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Abstract

In this report, the effectiveness of a detector-activated water mist system, Q-fog, has been compared to traditional residential sprinklers. In total, eight tests were performed with a realistic fuel (bed with pillow and duvet) based on the test procedure described in LPS 1655. The bed was placed at different locations in the room and was ignited at the pillow and below the bed, also according to LPS 1655. Temperatures were measured using six thermocouples at different locations and heights. Also, near field heat flux was measured using plate thermometers.

The results show that the detector-activated water mist system seems to be superior when the fuel package is located in front of the suppression system, and the fire starts on top of the bed. If the fire starts below the bed or if the bed is located in a less favorable location, the performance is similar to traditional sprinklers. Finally, if the fuel package is both located in an unfavorable location and ignition occurs below the bed, the traditional sprinkler is superior. However, few fatal fires start below the bed and therefore, the overall effectiveness can be expected to be higher for the detector-activated water mist compared to the bulb-activated sprinklers.

Table of content

1 Introduction

The number of fatalities in residential fires has declined steadily in most countries [1], and the remaining fatalities increasingly belong to a socio-demographically distinct group [2]. One of the most exposed groups is older people with limited mobility [3]. A distinct feature of those events is that the victim is typically in direct proximity to the location of ignition, e.g. clothes or bed/upholstered furniture [2].

Experiments have shown that traditional, bulb-activated sprinklers typically are too slow to prevent the fatality in these cases [4] and, therefore, other means of suppression has been attempted. One of those is to use a smoke detector to activate the suppression system. Even if there are rather robust, multi-criteria, smoke detectors available, the use of electronic activation requires an increased focus on consequences of false activation compared to traditional sprinklers, which are very robust. One way of reducing the potential consequences of false activation is using water mist where substantially less water is used.

One of those products currently on the market, Q-fog, have been used, primarily, in the Nordic countries for several years and have been found to successfully prevent incipient fires from the transition from smoldering to flaming mode. However, there are still concerns about the effectiveness of such a system in dealing with rapidly developing fires typically induced by a flaming ignition source coming into contact with highly flammable material such as upholstered furniture.

This paper intends to investigate this through a series of experiments comparing the performance of the selected detector-activated water mist system, Q-fog, and traditional, bulb-activated, residential sprinklers.

The procedure is based on the guideline for fire test protocols presented in CEN/TS 14972:2011 Annex B and the performance objective was selected to be near- and far-field temperatures compared to traditional residential sprinkler systems designed according to NFPA 13R.

2 Experimental Set-Up

The experimental set-up was based on the test for residential fires presented in LPS 1655 [5], but, to align with the design guidelines for the specific system, the size of the room was 5x5 meters instead of the 8.1x4.1 m in the standard. The ceiling height was also 2.9 m instead of the 3.6 m in the standard. Two walls were made of single sheet metal, one of concrete and one of fire-rated glass.

The fuel package was, in line with the standard, a metal-frame bed with a 15 mm plywood headboard, fitted with a polyether mattress. Only the material of the mattress is presented in the standard, but, in this case, an 80 mm polyurethane mattress with dimensions 2000x900 mm with a foam density of 25 kg/m^3 was selected. On the mattress, a pillow with a pillowcase and a single duvet was placed also in line with the standard.

The bed was placed in two different locations. One was in the middle of the room (A), and one was adjacent to a side-wall (B), see Figure 1.

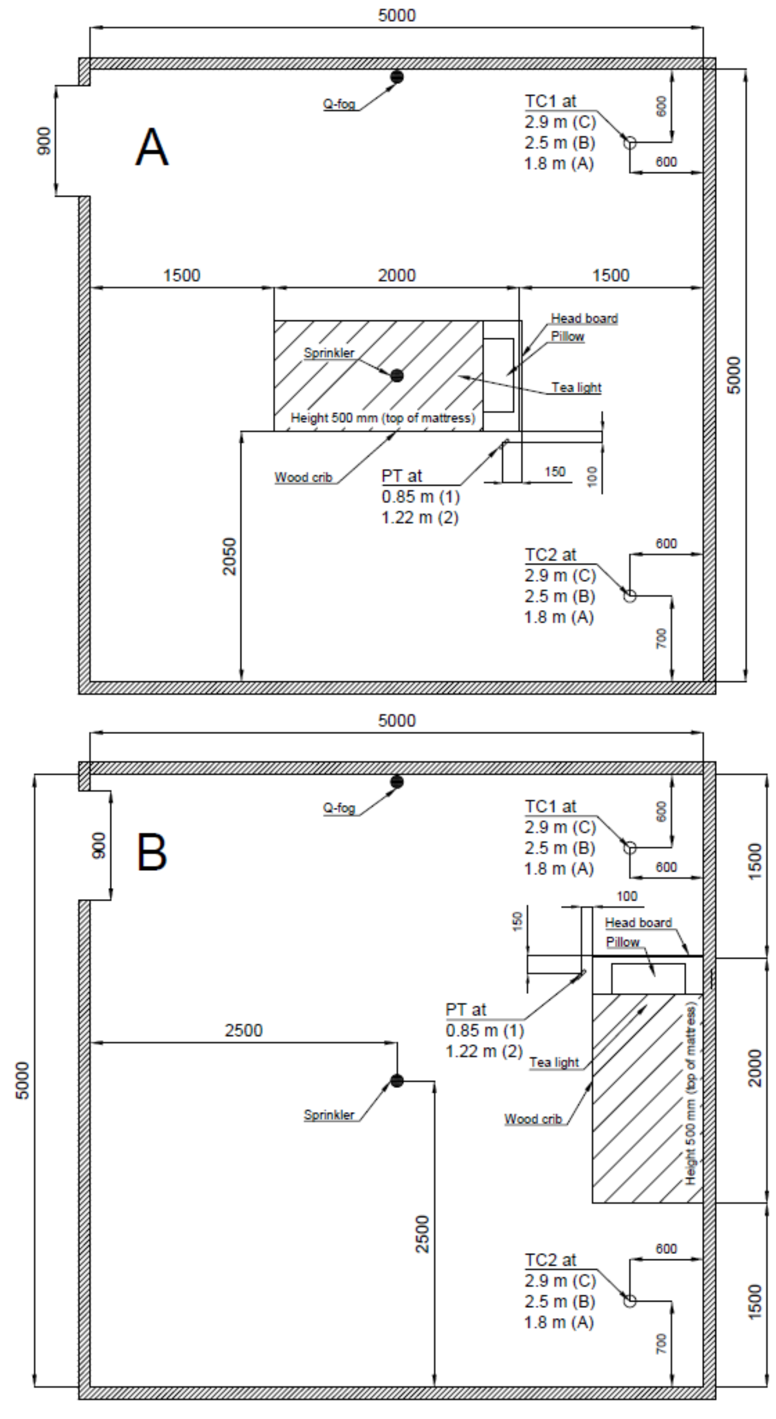

Figure 1 – Location of fuel package (bed), suppression systems (sprinkler and Q-fog), thermocouples (TC) and plate thermometers (PT)

Two different ignition sources are described in the standard

1. Standard tea light placed within the fuel package between the duvet and the pillow.
2. A No. 7 wood crib placed in a 100 ml tray of heptane beneath the fuel package.

In the standard, measurements should be performed by placing three thermocouples on the headboard. However, it was deemed more suitable to instead use two plate thermometers [6] to measure the near field heat flux and two thermocouple trees to measure the general gas temperature in the room. The thermocouples were placed at 1.8 m, 2.5 m and 2.9 m above floor level.

Finally, the standard gives the pass/fail criteria that the system should be capable of suppressing the fire for the discharge duration. In these tests, a comparison with traditional residential sprinklers was used instead. The sprinkler was a Tyco TY1234 with a K-factor of 43 fitted with a 68°C 3-mm-bulb. The discharge was 64.3 l/min based on a 5.5x5.5 m coverage area. The detector-activated water mist sprinkler was a Q2 delivered by Q-fog, which is a self-contained system with a pump, tank etc. The water mist nozzle has a K-factor of 0.93, capable of delivering 8.8 l/min at 90 bars.

In total, eight tests were performed, and a summary of the different configurations can be found in Table 1. All experiments were also documented with cameras at the opposite side of the fire-rated window.

Table 1 – Summary of tests

Test	Fuel location	Ignition source	Suppression system	Results in section
SA1	Mid-room (A)	Pillow (1)	Residential sprinkler	3.1
QA1	Mid-room (A)	Pillow (1)	Q-fog	3.1
SA2	Mid-room (A)	Below (2)	Residential sprinkler	3.2
QA2	Mid-room (A)	Below (2)	Q-fog	3.2
SA1	Side-wall (B)	Pillow (1)	Residential sprinkler	3.3
QA1	Side-wall (B)	Pillow (1)	Q-fog	3.3
SA2	Side-wall (B)	Below (2)	Residential sprinkler	3.4
QA2	Side-wall (B)	Below (2)	Q-fog	3.4

A picture from the experiments can be found in Figure 2 with thermocouple tree and plate thermometers visible in the background.

Figure 2 – Picture of a typical experimental set-up (left) and a picture of the Q-fog (right). Note that in the actual experiments, the unit was placed outside the room and only the nozzle placed in the room to prevent contamination of the unit.

3 Results

In section 3.1-3.4, the test results for each test configuration are presented individually, followed by section, 3.5, which summarizes the results from all tests.

3.1 Test A1: Bed in Mid-room and Ignition at Pillow

The near field heat flux, as measured by the plate thermometers, can be found in Figure 4.

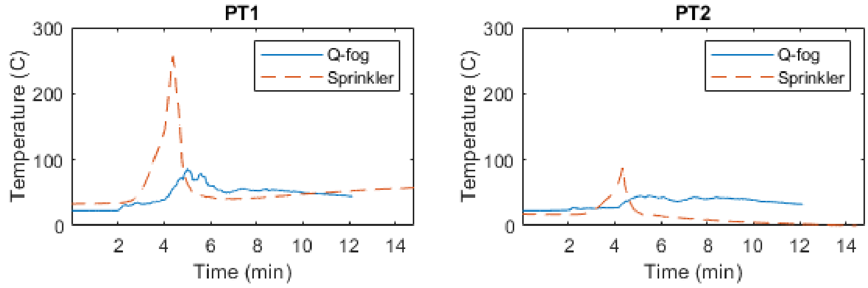

Figure 3 – Plate thermometer temperature for the SA1 and QA1 tests.

The gas temperatures in the room, as measured with two thermocouple trees with probe location at 1.8 m (A), 2.5 m (B) and 2.9 m (C), can be found in Figure 4.

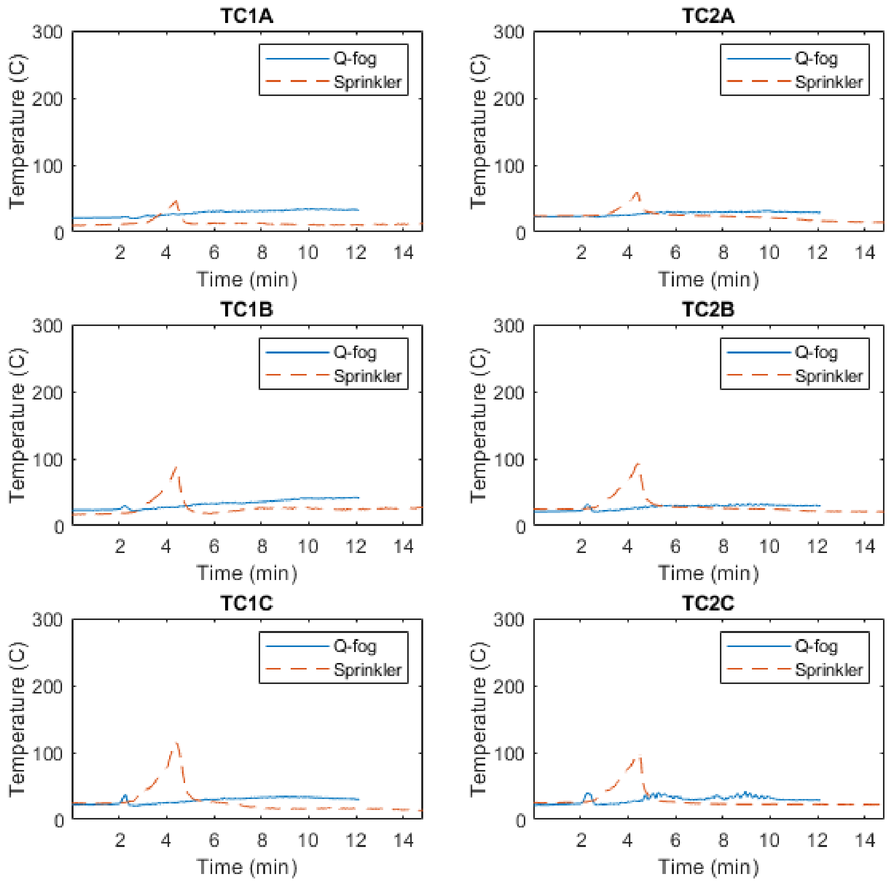

Figure 4 – Thermocouple temperature for the SA1 and QA1 tests.

The maximum temperature for each plate thermometer and thermocouple during the test can be found in Figure 5.

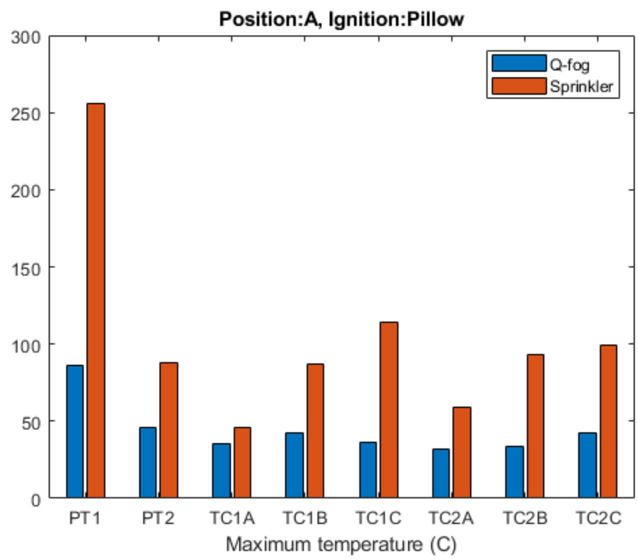

Figure 5 – Maximum temperature during the SA1 and QA1 tests.

3.2 Test A2: Bed in Mid-room and Ignition Below

The near field heat flux, as measured by the plate thermometers, can be found in Figure 6.

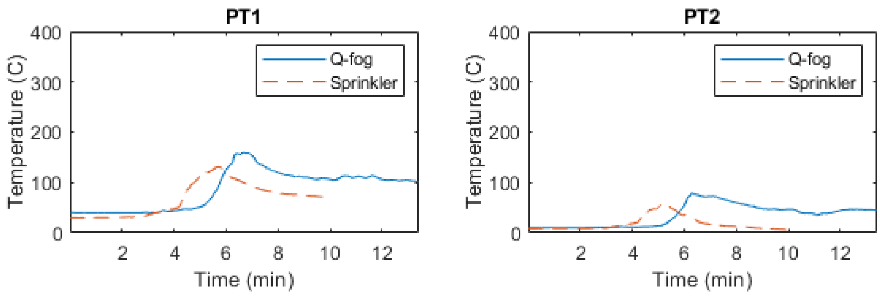

Figure 6 – Plate thermometer temperature for the SA2 and QA2 tests.

The gas temperatures in the room, as measured with two thermocouple trees with probe location at 1.8 m (A), 2.5 m (B) and 2.9 m (C), can be found in Figure 7.

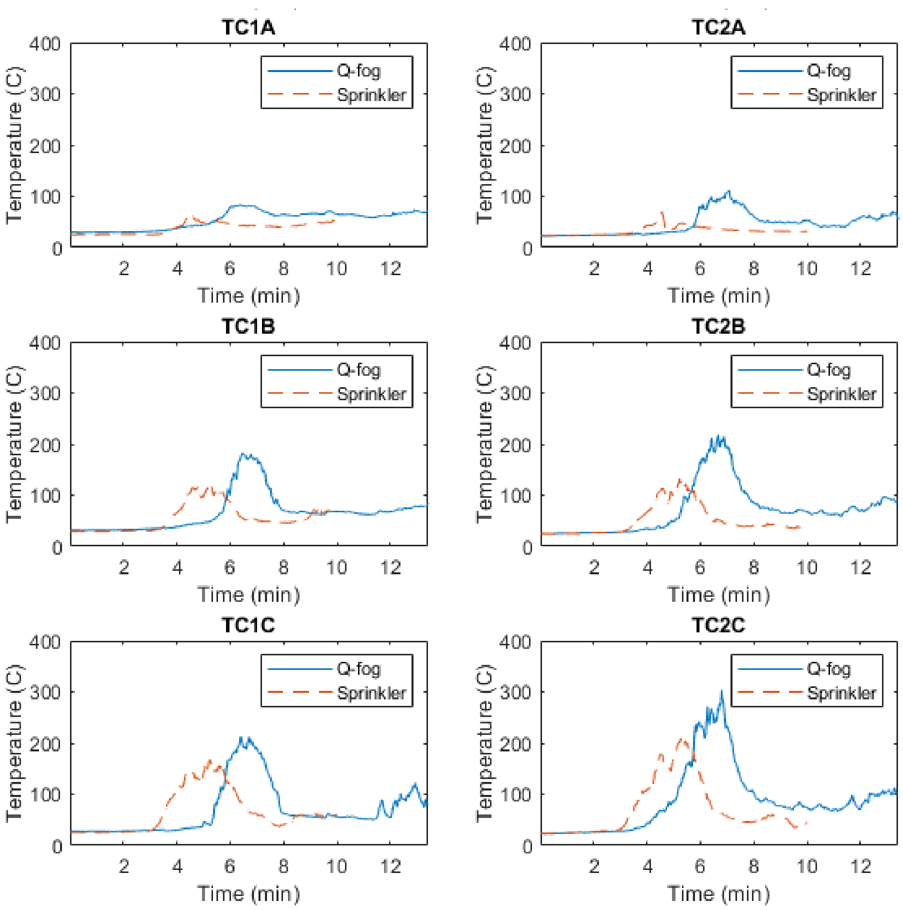

Figure 7 – Thermocouple temperature for the SA2 and QA2 tests.

The maximum temperature for each plate thermometer and thermocouple during the test can be found in Figure 8.

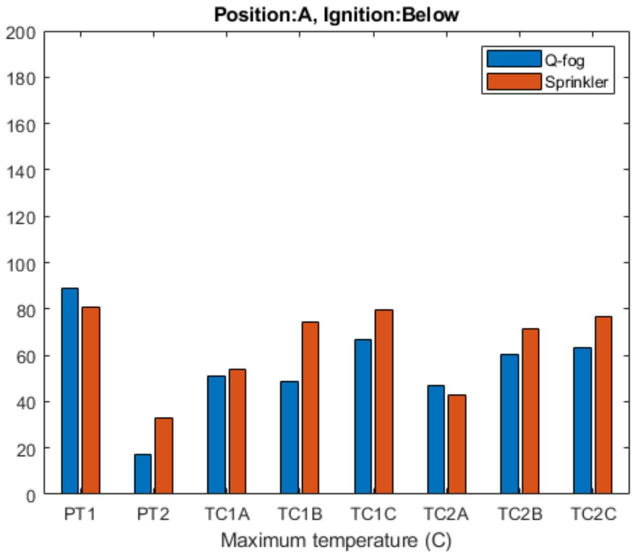

Figure 8 – Maximum temperature during the SA2 and QA2 tests.

3.3 Test B1: Bed close to Wall and Ignition at Pillow

The near field heat flux, as measured by the plate thermometers, can be found in Figure 9.

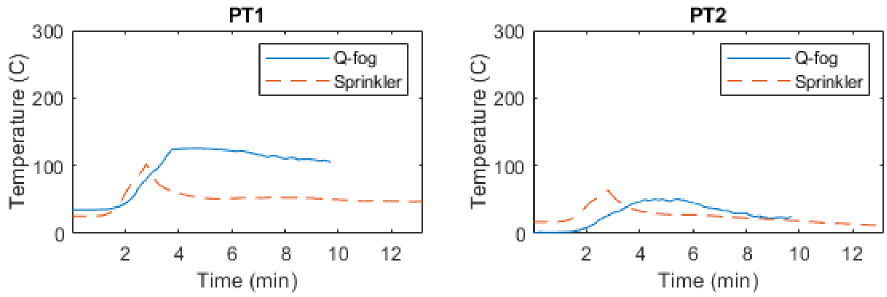

Figure 9 – Plate thermometer temperature for the SB1 and QB1 tests.

The gas temperatures in the room, as measured with two thermocouple trees with probe location at 1.8 m (A), 2.5 m (B) and 2.9 m (C), can be found in Figure 10.

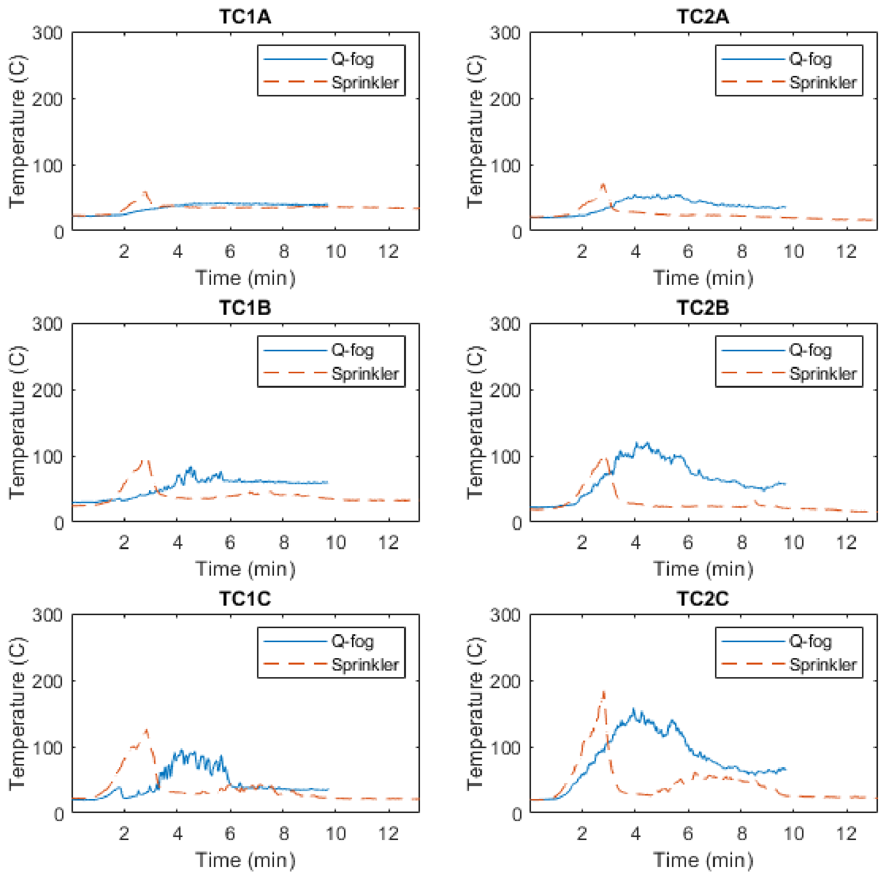

Figure 10 – Thermocouple temperature for the SB1 and QB1 tests.

The maximum temperature for each plate thermometer and thermocouple during the test can be found in Figure 11.

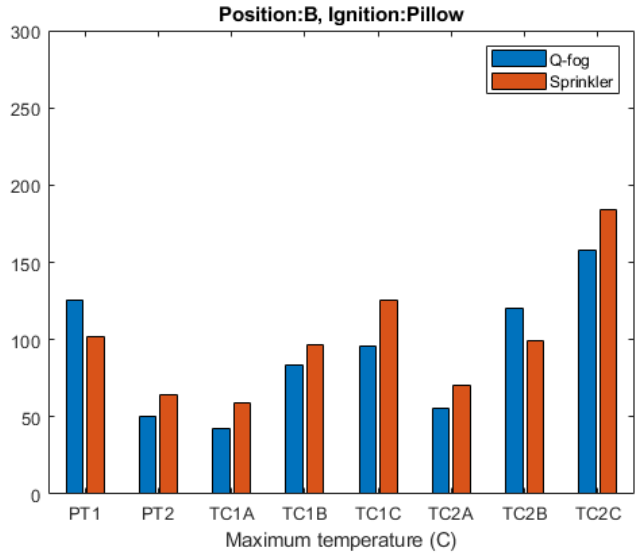

Figure 11 – Maximum temperature during the SB1 and QB1 tests.

3.4 Test B2: Bed close to Wall and Ignition at Below

The near field heat flux, as measured by the plate thermometers, can be found in Figure 12.

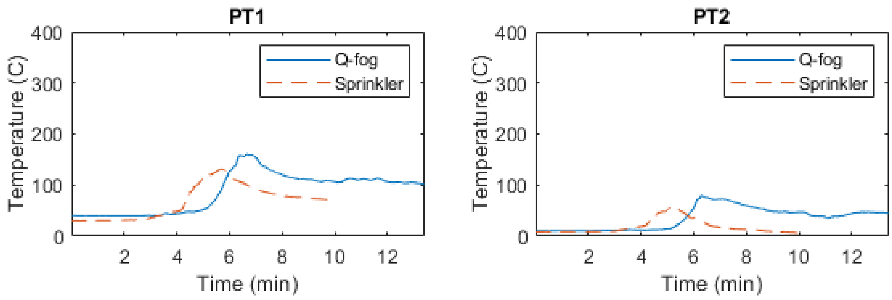

Figure 12 – Plate thermometer temperature for the SB2 and QB2 tests.

The gas temperatures in the room, as measured with two thermocouple trees with probe location at 1.8 m (A), 2.5 m (B) and 2.9 m (C), can be found in Figure 13.

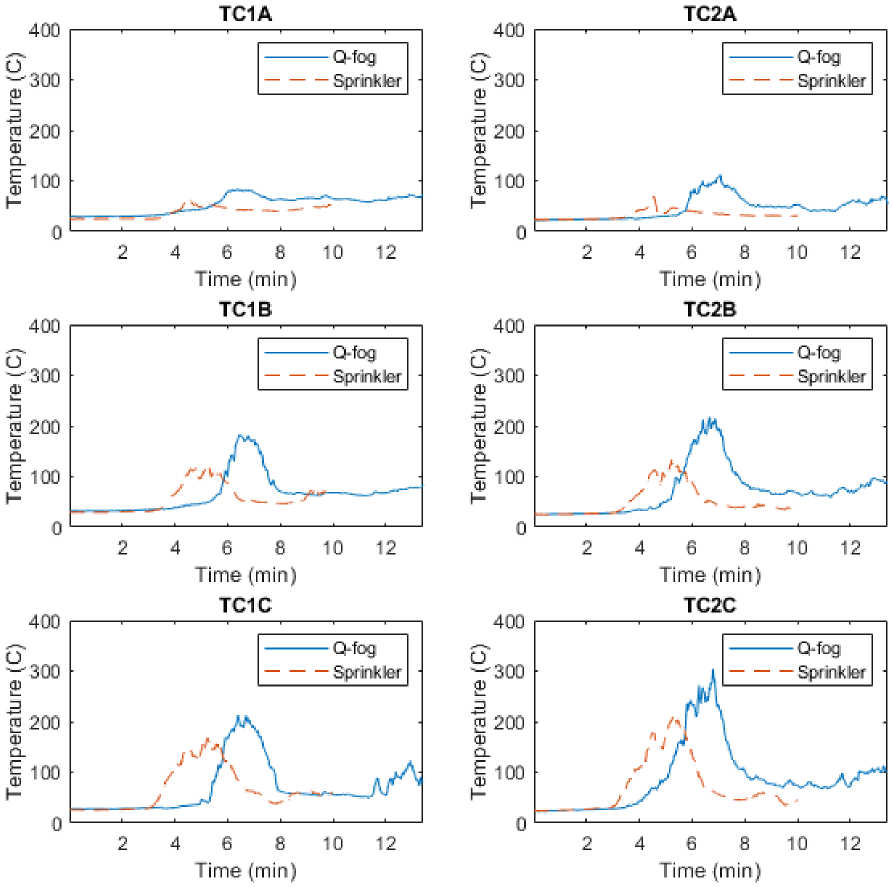

Figure 13 – Thermocouple temperature for the SB2 and QB2 tests.

The maximum temperature for each plate thermometer and thermocouple during the test can be found in Figure 14.

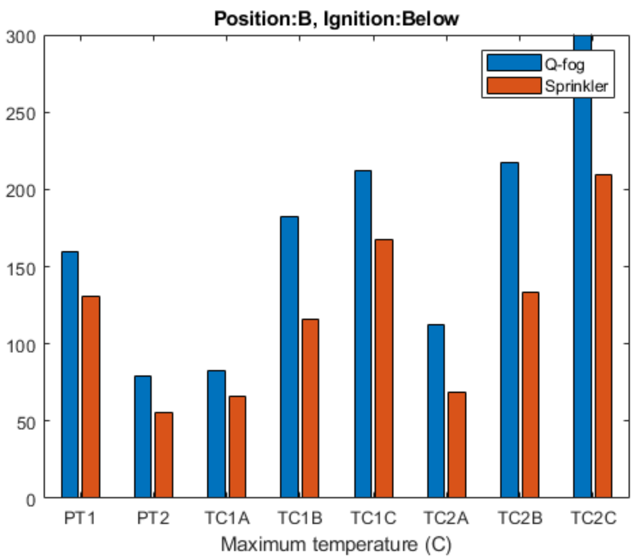

Figure 14 – Maximum temperature during the SB2 and QB2 tests.

3.5 Comparison of Results

To facilitate a comparison between the overall performance of each system, the difference in maximum plate thermometer temperature between Q-fog and traditional sprinklers are presented in Table 2.

Table 2 – Comparison of maximum plate thermometer temperature for detector activated water mist and traditional sprinklers. The percentage difference in temperature increase from ambient is presented in parenthesis.

Fuel location	Ignition location	PT1	PT2
Mid-room	Pillow	-170.3K (-72.9%)	-42.6C (-65.0%)
Mid-room	Below	8.4C (19.3%)	-15.7C (-64.1%)
Wall	Pillow	23.7C (23.7%)	-13.5C (-13.5%)
Wall	Below	28.7C (31.5%)	23.3C (51.4%)

Since six measurement points for thermocouples are included in the study, instead of presenting the difference for each individual thermocouple, the minimum, average and maximum difference between thermocouples is presented in Table 3.

Table 3 – Comparison of maximum thermocouple temperature for detector activated water mist and traditional sprinklers. The percentage difference in temperature increases from ambient is presented in parenthesis.

		Difference in maximum temperature for detector activated water mist and traditional sprinkler		
Fuel location	Ignition location	Minimum	Average	Maximum
Mid-room	Pillow	-78.0C (-84.4%)	-46.2C (-74.1%)	-10.9C (-60.4%)
Mid-room	Below	-25.4C (-45.0%)	-10.2C (-12.3%)	4.0C (31.3%)
Wall	Pillow	-30.4C (-44.9%)	-13.3C (-20.3%)	21.0C (22.3%)
Wall	Below	16.9C (29.9%)	58.3C (59.8%)	94.2C (96.3%)

The same results are also presented in Figure 15.

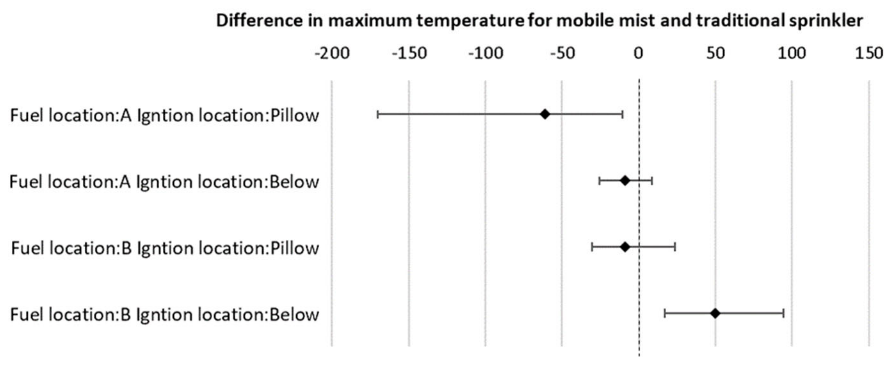

Figure 15 – Comparison of maximum thermocouple temperature for detector activated water mist and traditional sprinklers

4 Discussion

In the standard used for the fire test, LBS 1655, the pass/fail criteria are that the system should be able to suppress the fire for the discharge duration. This was achieved for all tests. The more stringent criteria presented in section 2, that the near- and far-field temperature should be equal or less compared to the tests with traditional sprinklers, was more inconclusive.

As can be seen in Table 2, Table 3 and Figure 15, the detector-activated water mist system seems to be superior when the water can easily reach the fire – when the fuel package is located in front of the suppression system, and the fire starts on top of the bed. If the fire starts below the bed or if the bed is located in a less favourable location, the performance is similar to traditional sprinklers. Finally, if the fuel package is both located in an unfavourable location and the ignition is below the bed, the traditional sprinkler is superior.

However, since most actual fires in residential occupancies typically start on top of the bed (e.g. from smoking), the performance of the system in most situations can be expected to be similar or superior to that of traditional sprinklers. This can be further enhanced if the system is directed towards the most probable point of ignition. Finally, it should also be acknowledged that a large proportion of actual fires undergo a long period of smouldering combustion [7]. For this scenario, the performance of the detector-activated water mist can be expected to be vastly superior since the temperature in the enclosure remains low until the fire transitions into a flaming mode.

The experimental campaign included eight tests. The original plan was to perform ten tests to get two repeats. However, due to practical constraints, these repeats could not be performed, but it is encouraged to perform additional tests so in the future. It would also be beneficial to increase the amount of instrumentation to also measure, for example, visibility and toxicity in the room.

5 Conclusions

The results indicate that the suppression performance of the detector-activated water mist system, Q-fog Q2, tested in this campaign can be expected to be similar or superior to traditional residential sprinklers in most practical situations.

The performance is superior if the fuel package is located in a favorable location and the ignition occurs in a location where the mist can easily reach the seat of the fire. If the fuel is located in a less favorable location or if the ignition occurs below the bed, the performance is similar. If the fuel is both placed in an unfavorable location and the ignition occurs below the bed, the traditional sprinkler is superior. However, few fires start below the bed. Also, since the detector-activated water mist tested was mobile it will probably in many situations be possible to direct it towards the main fuel in the room.

It should also be acknowledged that this is based on a flaming ignition source. If the ignition is smoldering, such a cigarette, the pre-burn time will be very long and, during this period, the temperature increase is too small to activate the bulb-activated sprinkler, but the smoke generated might be able to activate a smoke detector. In these cases, a superior performance of the detector activated water mist system can be expected.

In summary, based on the performed experiments, the overall effectiveness of the detector-activated water mist system can be expected to be higher than traditional sprinkler system for fires in the protected area.

6 Acknowledgement

This research was partly funded by Q-fog (the manufacturer of the tested system). The authors independently designed the experiment and also based it on a published standard to prevent potential suspicion of bias.

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