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# Fire Extinguishing Performance Evaluation of Perfluorohexanone Materials in Electrical Distribution Systems

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**Abstract** With the increasing emphasis on fire safety requirements, perfluorohexane fire extinguishing agents have found innovative applications in power distribution systems due to their unique properties. This article discusses the characteristics and advantages of perfluorohexane materials, as well as the application forms of perfluorohexane in power distribution systems. Based on this, a fire extinguishing test was conducted using a specific power distribution system as an example, simulating the initial stage of an indoor power distribution system fire. Gas concentrations of CO, NO, $SO_2$, and $O_2$ were measured before and after the fire, and the patterns of temperature and thermal radiation changes at different locations within the fire scene were analyzed. Perfluorohexane fire extinguishing agent was used to suppress the fire in the power distribution system. The test results indicate that in distribution system fires, perfluorohexane extinguishing agents have a fast extinguishing speed, capable of quickly extinguishing fires within 8 seconds, with significant heat absorption and cooling effects, achieving a cooling rate of up to 97.8°C/min. the concentrations of several gases decreased by 65.4% to 100% within a short time, and it did not cause any damage to the power distribution system. This achieved controllable fire suppression and improved extinguishing efficiency in power distribution system fires, representing a new approach to the suppression of initial fires in power distribution systems.

**Index Terms** perfluorohexane, power distribution system, fire extinguishing performance evaluation, fire extinguishing test

## I. Introduction

The power distribution system is the energy supply system in modern industrial, commercial, and residential buildings, supporting daily life and operational activities. However, over time, power distribution systems may develop fire hazards due to equipment aging, inadequate maintenance, or overload, posing significant risks to building safety. In the event of a fire, this could severely threaten the safety of personnel and property [1]-[3]. In distribution systems, the use of traditional water-based fire extinguishing agents poses an electric shock risk; materials in distribution system equipment release a large amount of latent heat when ignited, leading to re-ignition even after the fire extinguishing agent has been applied; and some spaces in distribution systems are narrow with complex equipment interconnections, requiring rapid and effective fire suppression [4]-[6]. Additionally, some fire extinguishing agent materials may react with distribution system environments and equipment materials such as iron and zinc, causing corrosion [7]. Therefore, selecting appropriate fire extinguishing materials is critical.

Among various gas fire extinguishing agents, Rajput and Saikia [8] compared argon, nitrogen, Novik 1230, and halon, finding that halon outperforms all other agents in fire extinguishing effectiveness but is not permitted for general applications. Rohilla et al. [9] introduced a concentrated aerosol fire extinguishing system, an effective halon alternative with excellent properties such as zero ozone depletion potential, low global warming potential, minimal space requirements, no oxygen depletion, and cost-effectiveness. It can be used for fire extinguishing operations in scenarios involving distribution systems. However, aerosol-based fire extinguishing agents have poor insulation properties and leave particulate residues, posing risks of heavy metal contamination [10]. Additionally, Zhang et al. [11] conducted numerical simulations on the fire extinguishing and cooling effects of heptafluoropropane fire extinguishing agents on electrical equipment. The heptafluoropropane spray resulted in a final temperature of 270 K, with the optimal safe distance between the spray nozzle axis and the electrical equipment being 0.8 meters. However, as a widely used fire extinguishing material, heptafluoropropane leaves hydrofluoric acid residues and can produce toxicity at high temperatures [12]. Perfluorohexane, on the other hand, has extremely low environmental hazards and high fire extinguishing efficiency, making it a widely studied alternative to halons.

Perfluorohexane is a colorless, transparent liquid with the molecular formula C6F12O. Under low-pressure conditions, perfluorohexane demonstrates superior performance advantages compared to other fire extinguishing agents due to its significantly enhanced vaporization efficiency and fire extinguishing speed. It offers excellent fire extinguishing performance, low environmental impact, and good safety, and is primarily applied in aviation, data centers, power, shipping, military, and precision equipment fire suppression systems [13]-[16]. He et al. [17] added perfluoro-triethylamine to perfluorohexane fire extinguishing agents, reducing the critical extinguishing concentration and flame core temperature for n-heptane flames. Pei et al. [18] developed an efficient, environmentally friendly, and cost-effective perfluorohexane O/W microemulsion, which significantly reduces the temperature of lithium-ion battery spray flames and can absorb harmful gases, offering better fire extinguishing performance than water mist extinguishing agents. Han et al. [19] developed core-shell-type perfluorohexane microcapsules made from sodium hexametaphosphate and gelatin, and evaluated their performance. In a closed environment, the capsules demonstrated strong combustion and explosion suppression properties and controlled release. Xing et al. [20] comprehensively evaluated the fire extinguishing performance of perfluorohexane, which has a lower minimum extinguishing volume concentration compared to other hydrofluorocarbons. Liang et al. [21] tested the fire extinguishing effectiveness of perfluorohexane extinguishing agent on a 271 Ah lithium iron phosphate battery under three temperature conditions: normal temperature, -40°C, and 85°C. The extinguishing efficiency was 11 seconds, 14 seconds, and 9 seconds, respectively, with no signs of reignition. The battery temperature remained below 90°C half an hour after extinguishing. Zhou et al. [22] evaluated the fire extinguishing effectiveness of perfluorohexane in extinguishing a 202 Ah lithium iron phosphate battery, with the flame extinguished within 2 seconds. Continuous application of perfluorohexane reduced the battery surface temperature at a rate of 0.24°C/second. Currently, there is a lack of research on the fire extinguishing performance of perfluorohexane materials in power distribution systems. As an environmentally friendly and efficient fire extinguishing agent, comprehensive research on perfluorohexane is of great significance.

The study explores perfluorohexane materials and their application forms in power distribution systems, including localized application in distribution boxes and combined distribution total flooding applications. To verify the fire extinguishing effectiveness of the new environmentally friendly fire extinguishing agent perfluorohexane on distribution system fires, a distribution system with dimensions of 0.60m × 0.80m × 2.3m was selected as the test subject. A perfluorohexane fire extinguishing test platform was established, and data loggers, high-temperature thermocouples, a heat radiation meter, an oxygen detector, and a composite gas analyzer to collect data. The distribution patterns of temperature changes in four thermocouples before and after the fire, heat radiation values, and changes in the mass concentrations of gases such as CO, NO, $SO_2$, and $O_2$ were statistically analyzed to evaluate the fire extinguishing performance of perfluorohexane materials in distribution systems.

## II. Application of perfluorohexane in power distribution systems

### *II. A. Perfluorohexane materials and their advantages*

Perfluorohexane has the chemical formula C6F12O. At room temperature, it is a liquid substance with a boiling point of 49.2°C and a saturated vapor pressure of 0.4 bar. It exhibits strong volatility and excellent insulating properties. A comparison of the performance of perfluorohexane with common fire extinguishing agents is shown in Table 1. As shown in Table 1, perfluorohexane has advantages such as low extinguishing concentration and rapid extinguishing, enabling effective fire control and suppression of fire spread. Compared to heptafluoropropane, it has a weaker greenhouse gas effect, decomposes quickly, and has a smaller impact on the climate and environment. Additionally, perfluorohexane has a high safety concentration and low toxicity, making it suitable for use in densely populated areas and meeting the safety production requirements of the power industry. After perfluorohexane is discharged as a fire extinguishing agent, carbon dioxide and IG541 may produce condensation water that adheres to equipment, potentially causing issues such as short circuits and corrosion, thereby damaging normal equipment. However, such issues do not occur when using perfluorohexane. Given its advantages of high dielectric strength, non-corrosiveness, low-carbon environmental friendliness, non-pollution, non-toxicity, excellent fire extinguishing performance, and ease of storage, perfluorohexane is well-suited as a fire extinguishing agent for the power industry.

The perfluorohexane fire suppression system is a highly efficient fire suppression system that uses perfluorohexane as the fire suppressant, controlling and extinguishing fires by spraying the perfluorohexane fire suppressant. Perfluorohexane can serve as an alternative to halon. Its chemical structure is identical to that of Novec 1230 produced by 3M Company, and it belongs to the fluoroketone family of compounds. At standard temperature and pressure, perfluorohexane exists as a colorless, odorless liquid. Due to its excellent performance and environmental friendliness, perfluorohexane has found widespread application in fire suppression. The latent heat of vaporization of perfluorohexane fire extinguishing agent is 1/25 that of water, meaning its vaporization heat is significantly lower than water's, enabling it to absorb heat around the fire source more quickly and rapidly lower the fire source's temperature. Additionally, perfluorohexane's vapor pressure is 25 times that of water, meaning it vaporizes into a gas more easily, allowing it to spread more quickly around the fire source and swiftly surround it. Perfluorohexane fire extinguishing agents primarily rely on heat absorption to achieve fire extinguishing effects. When perfluorohexane is sprayed onto the fire source, it rapidly vaporizes into a gas and forms a gas mixture with air. This mixture has a higher heat storage capacity than air itself. Therefore, it can absorb surrounding heat, rapidly lowering the temperature of the fire source and achieving fire extinguishing effects.

Table 1: The performance ratio of perfluoroethyl ketone and common extinguishing agent

| Item | Perfluoroethyl ketone | Carbon dioxide | Water mist | IG541 | Heptafluoropropane |
|---|---|---|---|---|---|
| Main extinguisher | Isolating oxygen, absorbing heat and cooling | Isolating oxygen | Isolating oxygen, absorbing heat and cooling | Isolating oxygen | Isolating oxygen |
| Extinguishing concentration(%) | 4~6 | 34 | - | 37~43 | 8~10 |
| Extinguishing time/s | ≤10 | ≤60 | ≥900~1 800 | ≤60 | ≤10 |
| Greenhouse gas effect | 1 | 1 | - | 0 | 3800 |
| Decomposition time | About five days | - | - | - | 36.5 years |
| Non-toxic reaction concentration(%) | <10 | <5 | - | <43 | <9 |
| Safety allowance(%) | 67~150 | The standard extinguishing concentration is suffocated | - | 7~13 | <13 |

Perfluorohexane fire extinguishing agent can extinguish Class A, B, C, and E fires, i.e., fires involving solids, liquids, gases, and electrical equipment. It is particularly effective for extinguishing fires involving electrical equipment, as it does not cause short circuits or damage to electrical equipment and does not cause secondary pollution to electrical equipment. This makes perfluorohexane fire extinguishing agent widely used in fields such as power, telecommunications, and computers. Perfluorohexane fire extinguishing agent possesses the heat storage capacity of existing commercial halon alternatives, meaning it can absorb more heat and release it during the extinguishing process, thereby maintaining a longer-lasting extinguishing effect.

### *II. B. Applications of perfluorohexane materials*

As distribution systems become increasingly complex, the power consumption and electricity usage of equipment have surged, making the fire risk in distribution systems a serious concern. Due to the high density of electrical equipment and complex operating environment within distribution systems, a fire could have catastrophic consequences. Perfluorohexane fire extinguishing agents offer an efficient, safe, and environmentally friendly fire suppression solution for distribution systems. Their primary applications in distribution systems are as follows.

#### II. B. 1) Local application

In power distribution systems, the localized application of perfluorohexane fire extinguishing agents is of great significance. Localized application enables precise fire extinguishing in specific areas, improving extinguishing efficiency, reducing the amount of extinguishing agent used, and minimizing the impact on equipment and the environment.

#### II. B. 2) Application of distribution boxes

Distribution boxes play a crucial role in distributing electrical power within the power distribution system of a finished oil storage facility. The application of perfluorohexane fire extinguishing agents in distribution boxes also plays a significant role.

Perfluorohexane fire extinguishing agents can rapidly respond to fires in distribution boxes, triggering and activating the fire suppression system immediately. For example, when a fire is caused by overloading, short circuits, or other issues within the distribution panel, the perfluorohexane fire suppression system can suppress and extinguish the fire source in an extremely short time, effectively preventing the spread of the fire.

Perfluorohexane fire extinguishing agents can rapidly lower the temperature at the fire scene, suppress flame combustion, and achieve efficient fire suppression. After extinguishing the fire, there is almost no residue left behind, eliminating the need for cleanup and reducing equipment downtime and maintenance costs.

Additionally, perfluorohexane fire suppression systems are typically equipped with sensitive detection and control systems that can automatically detect fires and swiftly initiate the fire suppression process, providing 24/7 uninterrupted protection for the safety of distribution panels. For example, some perfluorohexane fire extinguishing systems use linear detection tubing for fire detection, featuring a simple structure, easy installation, and high cost-effectiveness, making them particularly suitable for fire protection in small spaces such as distribution boxes. Figure 1 illustrates the application of perfluorohexane fire detection tubing in distribution boxes.

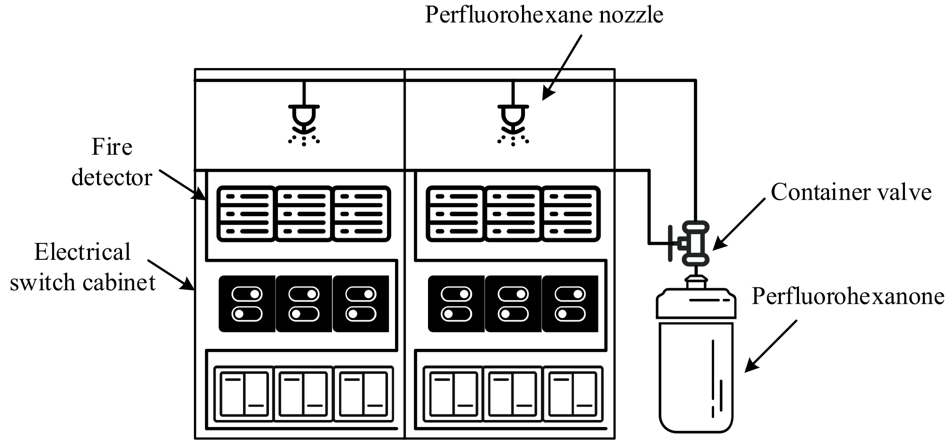


Figure 1: The application of the perfluoroethyl ketone fire pipe in the distribution box

**II. B. 3) Combination allocation total flooding application**

The combined distribution and total flooding application of perfluorohexane fire extinguishing agents in power distribution systems holds significant practical significance and application value. This application method enables comprehensive fire suppression coverage across a large spatial area, providing more reliable fire safety protection for power distribution systems. The total flooding application of perfluorohexane fire extinguishing systems in transformer rooms is illustrated in Figure 2.

In distribution rooms, the total flooding application of perfluorohexane fire extinguishing agents also offers numerous advantages. First, perfluorohexane fire extinguishing agents can quickly extinguish initial fires within seconds, effectively preventing the spread of flames. For example, when a distribution room catches fire due to causes such as electrical leakage, short circuits, overloads, or excessive contact resistance, the perfluorohexane fire suppression system can respond quickly, rapidly lowering flame temperatures and suppressing combustion reactions. Second, the environmental friendliness of perfluorohexane meets stringent environmental regulations, making it suitable for distribution rooms with special environmental requirements. Its non-conductive properties ensure safe use on electrical equipment without causing short circuits or other electrical faults. After extinguishing the fire, there is almost no residue, eliminating the need for cleanup and reducing equipment downtime and maintenance costs. Additionally, modern perfluorohexane fire suppression systems are typically equipped with sensitive detection and control systems that can automatically detect fires and swiftly initiate fire suppression procedures, providing 24/7 uninterrupted protection for distribution room safety. For example, some perfluorohexane fire suppression systems use mechanical linear detection, which can be reasonably laid out according to the internal structure of the distribution room, occupying minimal space and facilitating easy installation.

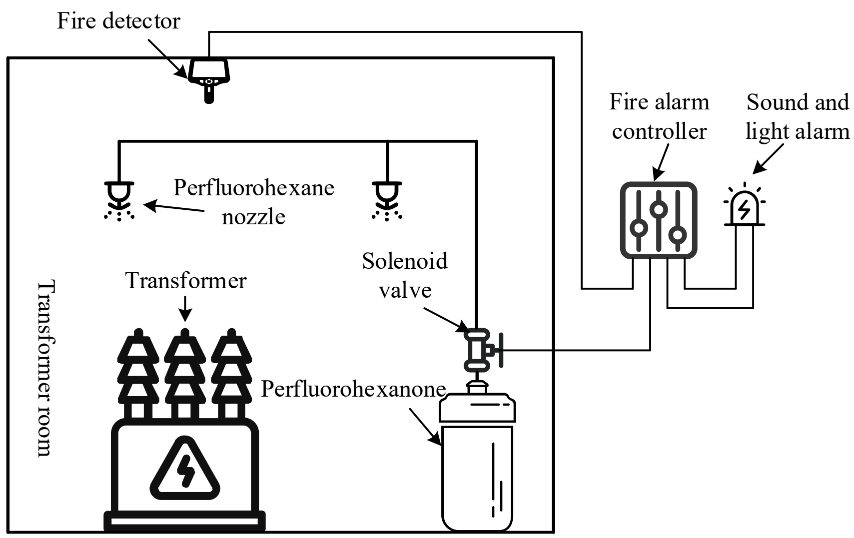


Figure 2: The full flooding application of the perfluoroethyl ketone fire extinguishing device

## III. Fire extinguishing performance evaluation test method

In view of the characteristics of fires in power distribution systems, in order to verify the fire extinguishing effectiveness of perfluorohexane as a fire extinguishing agent in power distribution systems, a test plan was formulated to evaluate the fire extinguishing performance of perfluorohexane in power distribution systems.

### *III. A. Experimental Design*

Through fire extinguishing tests, the fire extinguishing performance of perfluorohexane as a fire extinguishing agent for fires involving indoor power distribution systems and other equipment was verified and evaluated. The test simulated the scene of a fire in an indoor power distribution system, analyzing changes in gas concentration, temperature, and the distribution patterns of thermal radiation before and after the fire. This provided sufficient data support and basis for fire extinguishing in indoor power distribution systems.

The test platform includes a fire extinguishing test zone, a data collection zone, a fire extinguishing system zone, and a safety protection zone. The primary test subject is indoor distribution systems. The data collection zone includes data loggers, high-temperature thermocouples, thermal radiation meters, oxygen detectors, and composite gas analyzers. The simulated test design model distribution is shown in Figure 3.

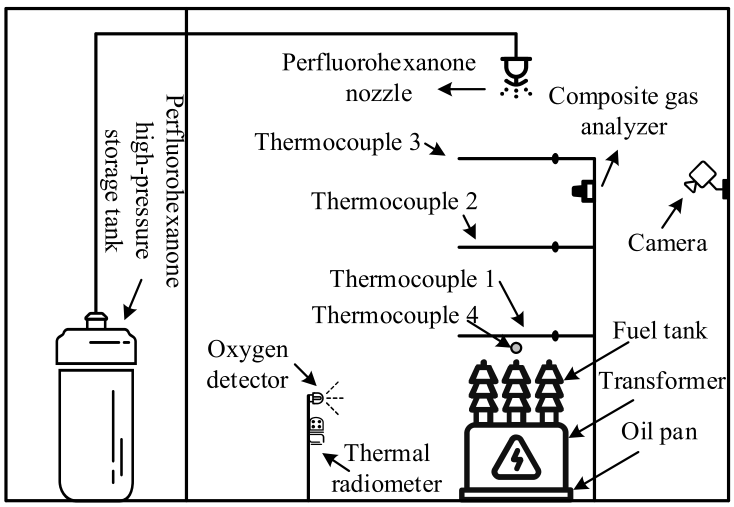


Figure 3: Indoor transformer layout diagram at the fire scene

### *III. B. Calculation of perfluorohexane usage*

The test used a distribution system with a width of 60 cm, a depth of 80 cm, and a height of 230 cm. The purpose of the test was to verify the applicability of perfluorohexane fire extinguishing agent for switchgear fires, with the key focus on calculating the amount of extinguishing agent required. Since national standards for the design and construction of perfluorohexane fire extinguishing systems have not yet been established, local standards were referenced to calculate the amount of extinguishing agent required. Actual amount of perfluorohexane used:

$$W = K\frac{V}{S}\cdot\frac{C_1}{(100-C_1)} \tag{1}$$

In the formula: $K$ is the altitude correction coefficient, with $K=1$ taken as reference in the design specifications. $C_1$ is the extinguishing concentration, with the extinguishing concentration of perfluorohexane ranging from 4.0% to 6.0%, and $C_1$ taken as the maximum value of 6%. $S$ is the specific volume of the overheated vapor of the extinguishing agent at 101 kPa atmospheric pressure and the minimum ambient temperature of the protected area, m³/kg. $V$ is the net volume of the protected area, m³.

On the day of the test, the ambient temperature was T = 22°C.

$S$ =0.0664+0.000274T=0.0664+0.000274×22=0.0724 (m³/kg)

$V$ =0.60m×0.80m×2.30m=1.104m³

$W$ =1×(1.104/0.0724)[6/(100−6)]≈0.97 (kg)

Remaining quantity of fire extinguishing agent in the high-pressure storage tank ΔW≈0.055kg

Total total fluorinated hexane filling quantity $W_o = W + \Delta W = 0.97 + 0.055 \approx 1.025$ (kg).

Select high-pressure storage tank specifications of 2 L, quantity 1.

### *III. C. Test Setup*

This test primarily simulates the initial stage of a fire in a power distribution system. Considering the potential risks associated with the joint operation of the perfluorohexane fire suppression system and the fire control system during a fire, the test was conducted without power supply.

Three circular oil pans with a diameter of 0.15m and a height of 0.15m were placed at the center of the top of the distribution system to simulate oil leakage from a damaged high-voltage bushing connection, creating a spray fire scene. Two rectangular oil pans, each measuring 0.55m in length, 0.55m in width, and 0.15m in height, were placed on either side of the distribution system's radiator to simulate a large oil pool fire and flowing fire caused by the rupture of the distribution system's cooling tubes, resulting in a significant oil leak. Three thermocouples are distributed directly above the distribution system. Thermocouple 1 is 0.35m from the transformer, Thermocouple 2 is 0.65m from Thermocouple 1, and Thermocouple 3 is 0.75m from Thermocouple 2. Thermocouple 4 is positioned above oil pan 2 on the side of the distribution system, aligned horizontally with the distribution system, with its front end aligned with the edge of the large oil pan, and vertically spaced 0.5 m from the upper edge of the oil pan. Considering the model of the power distribution system, the oil filling amount, and possible fire situations, the size, number, position, and oil volume of the oil pan are designed with reference to the dimensions of the combustion tank and oil pan in GB 25972-2010 “Gas Fire Extinguishing Systems and Components.”

### *III. D. Test procedure*

(1) Pour an appropriate amount of water into the bottom of the oil pan, use a measuring cup to add 450 mL of n-heptane, and place the oil pan at the bottom of the switchgear cabinet.

(2) The camera begins recording.

(3) The temperature recorder, thermal radiation meter, oxygen detector, and composite gas analyzer begin recording test data.

(4) Activate the igniter to ignite the n-heptane, which will ignite the cables and circuit breakers, etc. First, open the distribution system cabinet door and ignite for 20 seconds, then close the door and continue burning for 80 seconds, totaling 100 seconds of pre-ignition.

(5) Activate the perfluorohexane fire extinguishing system to spray the extinguishing agent.

(6) After the extinguishing agent has been sprayed, use the camera inside the distribution system to observe whether the flames have been extinguished. If the flames have not been extinguished within 60 seconds after the extinguishing agent has been sprayed, use the backup fire extinguisher to manually extinguish the flames.

(7) Clean up the test site and record and organize the experimental data.

## IV. Fire extinguishing performance evaluation test results

The test began by using an igniter to ignite the fuel tray, which then ignited the cables and circuit breakers, allowing them to burn freely. First, the doors of the distribution system switchgear were opened for a 20-second pre-burn, followed by closing the doors and continuing the burn for 80 seconds. When the total pre-burn time reached 100 seconds, the perfluorohexane fire extinguishing system was activated. The extinguishing agent was sprayed for 8 seconds, after which the flames were extinguished. From the flame state before and after the extinguishing agent is sprayed, it can be seen that the flame becomes more intense when the extinguishing agent first begins to spray. The flame reaches its maximum intensity after 3 seconds of spraying, and then, over the next 3 seconds, the flame detaches from the combustible material and spreads within the switchgear cabinet. After 8 seconds of spraying, the flame is extinguished.

### *IV. A. Temperature changes*

The temperature data changes of the thermocouples are shown in Figure 4, with different colored curves representing the four thermocouples. The temperature changes are divided into three stages. The sampling period from 0 to 100 corresponds to the stage where the flame transitions from nonexistent to maximum intensity. During this stage, the temperature changes of Thermocouple 4 are particularly noticeable, with the maximum temperature reaching over 620°C. Due to the slower heat diffusion toward the upper end, thermocouples 1, 2, and 3 exhibit smaller temperature changes, with a maximum temperature of approximately 95°C. The sampling interval from 100 to 220 corresponds to the stage after the discharge of the perfluorohexane fire extinguishing agent, during which the laboratory remains sealed. Thermocouple 4 decreases from high temperature to approximately 160°C within 4.5 minutes, with heat rapidly decreasing at a rate of 97.8°C/min, demonstrating a significant heat absorption effect during cooling. During the sampling period from 220 to 400, the laboratory door was opened, allowing airflow with the outside environment. The temperature dropped to outdoor levels, the flames were completely extinguished, with no reignition or rebound, and no residual sparks remained.

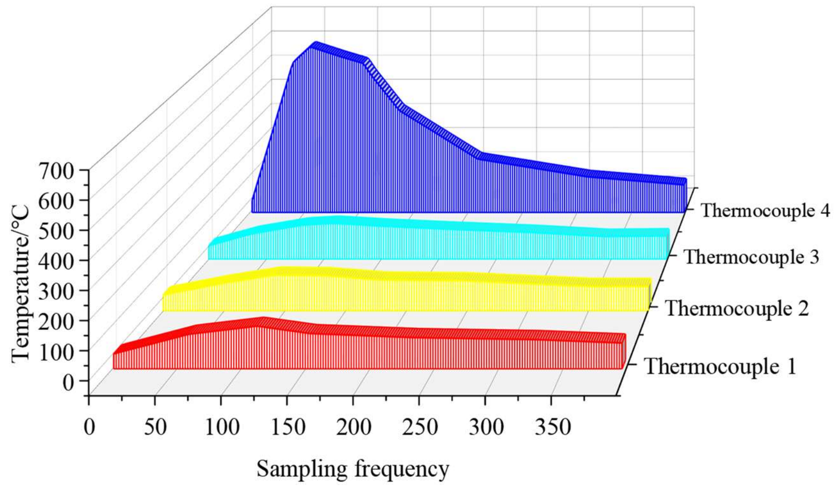


Figure 4: Temperature change trend diagram

### *IV. B. Changes in heat radiation values*

Figure 5 shows the thermal radiation change curve before and after fire extinguishing. At 25 seconds of pre-ignition, the thermal radiation value reached its maximum of 102 W/m², after which it fluctuated downward. At 73 seconds of pre-ignition, it dropped to 45 W/m², then rose to 62 W/m². When the perfluorohexane fire extinguishing system was activated, it fluctuated and dropped to 30 W/m². After the extinguishing agent was sprayed, the thermal radiation value sharply dropped to 0, remained at that level for 6 seconds, then rose to a maximum of 83 W/m² within 64 seconds, and subsequently decreased slowly.

The thermal radiation sensor was installed at the top of the distribution system. Before the pre-ignition, the switchgear door was open for 20 seconds, causing the thermal radiation value to rise sharply. After closing the door, the thermal radiation value became unstable and fluctuated downward. The analysis identified three main reasons: first, the smoke generated by combustion was significant, causing obstruction between the sensor and the flame. Second, after closing the door, the oxygen concentration decreased, leading to incomplete combustion. Third, the sensor surface was covered by smoke, reducing its sensitivity.

The extinguishing mechanism of perfluorohexane fire extinguishing agent primarily involves rapid vaporization upon release to absorb heat, thereby lowering the fire scene temperature to extinguish the fire. Therefore, after the extinguishing agent is sprayed, the thermal radiation sensor is also submerged by the extinguishing agent mist and absorbs heat, causing the thermal radiation value to drop sharply to 0. After the extinguishing agent vaporizes and evaporates, due to residual heat within the electrical distribution system, the thermal radiation value rises again to 83 W/m² before slowly decreasing. From the extent of the increase in thermal radiation values, it can be seen that the fluctuations and decreases in thermal radiation values before the extinguishing agent is sprayed are primarily caused by smoke generated by combustion blocking the sensors. After the extinguishing agent is sprayed, the temperature of the smoke decreases and settles, reducing the obstruction, so the thermal radiation values rise to a level higher than before the extinguishing agent was sprayed before slowly decreasing.

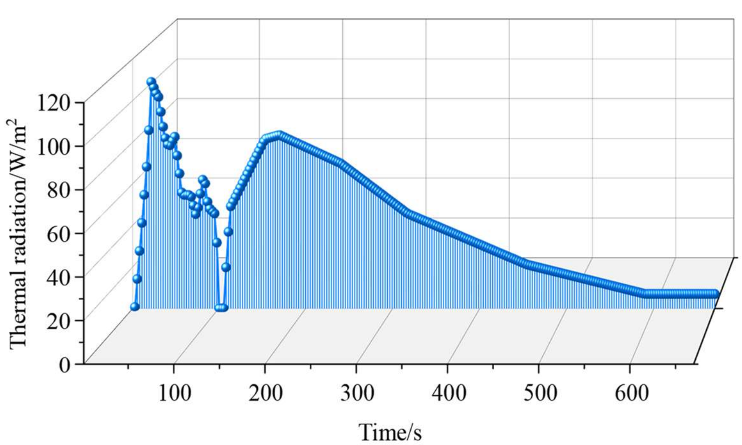


Figure 5: Curve of thermal radiation change

### *IV. C. Changes in gas concentration*

After the combustion test begins, it causes changes in the concentrations of various gases. The changes in composite gas concentrations and CO concentrations are shown in Figures 6 and 7. During the first 20 seconds, since the switchgear cabinet doors of the power distribution system were open, the gas concentrations remained largely unchanged. From the moment the cabinet doors were closed, the concentrations of $SO_2$, NO, and CO all rose rapidly. The $SO_2$ mass concentration peaked at 151 mg/m³, and after the flame extinguished, it decreased by 80.13% within 78 seconds, followed by a gradual decline. The NO mass concentration peaked at 47.5 mg/m³, then dropped to 0 within 55 seconds after the flame extinguished. The CO mass concentration reached the maximum range of the gas analyzer (1153 mg/m³) at 75 seconds into the test, remained at that level for 93 seconds, then rapidly decreased by 65.4% within 60 seconds, followed by a slow decline. Prior to the test, the volume percentage of oxygen was 18.5%. After closing the cabinet door during the test, the oxygen concentration decreased slowly, with the volume percentage dropping to a minimum of 55.5%. After the flame extinguished, it slowly returned to the original value.

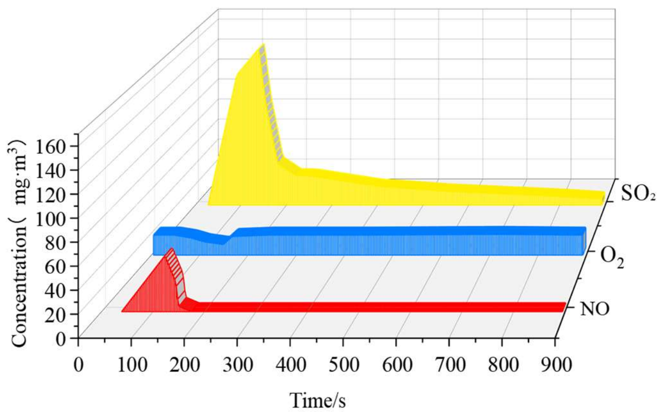


Figure 6: Change of compound gas concentration

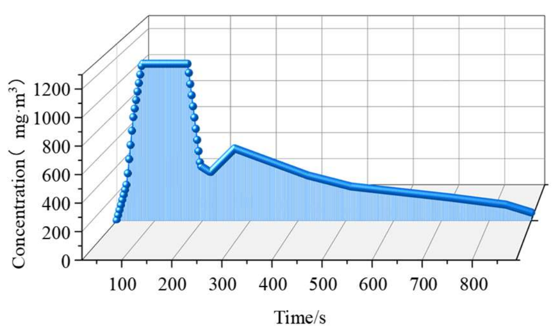


Figure 7: Change of CO concentration

## V. Conclusion

This paper applies perfluorohexane materials in fire prevention and control within power distribution systems. Through perfluorohexane fire extinguishing experiments on power distribution systems, data analysis is conducted on changes in experimental temperature, thermal radiation values, and gas concentration to investigate the fire extinguishing performance of perfluorohexane materials. The main findings of the study are as follows:

(1) Perfluorohexane fire extinguishing agents can effectively suppress fires in power distribution systems in a stable and non-destructive manner. They extinguish fires rapidly, with significant heat absorption and cooling effects, achieving a cooling rate of 97.8°C/min. There is no reignition, and no residual sparks remain. In a distribution system with dimensions of 0.60m × 0.80m × 2.3m and a volume of 1.104m³, a 2L high-pressure storage tank was selected, filled with 1.025kg of perfluorohexane. Upon activation, the spray can extinguish electrical fires caused by cables and engineering plastics in the distribution system within 8 seconds.

(2) After vaporization, perfluorohexane does not produce toxic gases such as CO, NO, or $SO_2$, and no residual byproducts remain after extinguishing the fire, causing no pollution to the air environment. The site is easy to clean up after extinguishing the fire. After vaporization, perfluorohexane can quickly extinguish flames in the distribution system, reduce the temperature

and thermal radiation at the fire scene, and rapidly lower the concentration of toxic and harmful gases such as CO, $SO_2$, and NO. The mass concentration of $SO_2$ decreased by 80.13% within 78 seconds, the mass concentration of NO dropped to 0 within 55 seconds, and the mass concentration of CO decreased by 65.4% within 60 seconds.

(3) Perfluorohexane does not cause corrosion or damage to the distribution system during fire extinguishing, enabling convenient and rapid reuse of resources, thereby achieving environmentally friendly, cost-effective, and efficient fire extinguishing.

(4) This experiment explored the application of the new environmentally friendly fire extinguishing agent perfluorohexane in distribution system fires, providing a new solution and data support for fire suppression in distribution systems. Further experiments will be conducted on fire suppression for internal short-circuit faults in distribution systems to further refine the data support.

## Funding

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