Analysis of Operation Time of Sprinkler by RTI Value

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Abstracts: *In this study, a scenario was developed and studied to find out the change in the operation time of the sprinkler head according to the difference in the RTI value of the sprinkler head in the event of a fire in a partitioned space. The simulation results of the operation time according to the change in the RTI value of the sprinkler head are as follows. As a result of analyzing the operation time of the sprinkler head for each scenario, it was confirmed that the lower the RTI value, the faster the operation time, and in the case of Scenarios 2 and 3, the change of the RTI value is not significant, either. Also, the sprinkler head in the same position did not operate at the same time because the sprinkler head near the window position was slower. Therefore, it was confirmed that the sprinkler head with a low RTI value should be used in places with high risk when a fire occurs, and that the sprinkler head should be installed in a position where the wind effect is insignificant.*

Keywords: RTI, Sprinkler System, Operation Time, Pyrosim.

1. INTRODUCTION

Sprinkler systems are automatic plant fire extinguishing systems that automatically detect fire and extinguish the fire, consisting of water sources, pressurized water supply systems, water flow detection devices, sprinkler heads, pipes, and valves. When a fire occurs in a fire-fighting object and the temperature rises, a fire detection device such as a heat sensor or a fire detector in the sprinkler head operates, and pressurized water in the pipe is radiated to the sprinkler head to perform fire extinguishing [1]. Since sprinkler systems are also systems to prevent fires, sprinkler systems play a vital role in extinguishing early fires. However, in some cases, sprinkler systems that automatically detect fire and extinguish the fire were left unattended [2] and 19 out of 20 large fires over five years were not equipped with sprinklers or did not work, leading to large fires [3]. However, in addition to these cases, there are cases of preventing fires through sprinkler systems. The fire in the Gosiwon, accommodations for examiners, was extinguished immediately without expanding due to the operation of the sprinkler system [4]. If the sprinkler system is operated smoothly, large-scale fires can be prevented.

Kim Jong-hoon and two others (2001) evaluated the adaptability of the model's predictive performance by comparing and analyzing the results by applying FASTLite, FDS, and SMARTFIRE among fire models currently used through fire experiments to measure sprinkler reaction time in indoor compartment spaces [5]. In Yoo Woo-joon's study(2018), a study was conducted to analyze the operation time of the sprinkler head due to the change in the loss factor of the sprinkler head based on the condition that the calorific value rapidly changes when a fire occurs in the compartment space [6]. In the study of Kim Sung-chan (2020), the number was analyzed to lower the airflow conditions quantitatively, and the analysis model of the sprinkler head was applied to identify the heat flow conditions [7]. The percussion of the airflow conditions applied in the flange test was studied. In the study of Seo-young Kim and Ha-sung Gong (2022), a study was conducted on whether the insulation on the ceiling was ignited compared to the ignition point of the ceiling insulation by measuring the temperature change at the same point depending on whether the sprinkler was operated or not. In the study of Choi Dae-hyun (2020), the current standard and revised guidelines were compared and analyzed for the operation time of the sprinkler head when the vehicle fire in the parking lot is adjacent to the beam through fire simulation.

In a study by Song Young-ju et al. (2019), a plan was proposed to evaluate evacuation safety at the underground parking lot [8]. In a study by Lee Tae-gu and Han Yeong-hae (2019), a review and improvement plan were studied to use the underground parking lot as an evacuation space in a disaster [9]. In the study by Hwang Chang-hwan and Kim Hak-joong (2016), the study of Kim Seo-young and Gong Ha-sung (2020), and the study of Choi Dae-hyeon and two others (2020) studied sprinkler systems in underground parking lots. However, when analyzing previous studies, no study compared the operation time of sprinkler systems according to the change in RTI values.

Therefore, this study compares and analyzes the operation time of the sprinkler system according to the change in the RTI value and uses it as primary data on the operation time of the sprinkler system according to the RTI value

2. HOW TO SET FIRE SIMULATION

2.1. Experimental Model Setting

This study conducted a simulation to analyze the operating time of sprinkler facilities by setting the partitioned place as a model. The size of the partitioned yarn is 10m wide, 5m long, and 2.6m high, and an opening 1.5m wide is installed to allow smoke to escape. The lattice size was applied in a size of 0.2 m x 0.2 m x 0.2 m. The compartmentalized place is shown in Figure 1.

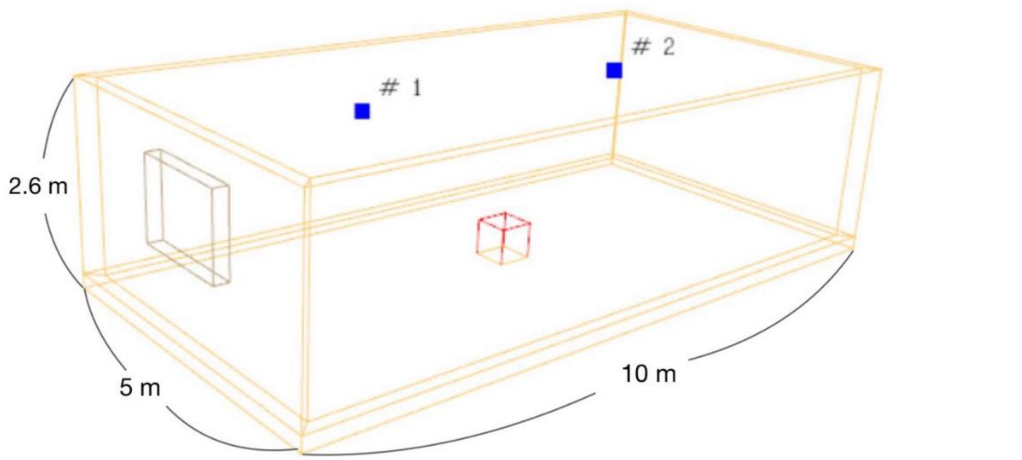


Figure 1. Compartmentalized Place.

2.2. Fire Heat Realease Rate and Seat of Fire Setting Experimental Model Set Up

The fire heat release rate and seat of fire setting are shown in Table 1. The seat of fire was located in the center of the compartment space, and the length of one side was set to 0.5m. The seat of fire surface area was 1.25 m^2, and the fuel of seat of fire was assumed to be wood oak. The maximum heat release rate was 2143.3 kW based on the heat release rate when a fire broke out in the chair, but 1714.4 kW/m^2, which is a value divided by seat of fire surface area in the maximum heat release rate, was set as the maximum heat emission value.

Table 1. Fire Heat Release Rate and Seat of Fire Setting.

Division	Content
The size of seat of fire	0.5m
The fuel of seat of fire	Wood-oak
The surface area of a fire in seat of fire	1.25m^2
Lattice size	0.2m x 0.2m x 0.2m
Maximum heat demission rate	1714.4kW/m^2

2.3. Sprinkler head Setting

The setting of the sprinkler head is shown in Table 2. The activation temperature of the sprinkler head was set to 72°C, mainly used in Korea, and the sprinkler head was set to two. The applied fire flow was set to 160 L/min by installing two heads according to the applied fire flow of NFSC 103 [10].

Table 2. Sprinkler head Setting.

Division	Content
Activation temperature	72 ℃
Number of heads	2
Applied fire flow	160 L/min

2.4. Fire Simulation Scenario

The fire simulation scenarios were set to four, as shown in <Table 3>. Scenario 1 analyzes the operation time when the RTI value is 91.3 $\sqrt{(m \cdot s)}$, and Scenario 2 analyzes the operation time when the RTI value is 104.5 $\sqrt{(m \cdot s)}$. Scenario 3 analyzes the operation time when the RTI value is 110.5 $\sqrt{(m \cdot s)}$. Scenario 4 analyzes the operation time when the RTI value is 171.3 $\sqrt{(m \cdot s)}$. According to each scenario, the RTI value was determined based on the value derived through the flange test because the RTI value was not provided to the manufacturer of the sprinkler system used in the study by Kim Sung-chan (2020) [11].

Table 3. RTI values according to scenario.

Scenario	RTI($\sqrt{(m \cdot s)}$)
1	91.3
2	104.5
3	110.5
4	171.3

3. ANALYSIS OF FIRE SIMULATION REAULTS

3.1. Scenario 1

The operating time when the value of the RTI of the sprinkler system was set to 91.3 $\sqrt{(m \cdot s)}$ was analyzed. In Figure 2, the temperature change of the sprinkler system was confirmed through the graph. It was confirmed that the temperature of the sprinkler head increased after 150 seconds. At 209.6 seconds, the temperature of #2 was 72°C, and #1 near the window was close to the window's position, so the temperature was 72°C at 211.7 seconds later than the operation time of #2.

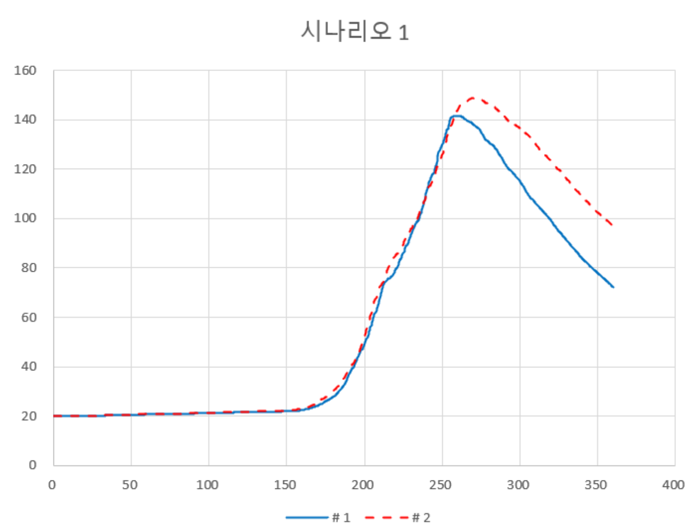
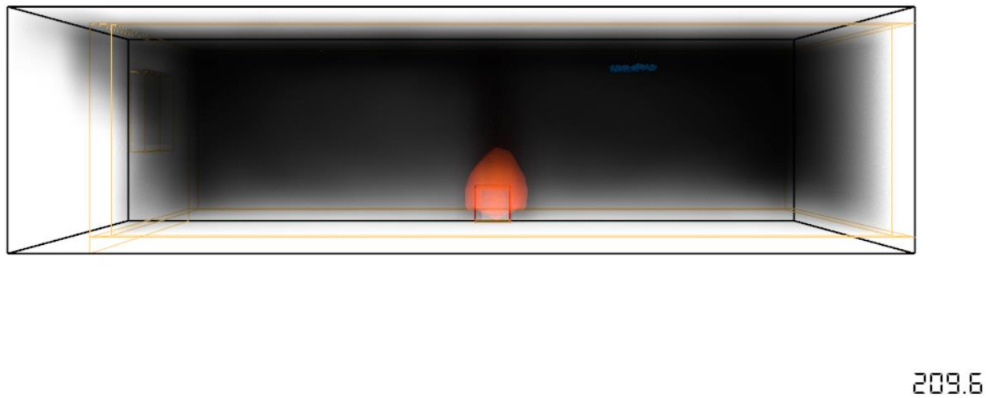


Figure 2. Temperature change on scenario 1.

When the temperature of the sprinkler head reached 72°C, it was confirmed that #2 of the two sprinkler systems operated first. # The operation time of 2 is 209.6 seconds, and when #1 is operated, it can be confirmed that it is operated at 211.7 seconds. # It was confirmed that the late operation time of 1 was located near the window, so the temperature rise was delayed. Figure 3 shows the sprinkler systems of #1 and #2.



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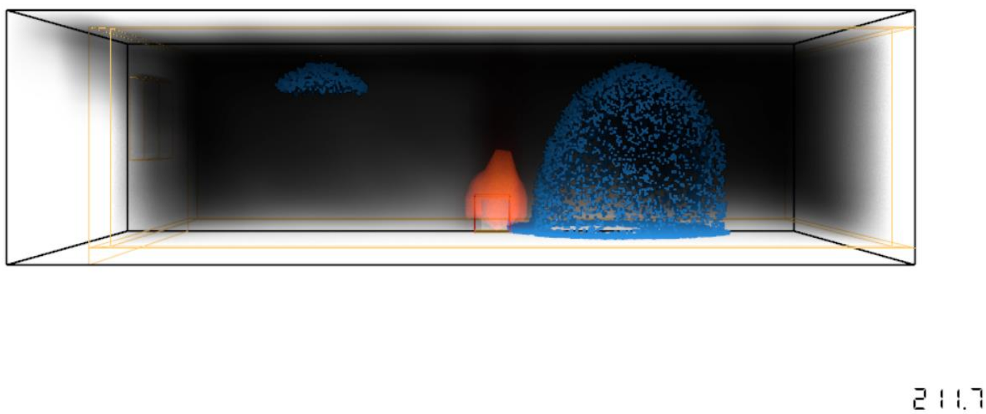

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Figure 3. Operation time for scenario 1.

3.2. Scenario 2

The operation time when the value of the RTI of the sprinkler head is set to 104.5 $\sqrt{(m \cdot s)}$ was analyzed. In Figure 4, the temperature change of the sprinkler head was confirmed through the graph. It was confirmed that the temperature of the sprinkler head increased after 150 seconds. When it was 212.5 seconds, the temperature of #2 was 72°C, and #1 near the window was close to the position of the window so that the temperature was 72°C at 215 seconds later than the operation time of #2.

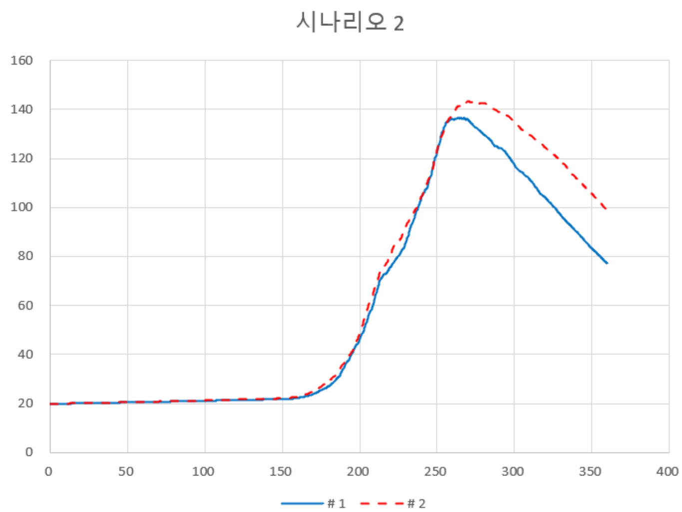
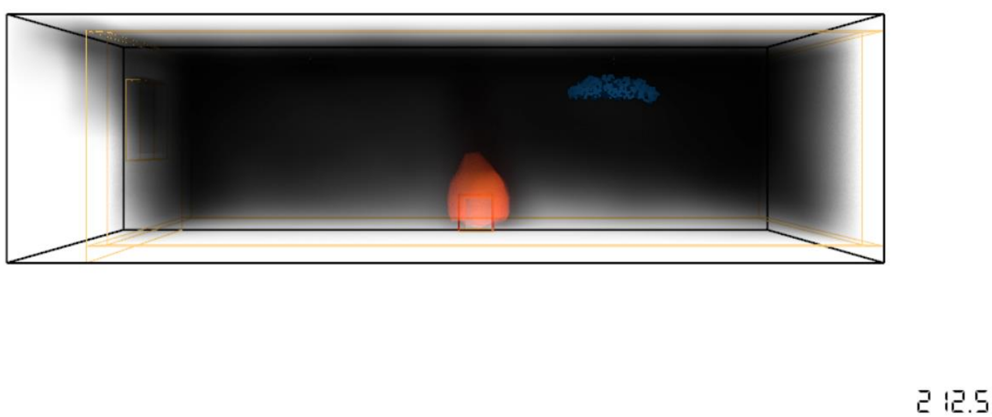


Figure 4. Temperature change on scenario 2.

When the temperature of the sprinkler head reached 72°C, it was confirmed that #2 of the two sprinkler heads operated first. The operation time of #2 is 212.5 seconds, and when #1 is operated, it can be confirmed that it is operated in 215 seconds. It was confirmed that the late operation time of #1 was located near the window, so the temperature rise was delayed. Figure 5 shows the sprinkler heads of #1 and #2.



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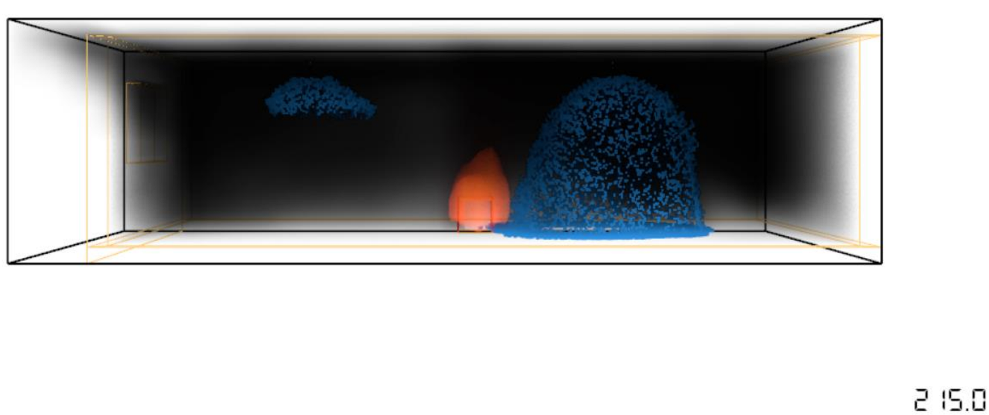

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Figure 5. Operation time for scenario 2.

3.3. Scenario 3

The operation time when the value of the RTI of the sprinkler head is set to 110.5 $\sqrt{(m \cdot s)}$was analyzed. Through Figure 6, the temperature change of the sprinkler head was confirmed through the graph. It was confirmed that the temperature of the sprinkler head increased after 150 seconds, and when it was 213.4 seconds, the temperature of #2 was 72°C, and #1 near the window was close to the position of the window so that the temperature was 72°C at 216.1 seconds later than the operating time of #2.

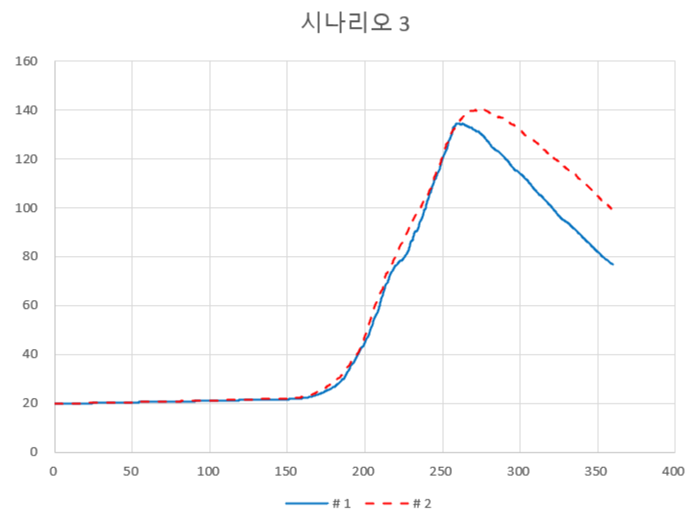
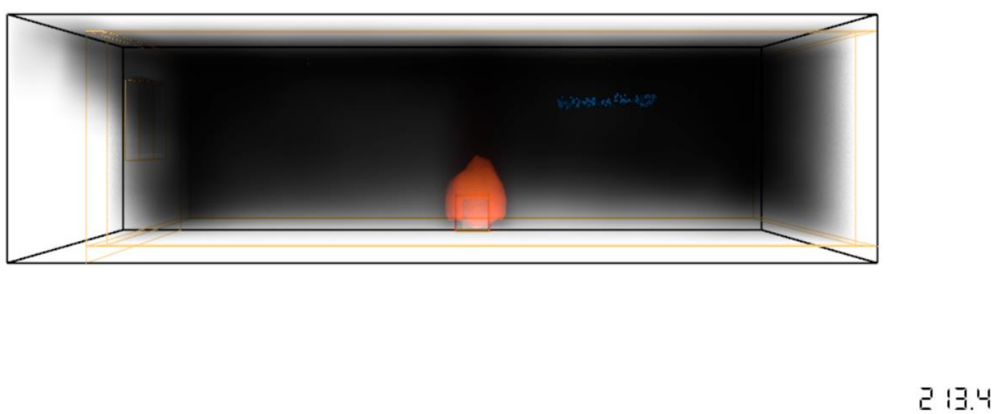


Figure 6. Temperature change on scenario 3.

When the temperature of the sprinkler head reached 72°C, it was confirmed that #2 of the two sprinkler heads operated first. The operation time of #2 is 213.4 seconds, and when #1 is operated, it can be confirmed that it is operated at 216.1 seconds. It was confirmed that the late operation time of #1 was located near the window, so the temperature rise was delayed. Figure 7 shows the sprinkler heads of #1 and #2.



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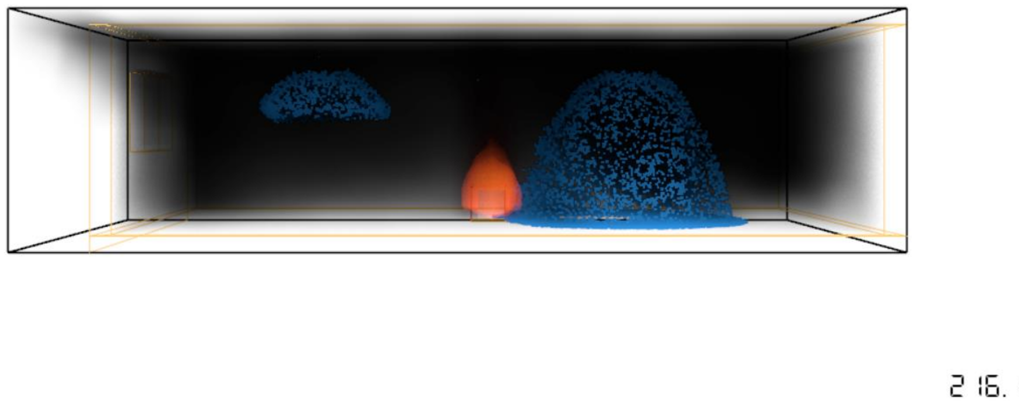

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Figure 7. Operation time for scenario 3.

3.4. Scenario 4

The operation time when the value of the RTI of the sprinkler head is set to 110.5 $\sqrt{(m \cdot s)}$ was analyzed. Through Figure 8, the temperature change of the sprinkler head was confirmed through the graph. It was confirmed that the temperature of the sprinkler head rose after 150 seconds, and when it was 222.6 seconds, the temperature of #2 was 72°C, and #1 near the window was close to the position of the window so that the temperature was 72°C at 224.2 seconds later than the operation time of #2.

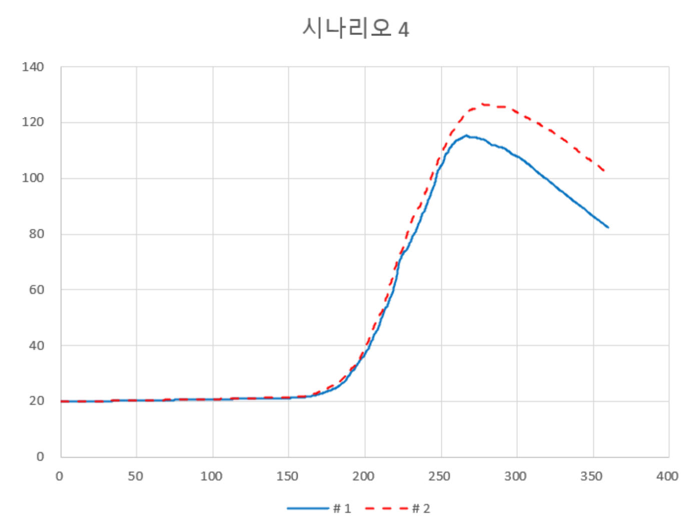
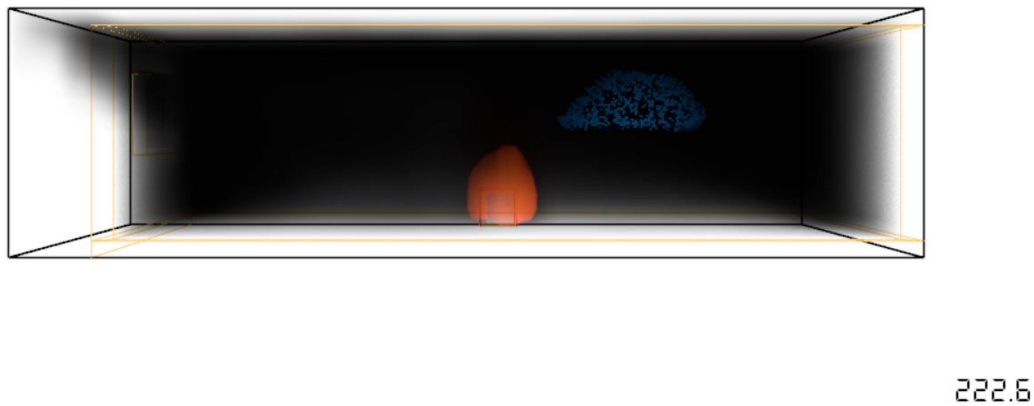


Figure 8. Temperature change on scenario 4.

When the temperature of the sprinkler head reached 72°C, it was confirmed that #2 of the two sprinkler heads operated first. It was confirmed that the operation time of #2 was 222.6 seconds, and when #1 was operated, the operation was 224.2 seconds. It was confirmed that the late operation time of #1 was located near the window, so the temperature rise was delayed. Figure 9 shows the sprinkler heads of #1 and #2.



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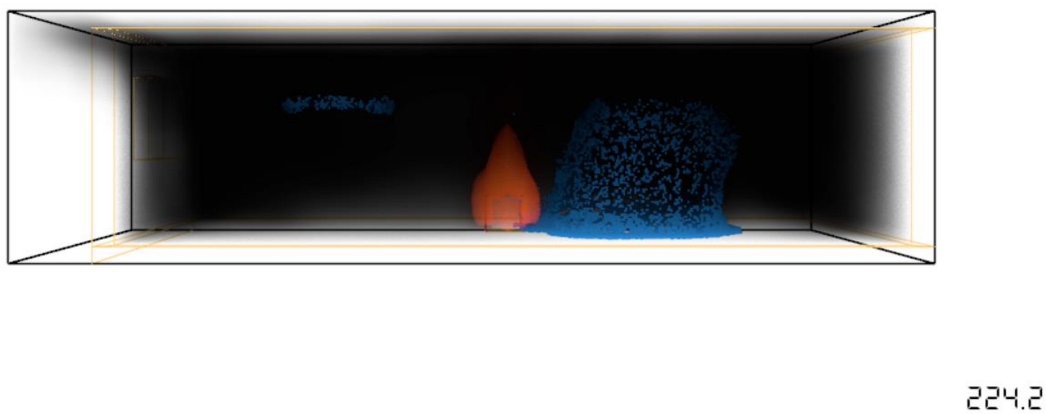

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Figure 9. Operation time for scenario 4.

4. CONCLUSION

In this study, a scenario was developed and studied to find out the change in the operation time of the sprinkler head according to the change in the RTI value of the sprinkler head in the event of a fire in a partitioned space. The simulation results of the operation time according to the change in the RTI value of the sprinkler head are as follows.

(1) A total of two sprinkler heads were installed, and it was set to operate when the temperature reached 72°C. In scenario 1, it was confirmed that the time when the two sprinkler heads reached 72°C was 209.6 seconds for #2 and 211.7 seconds for #1. The reason #1's operation time was a little late was that it was located near the window, so it was confirmed that the temperature rise was slow.

(2) In scenario 2, it was confirmed that the time when the two sprinkler heads reached 72°C was operated at 212.5 seconds for #2 and 215 seconds for #1. The reason #1's operation time was a little late was that it was located near the window, so it was confirmed that the temperature rise was slow.

(3) In scenario 3, it was confirmed that the time when the two sprinkler heads reached 72°C was operated at 213.4 seconds for #2 and 216.1 seconds for #1. The reason #1's operation time was a little late was that it was located near the window, so it was confirmed that the temperature rise was slow.

(4) In scenario 4, it was confirmed that the time when the two sprinkler heads reached 72°C was operated at 222.6 seconds for #2 and 224.2 seconds for #1. The reason #1's operation time was a little late was that it was located near the window, so it was confirmed that the temperature rise was slow.

As a result of analyzing the operation time of the sprinkler head for each scenario, it was confirmed that the lower the RTI value, the faster the operation time, and in the case of Scenarios 2 and 3, the change of the RTI value is not significant, either. Also, the reason why the sprinkler head in the same position did not operate at the same time was that the sprinkler head near the window position was slower.

Therefore, it was confirmed that the sprinkler head with a low RTI value should be used in places with high risk when a fire occurs, and that the sprinkler head should be installed in a position where the wind effect is insignificant.

For future research, it is necessary to study the effect of sprinkler systems on the slope through a study on the change of operating time when sprinkler systems with the same RTI value are installed at a slope..

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DOI: https://doi.org/10.15379/ijmst.v10i1.1433