International Journal of Advanced Smart Convergence Vol.10 No.4 117-123 (2021)
http://dx.doi.org/10.7236/IJASC.2021.10.4.117

IJASC 21-4-15

An Analysis of Working Hours by Type of Sprinkler Head Used at Indoor Gymnasiums

[1]Jae-Cheon, Ahn, [2]Ha-Sung, Kong

[1]Master student, Dept. of Fire and Disaster Prevention, Woosuk Univ., Korea
[2]Associate professor, Dept. of Fire and Disaster Prevention, Woosuk Univ., Korea.
E-mail: 119wsu@naver.com

Abstract

This study aims to analyze working hours of sprinkler heads when a fire occurs at an indoor gymnasium while sprinkler heads are installed in division of standard response type, special response type, and earlier response type. The fire scenario was designed under the assumption that the fire started from overheating of a heater in the indoor gymnasium has transferred on to a couch to spread. The analysis on the operation time of the standard response type sprinkler head, the special response type sprinkler head and the early response sprinkler head was conducted. The result showed that, in case of fire in a gymnasium, the time for opening of the heat sensor due to the heat from the fire varies by the type of the sprinkler head. When a special response type sprinkler is installed, it worked below the assessment standards. When an early response sprinkler head is installed, it worked appropriately according to assessment standards. Based on the results, we found that sprinkler heads will work properly when installed according to design relevant to laws and regulations. This means that there is a limit in installation of sprinkler heads based on the existing law-based design as for indoor gymnasiums. Again, we conclude that if sprinkler heads are installed based on design made through laws and regulations, more time will be needed for operation, making it highly likely to fail to stop a fire at an earlier point of time.

Keywords: *Indoor Gymnasium, Special Type, Early Response Type, Design Based on Laws and Regulations, Earlier Extinguishment*

1. INTRODUCTION

It is highly likely to increase loss of human lives and properties if a fire occurs at an indoor gymnasium which is a multi-purpose, large space due to rescue of audience of games and delayed fire extinguishing. However, safety measures to fires are poor and various risk factors relevant to the facility are increasing[1]. Fires which cause a lot of losses of human lives occur when there is a big fire while there is no proper working of sprinkler facilities and their original functions won't work, which leads to even bigger fires, based on a research[2]. The rapidly changing society is characteristic of rapid development of construction materials, landmark elements

Manuscript Received: October. 21, 2021 / Revised: October. 24, 2021 / Accepted: October. 28, 2021
Corresponding Author: 119wsu@naver.com
Tel: +82-63-290-1686, Fax: +82-63-290-1478
Associate professor, Dept. of Fire Protection and Disaster Prevention, Woosuk Univ., Korea

in architecture and cities, and lack of capacity of cities and there are so many tools inducing more fires such as flammables that answer to the sizes of buildings. Thus, behind the spectacular appearance, there are so many chances of loss of human lives and a great amount of properties[3]. As the smoke filling space is large, if stratification of smoke is not diffused, in the larges space, the people inside the building will suffer for a long time from smoke, At the same time, the time length for smoke to go down in the entire space becomes relatively long, which makes it hard to cause flashover. This is an advantageous environment for evacuation and safety[4].

A fire simulation is conducted with Pyrosim program which directly models 00 indoor gymnasium located in oo city, oo Province. If a fire occurs at a gymnasium, sprinkler heads can be installed by type. This is to cope with fires when the environment is open to heat.

Jongchil Yoon et al.[5] (2019) aimed to reduce concentration of toxic gases and increase visibility by capturing lot of by-products of combustion for performance-based design strong against toxic gases and smoke in order to secure safe evacuation, increase time to stay and minimize loss of human lives.

Daehyeon Choi et al.[6] (2020) compared and analyzed response times of sprinklers proximate to columns when air conditioners and fans worked to release smoke. This was based on the revised installation standards per running time of sprinkler heads proximate to columns. Thus, they covered the current fire safety standards and revised installation standards by comparing and analyzing.

Hyochan Jin[7] (2020) aims to analyze upward head opening and downward head opening to observe sprinkler head system for the fire-extinguishing water to enter into the fire center and to easily control a fire through the results of earlier fire extinguishment.

Seonghwa Eo[8] (2014) compared and analyzed the differences of technologies of other countries and Korea and aimed to explore the problems with the current sprinkler head technologies and improve them.

Jongchil Yoon et al.(2019) and Daehyeon Choi(2020) compared and analyzed sprinkler head response time when fans work as concentration of toxic gases decrease and visibility improves when the by-products of combustion are captured quickly.

Hyochan Jin(2020) and Seonghwa Eo(2014) see that earlier fire extinguishing takes place in a simulation analysis to easily control fires. They improve the problems with sprinkler technology standards by analyzing technology standards of foreign countries and Korea.

Mainly, the previous studies aimed to capture the by-products of combustion quickly when a fire occurs, reduce toxic gases, easily control a fire based on earlier fire extinguishment with a simulation analysis and improve problems with sprinkler technology standards. However, there is the need to study the characteristics of a fire by analyzing working hours by running various types of sprinkler heads as if a fire occurs in a public indoor gymnasium used by many people, smoke, heat, CO and CO_2 must be suppressed.

This study aims to improve indoor structure by converting sprinkler head installation in order to minimize damage done to the population in movement within the building if a fire occurs in a public indoor gymnasium. If a fire occurs, extinguishing shall take place basically while a fire simulation program shall help us to identify diffusion of the fire and analyze the amount and pressure of release of sprinkler heads installed indoors. The drawing of the actual 00 indoor gymnasium was referred to for modeling. Characteristic variables by type of sprinkler heads shall be entered to minimize damages from a fire with the opening of a head when a fire occurs. This way, we will be able to derive ways of improvement.

2. RESEARCH MODEL

The models for this study, as shown in **Figure 1**, sprinkler heads will be installed based on the laws pertaining to fire safety standards (NFSC 103) relevant to sprinkler facilities by categorizing sprinkler heads installed in an indoor gymnasium. Fire modeling was conducted covering part of the gymnasium through Pyrosim program

and working hours by sprinkler head were analyzed. Sprinkler heads were divided into standard response type, special response type and early response type and working hours were analyzed to assess safety.

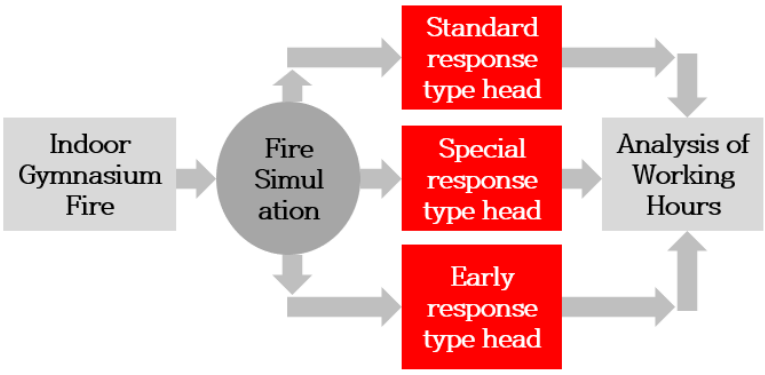


Figure 1. Research Model

3. FIRE SIMULATION

3.1 Setup of Fire Simulation

The structure to be modeled via computer programs was allowed to be constructed in 2003 and finally constructed in 2004. This is XX Gymnasium which is a convenience facility for the residents as equipped with exercise and gathering facilities. The area is 2,657.82 m^2 while the building-to-land ratio is 14.92% and the total floor area is 3,028.71 m^2. The structure consists of the first basement levels and two floors on the ground. The first basement area is 326.67 m^2, consisting of an electricity room and a machine room. The area for the first floor is 2,373 m^2 and consists of exercise and gathering facilities while the second floor is 1,021.26 m^2, consisting of audience seats, a projection room and a lighting room. On the right of the front of the first floor, there are two entrance doors and connecting passages. Indoors, there are a stage, and mobile baseball facilities while on the second floor, there are 1,000 audience seats and a high ceiling as high as 10 m.

The **Figure 2** is the entire structure of the first floor. A half of 198.9 m^2, the health facility area was subject to a fire simulation.

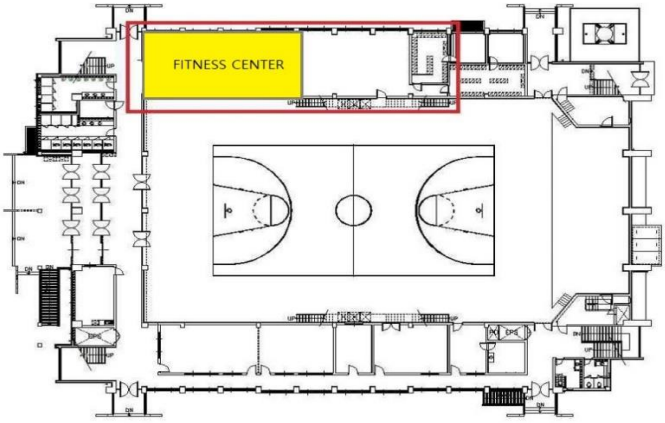


Figure 2. Design of Indoor Gymnasium Research Model

3.2 Construction of a Fire Simulation

Although a fire has never occurred, we shall predict the properties of a fire, establish human safety and disaster measures and get prepared for a fire. The technology to identify and improve human and building safety based on the experiences so far and computer data by observing time length as well as fire properties and evacuation courses is called a fire simulation[9]. Fire simulations are divided into statistical model covering statistical positions of risk assessment of a structure fire and mathematical model based on thermodynamics and hydromechanics. The latter consists of FAST (ZoneFire Model) and FDS (Field Model) [10]. Representative codes of the Field Model was made by BFRL (Building and Fire Research Laboratory) of the NIST (National Institute of Standards and Technology). The former models phenomena such as heat, pyrolysis, flame diffusion, smoke movement and fire growth[11] and visualizes and interprets movements of the by-products such as heat and smoke arising from a fire through Smokeview

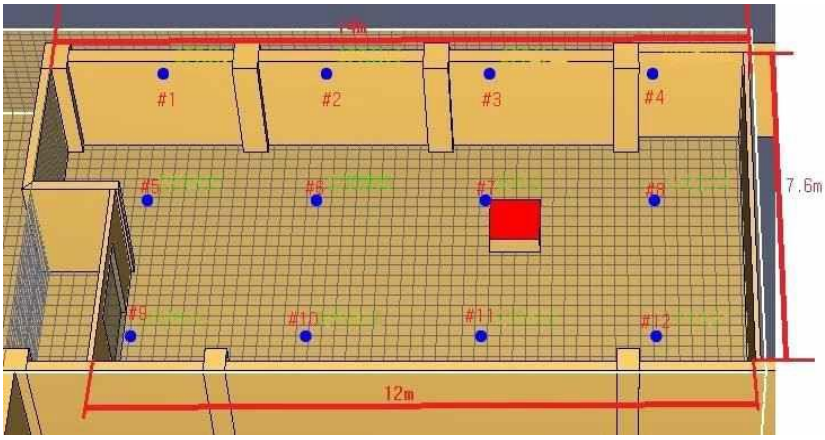


Figure 3. Structure of Indoor Gymnasium

Figure 3 shows the installation of sprinkler heads at 2.3 m of horizontal distance based on the sprinkler facility fire safety standards and other installation standards. The distance between two sprinkler heads is 3.25 m based on the calculation using 2.3 m. The head radius was applied to install 12 sprinkler heads based on the standards. On the right of the center, the source of fire was installed and time for head opening when there was a fire was measured.

4. FIRE SCENARIO

4.1 Scenario Structure

As for the scenario, a fire occurred from a heater located in the health site, which went over to a sofa. Scenario 1 was to analyze working hours of standard response type while scenario 2 and scenario 3 were to analyze special response type and early response type, respectively.

Table 1. Scenario

Scenario	Composition
Scenario 1	Working hours of standard response type sprinkler head when a fire occurs at the health site
Scenario 2	Working hours of special response type sprinkler head when a fire occurs at the health site

Scenario 3	Working hours of early response type sprinkler head when a fire occurs at the health site

4.2 Input Variables and Input Value for Fire Simulations

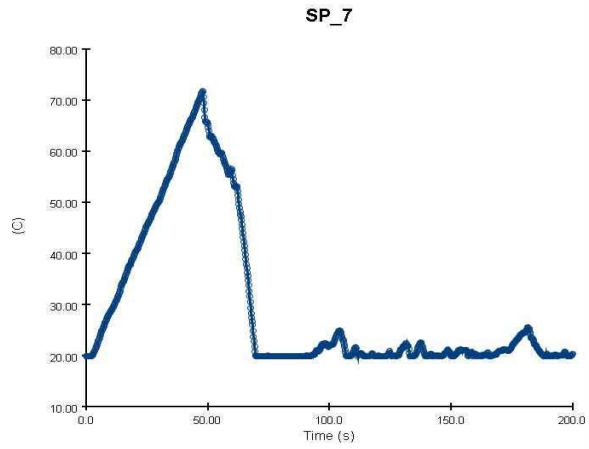
In order to calculate time lengths up to the temperature rise enabling working of sprinkler heads by type when a fire occurs at an indoor gymnasium, response materials, mesh cell sizes, working temperatures, RTI and heat release rates were placed as input values in **Table 2**. The sofa material was WOOK-Oak while mesh cell sizes were 0.25 m x 0.25 m x 0.15 m. The working temperatures for sprinkler heads were 72℃, 70℃ and 68℃ for standard response type, special response type and early response type, respectively. RTI values, which is the response index of sprinkler heads were 350 between 80 and 350, 80 between 50 and 80 and 50 when it is 50 or below for standard response type, special response type and early response type, respectively. HRR value, the heat release rate was 1,000 kW/m^2.

Table 2. Input Value of Fire Simulation

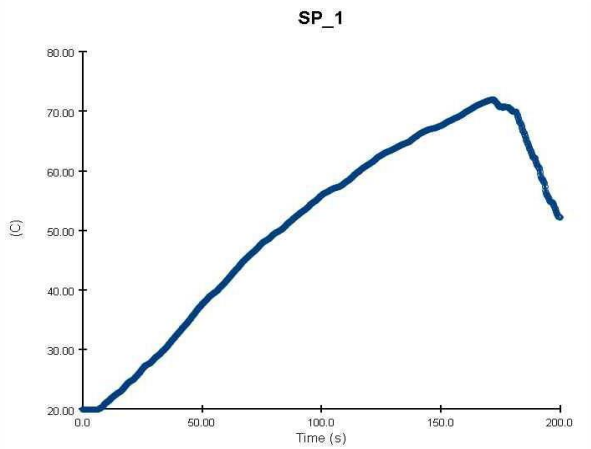
Type	Input Value	
Response material	WOOK_Oak	
Mesh cell size (m)	0.25 x 0.25 x 0.15	
Working temperature (℃)	Standard response type sprinkler head	72
	Special response type sprinkler head	70
	Early response type sprinkler head	68
Response Time Index(RTI) ($\sqrt{}$(m.s))	Standard response type sprinkler head	350
	Special response type sprinkler head	80
	Early response type sprinkler head	50
Heat Release Rate (kW/m^2)	1,000	

5. RESULTS and DISCUSSION

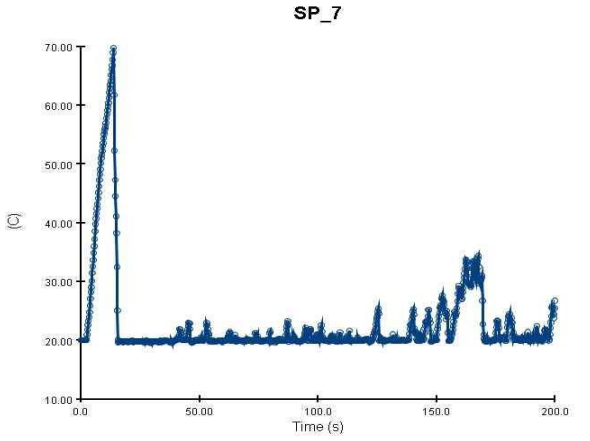
As shown in **Figure 4**, time for opening of sprinkler head differed by heat when a fire occurred at a gymnasium. In 4(a), standard response type head opened at 48 seconds for #7 and at 172 seconds for #1. In 4(b), special response type head opened at 14 seconds for #7 and at 94 for #9. In 4(c), early response type head opened at 9 seconds for #7 and at 74 seconds for #9.



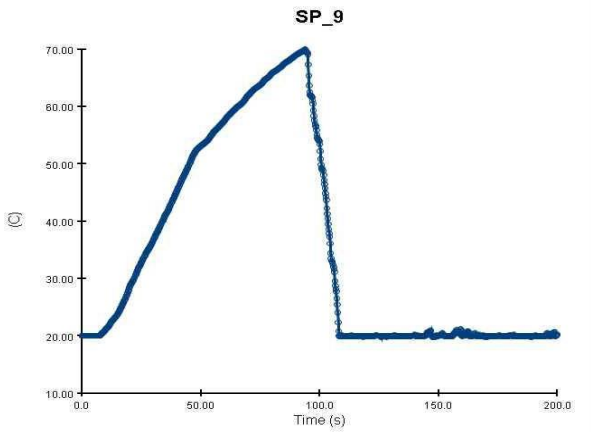
(a) Scenario 1 #7



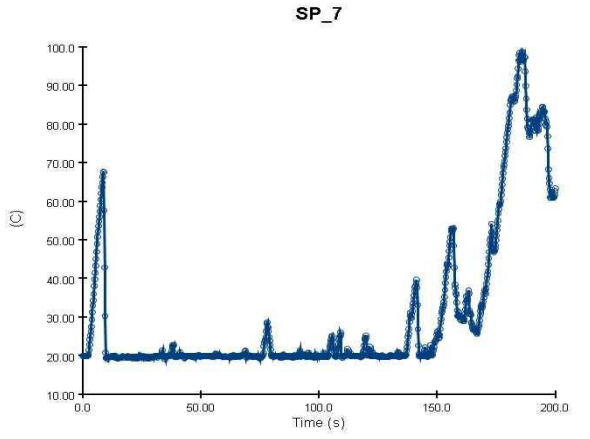
(a) Scenario 1 #1



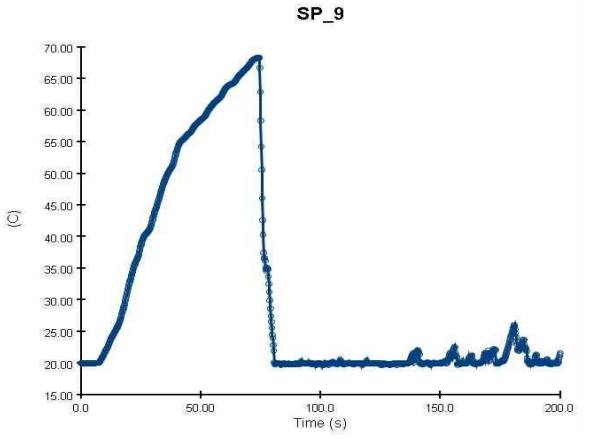
(b) Scenario 2 #7



(b) Scenario 2 #9



(c) Scenario 3 #7



(c) Scenario 3 #9

Figure 4. Temperature at Opening of Sprinkler Head by Type

As for Scenario 1, it is standard response type head. #5 and #9 opened late. It took 14 seconds in scenario 2. As for scenario 3, it opened at 9 seconds, which is faster than scenario 2. Sprinkler facilities installed at a gymnasium are characteristic of delayed opening time as the installed ones are preaction sprinkler facilities.

If two detector circuits work at the same time, the electronic valve will work, which will send water to the sprinkler pipe. This opens the heat collector of the head. If opened within ten seconds as shown in scenario 3, preaction sprinkler facilities will work. In this case, even if there is a delay, the fire won't become more serious.

6. CONCLUSION

This study analyzed the time length until working when sprinkler heads were installed at an indoor gymnasium in division of standard response type, special response type, and early response type. The results are as follows.

(1) As for standard response type, the head opened at 48 seconds for #7 while it opened at 172 seconds for #1.

(2) As for special response type, the head opened at 14 seconds for #7 and it opened at 94 seconds for #9.

(3) As for early response type, the head opened at 9 seconds for #7 while it opened at 74 seconds for #9.

For a future research, it is necessary to identify which type of sprinkler head is appropriate for indoor gymnasiums by making assessment standards for sprinkler heads to work at indoor gymnasiums.

REFERENCES

[1] Kwanghyun Kim, Junho Hong, Yongho Lee, Jungha Hwang, "A Study on Assessment of Evacuation Safety based on Case Studies Involving Indoor Gymnasiums" Korea Life and Environment Journal, p.433, 2013.

[2] Seong-hyeon Kim, "A Study on Ways to Improve the Standards for Prevention for Water Sprinkling with Domestic Sprinkler Heads", Department of Fire Extinguishment, Graduate School of Industrial Information, Mokwon University, p.1, 2019.

[3] Joonhae Jeong, "An Analysis of Types of Movement Disabilities of Sprinkler Facilities based on Self-inspection of Fire-extinguishing Faciliteis", Department of Disaster Prevention Engineering, Graduate School of City and Science, University of Seoul, p.1, 2011.

[4] Changhoon Chae, "A Comparative Analysis of Simulation on Operation Characteristics by Height of Installation of Sprinkler Heads," Department of Fire-extinguishing Engineering, Graduate School of Environment Design, Gachon University, p.35, 2012.

[5] Dongchil Yoon, Yongseop Choi, Hakjoong Kim, "A Study on Removal of Smoke and Toxic Gases through Sprinkler Head Working" Proceedings for the Korea Disaster Prevention Symposium, p.165.

[6] Daehyeon Choi, Jaemoon Lee, Sehong Min, "A Study on Analysis of Working Time of Sprinkler Heads Proximate to Column based on Fire simulations," Proceedings for the Korea Disaster Prevention Symposium, p.271.

[7] Hyochan Jin, "A Study on Downward Head Opening Time of Vertical Sprinkler Head System", Department of Fire-extinguishing and Disaster Prevention, Graduate School of Engineering, Kyonggi University, p.2, 2020.

[8] Seonghwa Eo, "A Study on Improvement of Technology Standards for Korean Sprinkler Heads", Department of Fire Extinguishment, Graduate School of Industrial Information, Mokwon University, p.2, 2014.

[9] Jaeseong Yoon, "An Interpretation of Fires in High-rise Apartments Using a Fire Simulation Program" Department of Safety Engineering, Graduate School of Industry, Chungbuk National University, p.19, 2010.

[10] Seonhwan Gu, "A Study on Fire Characteristics of Dual Skin Structure Using a Fire Simulation," Master's Thesis, Department of Fire Extinguishment, Graduate School, Dongshin University, p.20, 2013.

[11] Sangmoon Kim, Sangyeol Yoon, Gyongcheon Kim,"Simulation", Korea Visualization Information Proceedings, 4(1), p.11, 2006.