



Discussion on active Fire Protection Systems for Data Center

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Abstract. In the era of rapid information technology development, data centers are crucial for modern society's operation, housing valuable equipment and vast amounts of data. A fire in data centers would lead to immeasurable losses, making active fire protection systems essential. The existing researches on data center fire suppression systems are reviewed. Some relevant design specifications and standards are listed and discussed. An applicability analysis of different fire protection systems, including gaseous clean agent systems, water mist fire extinguishing systems, and water sprinkler systems, is carried out. Gaseous clean agent systems are highly recommended but have limitations such as being "one-shot" and having space restrictions. Water mist systems have advantages of less damage to electronic equipment and better fire extinguishing effect under certain conditions, but also share some drawbacks with gaseous systems. Water sprinkler systems have no space limitations but may cause damage to the information technology equipment (ITE) by improper design or operation. It has been concluded that rooms for storing valuable data or high value ITE should be small or medium sized, and gaseous fire suppression systems are suitable for this situation. For large space ITE rooms, preaction sprinkler systems could be considered, along with the improvement of related detection and control systems and drainage facilities.

Keywords: Data Center, Fire Protection System, Design Specifications, Gaseous Clean Agent System, Water Mist Fire Extinguishing System, Water Sprinkler System.

1 Introduction

In the context of the burgeoning development of information technology, data centers have emerged as the important infrastructure underpinning the operations of modern society. These centers are home to a vast array of high value electronic equipment and colossal volumes of data. In the event of a fire, the resulting losses would be immeasurable[1]. Active fire protection systems, as a vital approach to fire prevention and response, assume an irreplaceable role in safeguarding the security of data centers. They can not only protect equipment and data but also ensure business continuity and meet regulatory requirements.

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There has been a body of research focusing on fire suppression systems designed for use in data center, especially for the information technology equipment. Ji et al.[2] implemented an automated sprinkler system as the fire suppression system for the primary data center of China Railway. Zhu et al.[3] designed and analyzed the gas fire extinguishing system, water mist fire extinguishing system and preaction sprinkler system used in the computer room of the data center. It has been concluded that gaseous fire extinguishing system is the most commonly used fire extinguishing system in China. The preaction sprinkler system has the characteristics of lowest total investment and simple installation and maintenance. However, the equipment could be greatly damaged by water by improper design or operation. The water mist fire extinguishing system is complicated, the installation requirements of equipment are high, and it is less used in the actual project at present. Li[4] conducted numerical simulations to study fire behavior and fire extinguishing effect of fire detection tube fire extinguishing system in small confined spaces within equipment, and it was found that fire detection tube fire extinguishing system is effective in extinguishing fires during their initial stages. Regardless of the fire suppression technology employed, the timely detection of a fire is paramount to its successful extinguishment. Innovative technologies, such as the Internet of Things (IoT), should be integrated to safeguard data center rooms where the potential for significant loss due to fire is high[5-7]. It could be effectively combined with gas-based fire suppression systems or automatic sprinkler systems to enhance safety measures.

Although the probability of a fire originating from digital equipment, such as servers and storage units, is low due to the limited energy available during any fault and the small amount of combustible material inside the equipment[8], the potential risk can still be substantial considering the huge loss caused by fire in data center. Therefore, It is worth further discussion for choosing the appropriate fire extinguishing system for data center.

2 Specifications for Fire Extinguishing Systems for Data Center

Currently, the design of fire extinguishing systems for data center can refer to several specifications and standards including *Standard for the Fire Protection of Information Technology Equipment (NFPA 75-2020)*, *Standard on Clean Agent Fire Extinguishing Systems (NFPA 2001)*, *Telecommunications Infrastructure Standard for Data Centers (TIA-942-2005)*, *Standard on Water Mist Fire Protection Systems (NFPA 750)*, *Standard for the Installation of Sprinkler Systems (NFPA 13)*, *Code for Fire Protection Design of Buildings (GB 50016-2014, 2018 edition)*, *Code for Design of Data Centers (GB 50174-2017)*, *Code for Design of Sprinkler Systems (GB 50084-2017)*, *Technical Code for Water Mist Fire Extinguishing Systems (GB 50898-2013)*, *Code for Design of Gas Fire Extinguishing Systems (GB 50370-2005)*. These specifications and standards are listed in Table 1.

Table 1. Specification system for fire extinguishing for data center

Specifications systems	Name of specifications	Remarks
Fire protection design standards	<i>NFPA 75-2020</i>	
	<i>TIA-942-2005</i>	
	<i>NFPA 2001</i>	
Fire protection facilities standards	<i>GB 50016-2014,2018 edition</i>	
	<i>GB 50174-2017</i>	aligned with <i>TIA-942</i>
	<i>GB 50084-2017</i>	aligned with <i>NFPA 13</i>
	<i>GB 50898-2013</i>	aligned with <i>NFPA 750</i>
	<i>GB 50370-2005</i>	aligned with <i>NFPA 2001</i>

3 Applicability Analysis of Fire Extinguishing Systems for Data Center

3.1 Gaseous Clean Agent Systems

Gaseous fire suppression systems are the most recommended fire extinguishing system for data center according to *NFPA 2001*, *TIA-942*, *NFPA 75-2020*, *GB 50016-2014 (2018 edition)*, *GB50174-2017* and *GB 50370-2005*. The present research results[3] also show that the clean reagent fire suppression systems are advanced solution designed to provide the highest level of fire protection for sensitive environments such as computer rooms, data centers, and associated electrical and mechanical rooms. These systems are particularly well-suited for protecting critical infrastructure where traditional water-based systems (like sprinklers) could cause significant collateral damage.

Gaseous fire suppression systems however also has some limitations. Firstly, they are "one-shot" systems. If the fire is not fully extinguished during the initial discharge, the system cannot be immediately reused, and thus the fire could spread to other rooms. Secondly, gaseous fire suppression systems require effective room sealing to maintain gas concentration for enough time to extinguish the fire. Based on *GB 50016-2014 (2018 edition)*, in a scenario where the data center room contains no other flammable materials except the ITE, and the room space is quite large, it may be more efficient to use localized fire protection systems rather than installing a large automatic fire extinguishing system to protect the entire room. The linear heat detection systems which also belong to the gaseous clean agent systems are are typical localized fire protection systems. They are designed to detect fires by sensing temperature changes along the length of the tube. However, their requirement for a enclosed cabinet space may conflict with the need for proper airflow and cooling in ITE cabinets. This inconsistency makes fire detection tubes unsuitable in many situations. Thirdly, there are specific limits on the maximum area and volume of the room for using gaseous fire suppression systems according to *GB 50370-2005*. For a pipe network gaseous fire suppression system, the area of a single protection area should not exceed 800 m², and the volume should not exceed 3600 m³. As for the prefabricated gaseous fire suppression system, the limitations on the maximum area and volume of the protected room are more strict. The reason behind these limits is that in overly large spaces, it's extremely challenging to

rapidly achieve a uniform distribution of the gaseous clean agent concentration, and it can lead to a delay in the fire suppression time. In severe cases, it may even result in the failure of fire extinguishing.

3.2 Water Mist Fire Extinguishing System

The water mist fire extinguishing system applied in the data center room exhibits remarkable advantages in multiple dimensions. These include ensuring the safety of personnel, safeguarding equipment integrity, being environmentally friendly, featuring relatively low initial investment, and having manageable maintenance costs. However, the water mist fire extinguishing system shares two disadvantages with the gaseous fire suppression system. Firstly, the enclosed cabinet space is required. Secondly, there are also limitations on the maximum volume of the protected space. According to *GB 50898-2013*, for a pump supplied system, the volume of a single protected area should not exceed 3000 m³, while for a self-contained system, it should not exceed 260m³. Referring to the test results of the International Maritime Organization (IMO), the volume of the protection area in the physical fire simulation test is generally no more than 3000 m³ for the pump supplied system. The effectiveness of the system must be verified through further tests when exceeding this volume. Given the limited continuous water supply capacity of the self-contained system, the maximum volume of a single protective zone is required to be smaller than that of the pump supplied system.

3.3 Water Sprinkler Systems

According to *NFPA 75-2020*, sprinkler systems are allowed in ITE rooms. However, their installation must be based on a comprehensive consideration of the building's specific conditions and the results of a risk assessment to determine whether to install and how to install them. If a sprinkler system is already installed in the building, the ITE room should be incorporated into this system. In cases where the building lacks a sprinkler system, a risk assessment is essential to decide whether a separate installation of water sprinkler system is necessary. Based on *TIA-942-2005*, when data centers can afford higher reliability and better hazard mitigation capabilities, a preaction sprinkler system offers a more advanced level of protection. In accordance with *GB 50174-2017*, automatic sprinkler systems can be installed in Class A data centers with data backup, as well as in the ITE rooms of Class B and Class C data centers.

Moreover, *NFPA 75-2020* indicates that a prevalent misapprehension that electronic devices exposed to water and moisture will incur permanent damage. In actuality, water that is sprayed, splashed, or dripped onto electronic devices can be readily removed. Even electronic devices that have been fully submerged in water are potentially repairable. Nevertheless, in all cases of water damage, taking immediate countermeasures is crucial. Most importantly, all power sources of the device should be cut off before the water spraying of the sprinkler system.

Compared with the gaseous fire suppression system and the water mist fire extinguishing system, the sprinkler system has no limitations on the maximum area or volume of the protected area. Moreover, the water supply can be rapidly replenished by

fire trucks, enabling continuous firefighting operations and reducing the likelihood of fire spread. As long as relevant factors are fully considered in the design, such as cutting off the power supply of ITE before fire extinguishing operation automatically, and improving the drainage measures in the ITE rooms, the preaction sprinkler systems can be considered for extinguishing fires for the ITE rooms in data centers.

3.4 Applicability of Fire Extinguishing Systems for Data Center

The recommended active fire protection systems of three relevant specifications or standards are shown in Table 2.

Table 2. The recommended active fire protection systems for different ITE room

ITE room characteristics		Active fire protection systems		
		Gaseous Clean Agent Systems	Water mist fire extinguishing system	Water sprinkler Systems
Rooms storing valuable data or high value ITE	$A \leq 800 \text{ m}^2$ and $V \leq 3000 \text{ m}^3$	R	Ac	
	$A \leq 800 \text{ m}^2$ and $3000 \text{ m}^3 \leq V \leq 3600 \text{ m}^3$	R	U	
	$A \leq 800 \text{ m}^2$ and $V \leq 3000 \text{ m}^3$	R	Ac	Ac under certain conditions
Other ITE rooms	$A \leq 800 \text{ m}^2$ and $3000 \text{ m}^3 \leq V \leq 3600 \text{ m}^3$	R	U	
	$A > 800 \text{ m}^2$ or $V > 3600 \text{ m}^3$	U	U	

Note: R, Ac and U stands for recommended, acceptable and unacceptable respectively. Ac under certain conditions indicates that the water sprinkler systems can be adopted when the power supply of ITE before fire extinguishing operation can be cut off automatically, and the drainage facilities in the ITE rooms are fully equipped.

A and V stands for room area and room volume respectively.

4 Conclusions and Recommendations

To mitigate the risk of fire propagation from adjacent areas to valuable equipment, the enclosures utilized for storing valuable data or high value ITE shall be positioned within a room with a maximum area of 800 m^2 and a maximum volume of 3600 m^3 . The gaseous fire suppression systems should be installed in the rooms. A smaller space facilitates the swift dispersion of the gaseous clean agent, enabling the achievement of the designed fire extinguishing concentration. Moreover, the gaseous clean agent inflicts minimal damage on the ITE, thereby being more conducive to the post-fire restoration of the equipment. For rooms with a large space, a preaction sprinkler system is worth for consideration. The automatic fire detection system, the fire alarm system and automatic ITE control system should be improved to ensure that the ITE have been turned off before the sprinkler system starts, so as to achieve timely fire detection, effective

fire control and less damage for ITE during fire extinguishing. At the same time, the drainage system in the ITE room needs to be improved so that the water can be drained in time after a fire, enabling the equipment to resume operation as soon as possible.

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