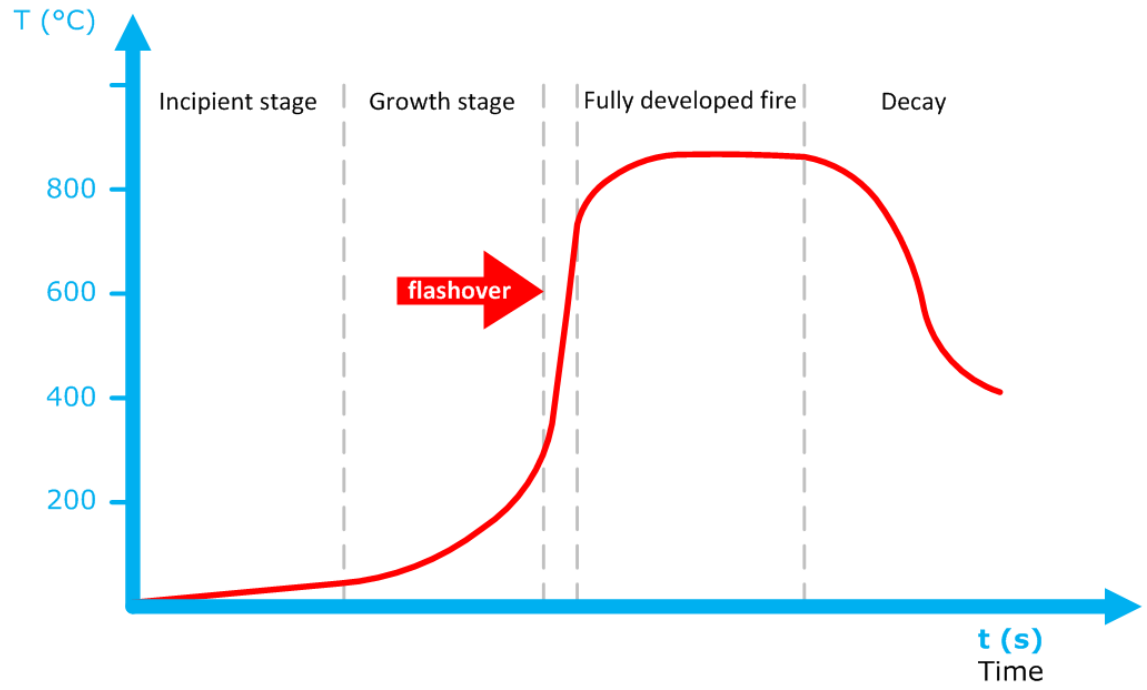

figure 1 The traditional fire growth curve. Nowadays this is defined as the ventilated fire development. The Y axis has several different temperature indications. However, the X axis has nothing. There are no numbers indicating different time units. *(Figure: Karel Lambert)*

Some people understood that this time frame was evolving. It seemed as though fire was developing faster and faster. Steve Kerber has studied this phenomenon extensively. He furnished a living room using modern day furniture and then set it on fire. Then he did the same with using a room with furniture from the '50s. He found that the time to flashover (incipient and growth stage from figure 1) for modern furniture was somewhere between 2 and 4 minutes. For a living room from the '50s, this was 30 minutes. That is a very important difference that determines how we fight fires.

In the past, the creed was "First we rescue, then we put the fire out". This makes sense when you have 30 minutes to perform a search & rescue. Because fire development changed so drastically, the creed has changed to "First put the fire out".

We now know more about fire behavior and we understand it better as well. We can put a number on the time to flashover. We cannot however, put a figure on how long it takes to search a room. Likewise we do not really know what the differences are between

various searching methods. In the past, this did not really matter much either. After all, there was plenty of time to get the search done. Now that fire is progressing faster, it becomes more and more important to understand how quickly crews search a room. Commanding officers can then assess how many crews they need to search a given building.

In July of 2017, experiments were done in Oostkamp to gain insight into search & rescue methods. *How long does it take to search a room? Which methods are efficient and which aren't?*

2 The experiments

2.1 The participants

Experiments were conducted two days in a row: on Friday and Saturday. That way, both career and volunteer firefighters were able to participate. Firefighters from 12 different Flemish fire departments, the fire service of Brussels and from the Netherlands participated in the trials. In total, there were 88 firefighters forming 44 duo's or two man crews. The participants also made a good representation of the average firefighter manning a fire engine in Belgium and performing the search & rescue on the fire ground. This was concluded because of the following reasons:

- Age of the participants ranged from 21 to 62 years.
- The number of years in the fire service ranged from 1 to 33.
- Height of the firefighters ranged from 1m68 to 1m98.
- Weight of the firefighters ranged from 57 to 118 kg.
- The BMI ranged from 18 to 36.
- About one third of the participants was a career firefighter.
- There were participants from busy stations, as well as from stations where there aren't that much fire calls.
- There were firefighters who regularly trained in live fire conditions, as well as people who rarely got the opportunity to do so.

2.2 How the tests were conducted

Each two man crew had to go through a test battery consisting of eight experiments. After each test there was a period for resting. These rests varied in time and there were drinks, snacks and fruit made available so that everyone could sufficiently recover in between experiments. This was necessary so that the different tests could be compared to one another.

Each test started with a briefing. The briefing was printed out on paper so that each crew got exactly the same information. The goal was to simulate a smoke filled environment in which the firefighters would operate. To achieve the lack of visibility, participants were

blindfolded. This would render them unable to see anything at all. Secondly, the goal was also to simulate a modern approach in which firefighters are crouched or in a low stance close to the floor. So the participants were instructed to keep at least one knee on the floor at all times.

Before the test started, relevant information was collected: pressure of the breathing apparatus, heart rate and oxygen saturation. The participants had to signal whether they had sufficiently recovered from the previous exercise.

Next, the crew had perform an exercise in full turnout gear and BA while blindfolded. In seven of the eight tests, this was a search & rescue action. The last experiment consisted of advancing an attack line towards a fire.

After they had completed a test, BA pressure, heart rate and O^2 saturation was measured again. Participants had to indicate how the exercise went for them: *How hard was the exercise for you?*

2.3 Seven search & rescue experiments

Seven different rooms were made using temporary construction fences. These fences were also covered with plastic tarp so that people could not see what the setup of the room was from the outside. Also, additional wall were built so that participants could not look inside from door openings to get an idea of the situation before starting their test.

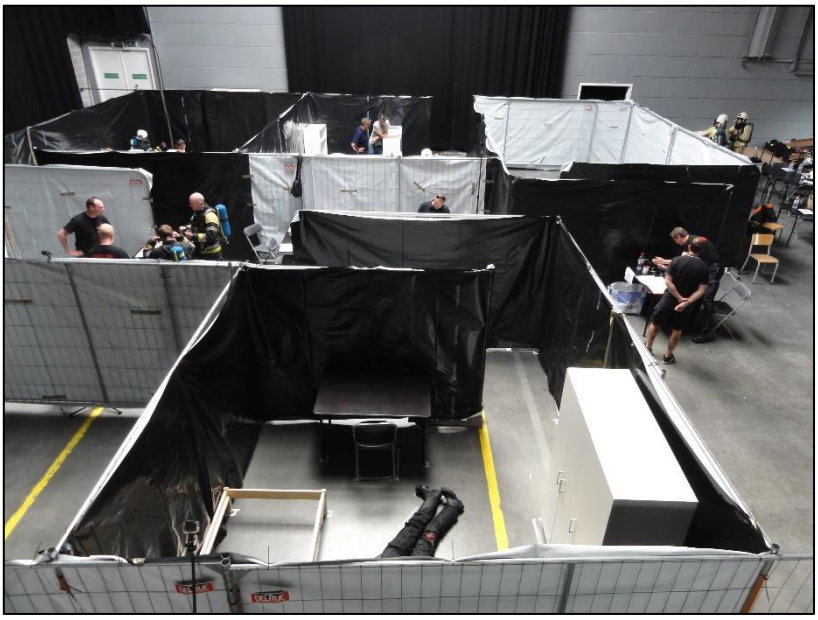

figure 2 A view on the inside rooms made of construction fencing. *(Photo: Nathalie Van Moorter)*

Four rooms were set up like a bedroom and the other three were made to simulate an office. There was an empty bedroom and an empty office (both without any furniture). The bedroom was about 12 m²: 3.5 by 3.5 meters. The office was about 31 m²: 6.82 by 4.5 meters. Duplicates of these rooms were also made with furniture set up according to specific instructions. Then a third setup consisted of the bedroom and office with furniture and a victim inside. The victim was a dummy that weighed 70 kg. These six rooms were set up inside a hall. The goal was that each crew would search these rooms without a hose line. For these rooms, they had been briefed that an attack crew had already achieved knockdown on the fire and were in the process of extinguishing. The seventh room was a furnished bedroom with a victim, set up outside. There, the test had to be done with a charged hose line. The briefing for this test had been altered accordingly.

2.4 One hose line advancement experiment

figure 3 The hose line advancement experiment *(Photo: Nathalie Van Moorter)*

Finally, a 10 m long hallway was built using construction fences. Again it was lined with plastic tarp so no one could see the experiment was in a hallway. The goal of this setup was for crews to advance along the hallway towards a fire. During the advance, crews would need to sufficiently cool the hot smoke.

3 Results

3.1 The bedrooms

There was a clear distinction between the four different bedroom experiments. The empty bedroom was searched in the smallest amount of time. This was done with an average speed of 4.63 m²/min. However there were large differences among the crews. The quickest crews completed the search in less than half of the time while the slowest crews needed three times more time.

Table 1 Test results of the four bedroom experiments: the average time for searching the room as well as the fastest and the slowest time. The fastest and slowest time were also calculated as percentages of the average time.

	Average (min)	Fastest (min)	Slowest (min)
Empty	2.33	0.95	7.28
		41%	312%
Furnished	3.17	0.83	6.33
		26%	200%
With victim	3.84	1.42	7.60
		37%	198%
With hose line	6.14	1.98	19.53
		32%	318%

The furnished bedroom took a bit longer to search. If a crew had to rescue a victim, time increased again. It should be noted that victims were intentionally placed relatively close to the door opening to avoid exhaustion. Firefighters had to be able to start each test in the same conditions.

figure 4 Searching with a hose takes longer and air consumption is higher. *(Photo: Steve De Blauwe)*

Searching with a hose line took the longest. On average, 60% more time was needed for a search with an attack line as opposed to without one.

The time needed to search a room is not the only thing that was affected by this. Air consumption is not a fixed number. Operating without a hose line results in an air consumption of 66 to 70 liters per minute. The individual difference are huge though: from 29 to 184 liters per minute. The average consumption while working with a hose line is 84 liters per minute. That is 21% higher. Because of the longer time it takes to search and the higher consumption, the total amount of air used while operating a hose line is almost doubled as opposed to working without a line.

3.2 The office

The office was about 2.5 times the size of the bedroom. However, this did not mean the search times were 2.5 longer as well. The empty office room took only 22% more time to search. This became about 70% more time in the furnished office and the furnished office with victim. The average air consumption in the three office experiments varied from 62 to 74 liters per minute and was comparable to the bedroom experiments without hose line.

Table The test results of the 3 office experiments: the average time needed to search the room, as well as the fastest and the slowest time. The fastest and slowest time are also calculated as percentages of the average time.

	Average (min)	Fastest (min)	Slowest (min)
Empty	2.85	1.15	5.40
		40%	189%
Furnished	5.46	2.58	9.50
		47%	174%
With victim	6.48	2.50	10.07
		39%	155%

3.3 The hose advancement experiment

The time needed to cover 10 meters while working a hose line was 1.71 minutes on average. The fastest team cleared the hallway in 0.63 minutes while the slowest team took 4.57 minutes. An important difference compared to the search exercise was the air consumption. The average air consumption was 98 liters per minute.

4 Lessons for the fire service

What do all of these experiments mean for the fire service? The number of experiments is limited, but still it is possible to draw some conclusions and make some recommendations.

4.1 Air consumption

A breathing apparatus contains 2040 liters of air at a pressure of 300 bar. A safety margin of 50 bar is kept as a reserve. This means a firefighter has 1700 liters of air available to him for fire ground operations.

Some training courses speak of an air consumption of 40 liters per minute. However, for search & rescue without a hose line this is closer to 70 liters per minute; when having to carry a hose line along, this becomes 84 liters per minute. So on average, crews can search for 24 minutes without a hose line and 20 minutes with one, before they have to start withdrawing. When advancing a hose line towards a fire, air consumption is 98 liters per minute on average. That is 2.5 times the amount that was posited by the various training courses. This rate of air consumption leads to operational time frames of around 17 minutes, which is substantially lower than what is taught in training. Firefighter training courses, and also those of company officers and chief officers, should be updated so that a more realistic idea is formed of the possibilities of a single BA bottle.

4.2 Search & Rescue

There are large differences among the different crews. Some crews were able to get the job done very quickly, while others took a lot longer. There are several reasons for this:

- "Broad sweep": immediately take up positions alongside each other
- Swift progress
- Situational awareness

figure 5 When searching a room, firefighters can perform a broad sweep by positioning themselves alongside one another. This allows them to cover a larger surface area more quickly. *(Photo: Steve De Blauwe)*

In the past, SCBA training taught firefighters to position themselves in a single file or one behind the other. That was the old method of operation. Nowadays, crews are taught they can easily be a few meters apart when doing interior firefighting. That way they can move the hose line more easily. When searching a room without a hose line, firefighters can link up hands and search in a broader pattern. This allows them to search through larger areas.

Some crews were hesitant in their search. Progress was not very swift and the crews halted their search on occasion. Other crews did progress very swiftly through the room.

A third reason for the large differences is that some crews did not have a good situational awareness. They searched through some parts of the room more than once. By doing this, valuable time is lost.

figure 6 This crew uses the old method and stays in a single file. The second firefighter holds on to the BA of the first one as was taught in the past. This slows down their progress and efficiency. The lead firefighter has not even noticed the victim next to him. If the second firefighter would position himself alongside the first, they would have immediately found the victim. *(Photo: Steve De Blauwe)*

Contrary to this, the faster teams forgot or skipped some parts of the room. For instance, not everyone searched inside the closet or the bed was not checked thoroughly enough. Crews have to compromise between speed and thoroughness.

These three items should be included in an update of the basic firefighter training course. In both cold and live fire training, this could be stressed so that everyone can learn from these experiments.

The tests have also shown that working a hose line during search & rescue, increases both overall time needed and air consumption. This means that a much smaller area can be searched on a single BA bottle. Some situations absolutely require the search crew to bring a hose line along. A typical example is searching in an apartment building in which the fire has not yet been located. In this situation, a search crew could just as well stumble upon the fire and they would just as well have to cool the gases. Then again, some situations maybe do not require a hose line. An example of this is searching an apartment above a burning apartment in a building with concrete floors. Here, the crew is less likely to need water.

It is up to both chief and company officers to make this assessment. Their training should therefore have something in it, that will help them make that choice.

The fastest crews generally had more experience and/or had more training opportunities. Herein lies yet another lesson for the fire service. There should be sufficient training of search & rescue so that such an action will go swiftly on the fire ground. Lives literally depend on this.

4.3 Further research

These experiments were rather limited in scope and differed to reality in a number of ways:

- Each experiment was about searching a single room. In reality, several rooms will have to be searched most of the time.
- The experiment commenced at the doorway of the room. In reality, there is often a path leading up to the start of the search. Firefighters will usually be consuming air from their BA. This path also taxes firefighters physically so that most of them

will start the search with elevated heart rates. This is especially through when having to climb stairs.

- The size of the rooms was limited to 12 m² and 31 m². In reality, much larger rooms will have to be searched.
- There was only one victim in the room that was relatively close to the door so that firefighters wouldn't become exhausted. After all, they had to be able to recover fully so that they could start the next experiment. That will be different too on the fire ground.
- There was no real smoke and no heat.
- Crews were blindfolded so that they could not see anything at all. In reality, firefighters will often still be able to see a little bit.

In the future, new experiments should be run in which several of the restrictions above are lifted. Such experiments could give us more insight into how we do search & rescue. As soon as we are able to test in real smoke, we can leave the blindfold behind use a thermal imaging camera. This will lead to bigger insight into what we are able to do and what not. It is important for the fire service to know what we are capable of.

5 Word of thanks

These experiments were the result of work and contributions of many different people and organizations. KCCE endorsed setting up the experiments. Fire department Zone 1 supplied a fire engine and BA container along with the personnel to operate them. Ikea supplied the furniture used during testing. CFBT-BE covered all other necessary expenses (food, fencing, blindfolds, …).

Fire departments Zone 1, Midwest, Westhoek, Antwerp, Brussels, East, Kempen, Rand, Waasland, Noord-Limburg, Fluvia, Meetjesland and Flemish Ardennes have supplied participants without which these tests would have been pointless. Each of these firefighters willingly took part in the series of tests. There was a good vibe in the group and everyone enjoyed themselves.

Furthermore during the days of the actual experiments, 29 volunteers showed up to help the participants for free. The days before and after the tests, another 8 volunteers helped setting up and cleaning up afterwards.

Finally, I would like to thank Neja Jekovec, the student in fire safety engineering who wrote her thesis on these experiments and provided some very valuable insights.

Through working together with a lot of people and different organizations, a small bit of scientific research into search & rescue was accomplished. Hopefully, we can build on that in the future.

6 Bibliography

[1] *Kerber (2012) Analysis of Changing Residential Fire Dynamics and Its Implications on Firefighter Operational Timeframes, Fire Technology, 48, 865–891*

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