Research on the Application and Development of Thermal Imaging Technology in Fire Prevention and Control in China

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Abstract. Thermal imaging technology, with its advantages of early warning capabilities, all-weather operation, and non-contact monitoring, has gradually become a core technology for fire prevention and control. This article systematically analyzes the application value of thermal imaging technology in forest fire prevention, industrial, and civilian scenarios in China, based on its basic principles and development in China, and provides a scientific outlook on its future development trends in China.

Keywords: Thermal imaging technology, fire prevention and control, China, application scenarios and industry development

1 Introduction

Fire, as one of the most frequent and widespread types of disasters worldwide, poses a serious threat to people's lives and property, the ecological environment, and public safety due to its suddenness, rapid spread, and high difficulty in fighting. [1] According to the "Global Fire Prevention and Control Development Report" released by the World Fire Protection Association (CTIF) in 2025, there are approximately 230 million fires worldwide each year, with an average annual economic loss of US$320 billion. [2] Traditional fire detection mainly relies on smoke detectors or temperature sensors. [3] Such devices have prominent problems such as slow response, poor environmental adaptability, and high false alarm rate. [4] They are difficult to meet the needs of refined and all-time fire prevention and control in complex scenarios. Thermal imaging technology, due to its technological advantages, can capture abnormal temperature signals on the surface of objects to achieve early identification and warning of fire hazards. In recent years, due to the significant reduction in the cost of domestically produced thermal imaging equipment, the deep integration of artificial intelligence algorithms, and the strong support of relevant policies, thermal imaging fire prevention technology has been vigorously promoted and used in China, and has become an important part of building an intelligent fire protection system.

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2 Advantages and Development of Thermal of Imaging Fire Prevention Technology

2.1 Advantages of Thermal Imaging Fire Prevention Technology

The core theoretical basis of thermal imaging technology is Planck's law of blackbody radiation, which states that any object with a temperature above absolute zero (-273.15℃) will continuously emit infrared radiation. The energy of this radiation is proportional to the fourth power of the object's absolute temperature, conforming to the Stefan-Boltzmann law, expressed as $W = sigmaT^4$, where $sigma$ is the Stefan-Boltzmann constant, with the value of $5.67 \times 10^{-8} W/(m^2 \cdot K^4)$, and T is the absolute temperature of the object. [5] The thermal imaging device receives the infrared radiation signal emitted by the object through an infrared detector, converts it into an electrical signal, and generates a temperature distribution image of the object surface after signal conditioning, image processing and other processes, thereby realizing non-contact and accurate monitoring of the object temperature.

In fire prevention and control scenarios, thermal imaging technology typically uses far-infrared radiation in the 8-14 micrometer band for imaging. This band of infrared radiation has strong penetrating power, effectively penetrating obstacles such as smoke and dense fog, and is not limited by lighting conditions. Its temperature measurement accuracy reaches ± 0.5℃, enabling 24-hour temperature monitoring. Based on this characteristic, thermal imaging equipment can accurately detect temperature anomalies in the fire source and surrounding objects before an open flame appears, achieving early warning of fire hazards. Therefore, thermal imaging technology has the following advantages for fire prevention:

(1) Early Warning Capability: The core advantage of thermal imaging technology lies in its ability to provide early warnings when abnormal temperatures are observed on the surface of objects in the early stages of a fire. This allows for the detection of fire hazards 30-60 minutes earlier than traditional fire prevention equipment, significantly reducing casualties and property damage.

(2) All-Weather Operation Capability: Based on the principle of infrared radiation monitoring, thermal imaging technology is not limited by lighting conditions and can operate stably in harsh environments such as nighttime, foggy days, and rainy days, achieving 24-hour uninterrupted monitoring.

(3) Non-Contact Monitoring: Thermal imaging technology uses a non-contact monitoring method, eliminating the need for direct contact with the monitored object. This allows for remote temperature monitoring, avoiding interference with the normal operation of the monitored object and reducing safety risks during the monitoring process.

(4) Intelligent Identification and Low False Alarm Rate: Modern thermal imaging fire prevention equipment integrates artificial intelligence algorithms, accurately identifying fire and interference sources such as smoke, sunlight reflection, and animal activity, keeping the false alarm rate below 1%, significantly superior to traditional fire prevention equipment.

(5) System linkage capability Thermal imaging fire protection equipment can be linked with fire control panels, audible and visual alarms, sprinkler systems, smoke

exhaust equipment and other fire protection facilities to build a complete fire prevention and control closed loop and realize automatic handling after fire warning.

2.2 The Development of Thermal Imaging Fire Prevention Technology in China

According to industry report data released in 2026, the global market size of fire thermal imaging detection systems has reached US$2680 million, an increase of 8.7% over the previous year, with a compound annual growth rate (CAGR) of 8.0%-8.5%. [6]

Internationally, infrared thermal imaging technology has been developed earlier and has progressed rapidly, especially in countries such as the United States, France, Israel, Japan and South Korea, where they are in a leading position globally. Companies such as Fluke in the United States dominate the high-end market with their technological advantages. [7] In 2025, Teledyne FLIR's global market share exceeded 35%. Through continuous exploration and technological accumulation, my country has already acquired the independent R&D and mass production capabilities of infrared detectors. Companies with independent R&D and production capabilities of infrared detectors mainly include IRay Optoelectronics, Guide Infrared, Dali Technology, Hikvision, etc. Chinese companies rely on localized service capabilities, high cost performance and policy adaptability to quickly break through in new application scenarios such as new energy and data centers in China, while actively exploring emerging markets such as Southeast Asia, the Middle East and Latin America. In 2025, the global market share of Chinese companies reached 28%.

In 2025, the Chinese market accounted for more than 20% of the global thermal imaging market [8], with a market size of US$536 million, a 10.2% increase compared to 2024, which is higher than the global average growth rate. With the implementation of relevant policies such as the "Forest and Grassland Fire Prevention and Control Regulations", and the rapid development of application scenarios such as new energy, data centers, and industrial parks in China, the demand for thermal imaging fire prevention in China has shown explosive growth, and the market size is expected to exceed US$800 million in 2028.

2.3 Technical Challenges

Although thermal imaging fire prevention technology has achieved rapid development and been widely applied in multiple scenarios, it still faces the following limitations due to its technical constraints:

(1) Insufficient environmental adaptability: Thermal imaging technology is affected by environmental factors such as wind, haze, or sunlight. Under these conditions, the detection range of thermal imaging devices is impacted, and their accuracy is reduced.

(2) High initial investment: Thermal imaging equipment typically requires a significant initial investment. Although prices have decreased in recent years, advanced systems remain expensive for some users.

(3) Limited depth perception: Thermal imaging technology cannot penetrate solid objects and is easily reflected, which means it can only measure surface temperature.

This limits its ability to detect potential issues in certain materials or structures.

3 Application Scenarios of Thermal Imaging Fire Prevention and Control Technology in China

Thermal imaging technology is widely used in fire prevention and control in China, mainly in the following scenarios:

3.1 Forest Fire Prevention Scenarios

Forest fire prevention is one of the most mature and widely used applications of thermal imaging technology. Forest fires are characterized by their suddenness, rapid spread, difficulty in extinguishing, and wide impact. Traditional manual patrols and visible light monitoring are limited by environmental conditions and labor costs, making it difficult to achieve all-weather, full-coverage monitoring of forest fire prevention. According to data released by the National Forestry and Grassland Administration in 2025, the average annual incidence of forest fires in my country is approximately 0.8 fires per 10,000 hectares, with more than 80% of fires spreading due to delayed early detection. The application of thermal imaging technology can increase the early detection rate of fire points to over 95%, effectively curbing the spread of fires.

The main applications of thermal imaging technology in forest fire prevention are as follows:

(1) Early fire warning: Thermal imaging equipment can accurately capture small fire sources with an area of not less than 0.1 m^2, identifying abnormal surface temperatures of objects 30-60 minutes before open flames appear, thus gaining golden time for fire suppression. Statistics show that forest fires using thermal imaging early warning technology have an average burned area reduced by 75% compared to traditional monitoring methods, and fire suppression costs reduced by 60%.

(2) Dynamic Fire Monitoring: By combining thermal imaging equipment with technologies such as drones and satellites, an integrated air-space-ground forest fire monitoring network can be constructed. This network can track the speed, direction, and area of fire spread in real time, providing accurate data support for fire command centers. For example, in the 2023 forest fire in the Daxinganling Mountains of Heilongjiang Province, the thermal imaging monitoring system generated a real-time dynamic map of the fire spread, clearly showing that the fire was advancing northeast at a speed of 2 kilometers per hour. Based on this, the command optimized its deployment, creating a 200-meter firebreak in front of the fire, successfully blocking its spread. By 2025, the coverage rate of the integrated air-space-ground monitoring network in key forest areas in northern my country had increased from 65% in 2020 to 92%.

(3) Post-Disaster Resurgence Investigation: After a fire is extinguished, thermal imaging equipment can comprehensively scan the ash area, accurately identifying hidden underground fire sources and incompletely extinguished high-temperature hotspots, effectively preventing secondary reignition of the fire. Thermal imaging drones scan the entire fire area, accurately identifying hidden underground fire sources and high-

temperature hotspots through temperature anomaly detection until it is confirmed that there are no abnormal temperature points in the fire area, thus completing the entire firefighting process. Data shows that the application of thermal imaging technology can reduce the reignition rate of residual fires from 12% using traditional detection methods to below 1.5%.

3.2 Industrial Fire Prevention Scenarios

Industrial sites such as petrochemical, power energy, and warehousing logistics contain a large number of flammable and explosive materials and high-temperature operating equipment, resulting in a high fire risk level. According to statistics released by the Ministry of Emergency Management in 2024, industrial fires accounted for 18% of all fires nationwide, but caused 42% of the economic losses. The application of thermal imaging technology in industrial fire prevention can effectively prevent fires caused by equipment overheating and electrical faults, reducing the incidence of industrial fires by more than 35%, demonstrating significant application value.

(1) Equipment Overheating Monitoring: In the petrochemical industry, thermal imaging equipment can automatically measure the temperature of key equipment such as reactors, storage tanks, and pipeline flanges in real time, promptly identifying potential overheating hazards and preventing fires caused by equipment failures. In 2024, Sinopec Group implemented the "Intelligent Thermal Imaging Inspection System" in its 42 refining and chemical enterprises. This system integrates non-cooled infrared modules and artificial intelligence temperature anomaly recognition algorithms to achieve automatic temperature measurement and anomaly alarms for key equipment parts. Pilot data shows that the system reduced the average equipment overheating warning response time from 45 minutes to less than 6 minutes, decreased unplanned downtime events by 28.4% annually, and directly reduced economic losses by approximately 120 million yuan.

(2) Electrical Fire Prevention: In the power energy industry, thermal imaging equipment can monitor the real-time temperature of electrical equipment such as distribution cabinets and transformers, promptly detecting temperature anomalies caused by aging electrical lines and poor contact, thus preventing electrical fires. Quarterly inspections using uncooled infrared thermal imagers achieved an 89.2% accuracy rate in identifying potential hazards, increasing inspection efficiency by 6 times compared to traditional manual inspections.

(3) Warehousing and Logistics Fire Prevention: In large logistics warehouses, thermal imaging equipment can penetrate shelf gaps to monitor temperature rise inside stacked goods, effectively preventing the risk of spontaneous combustion of special goods such as lithium batteries and chemicals.

3.3 Civil Fire Prevention Scenarios

According to a report released by the China Fire Protection Association in 2025, civil fires accounted for 72% of all fires nationwide, with high-rise building fires and electric vehicle fires showing average annual growth rates of 8.3% and 12.5%, respectively.

The application of thermal imaging technology in civil fire prevention scenarios can effectively improve the intelligence level of civil fire prevention and provide more reliable protection for residents' lives and property.

(1) High-rise building fire prevention: High-rise building fires are a key and difficult point in urban public safety prevention and control. Thermal imaging equipment can identify potential electrical fire hazards by detecting temperature differences on the wall surface at night or in the event of a power outage, achieving early warning. Simultaneously, during the firefighting process on the exterior facade of high-rise buildings, thermal imaging equipment can assist drone-mounted systems in creating three-dimensional thermal map models of the fire spread path, providing dynamic decision support for the fire fighting command center. By the end of 2025, the coverage rate of thermal imaging fire prevention equipment in super high-rise buildings in first-tier cities in my country reached 85%, and in second-tier cities, it reached 68%.

(2) Fire Prevention for Electric Vehicle Charging Stations: Electric vehicle charging stations are among the most frequent sites of civil fires in recent years. Thermal imaging equipment can monitor the temperature anomalies of charging stations and charging vehicles in real time, preventing fires caused during charging. Hikvision's electric vehicle charging station fire prevention products have built-in smoke detection and solar reflection filtering algorithms, which can accurately identify temperature anomalies during charging and achieve second-level alarms. After this series of products was deployed in more than 200 communities across the country, the incidence of electric vehicle charging fires in the relevant communities decreased by 78%, effectively reducing the risk of civil fires.

(3) Fire Prevention in Commercial Venues: Shopping malls, hotels, restaurants, and other commercial venues have high population density and fire load, resulting in a high risk of fire. Thermal imaging equipment can achieve 24-hour uninterrupted monitoring, promptly detecting temperature anomalies in key areas such as kitchens and power distribution rooms, preventing fires. Intelligent thermal imaging cameras not only have fire early warning functions but can also guide residents to evacuate through sound and light alarms.

4 Future Development Trends

With the continued implementation of policies such as the "Forest and Grassland Fire Prevention and Control Regulations," the government will increase its support for thermal imaging fire prevention technology, promoting the large-scale deployment of thermal imaging equipment in forest fire prevention, industrial fire prevention, and civilian fire prevention scenarios. It is projected that from 2026 to 2030, the annual deployment of thermal imaging fire prevention equipment in my country will increase by an average of over 15% annually, and by 2030, the coverage rate of thermal imaging equipment in key forest areas and large industrial enterprises nationwide will reach 100%.

Thermal imaging fire prevention technology will be deeply integrated with artificial intelligence (AI) big data models, the Internet of Things (IoT), and 5G technology. Through AI big data models analyzing historical data, meteorological data, vegetation

data, and other multi-dimensional data, intelligent decision-making and early prediction of fires will be achieved. The deep integration of thermal imaging equipment with IoT and 5G technologies, leveraging the high-speed transmission of 5G technology to achieve real-time transmission of imaging data, and combining with IoT platforms to realize remote management, parameter adjustment, and linkage control of thermal imaging equipment, will form a more intelligent and efficient fire prevention and control network.

To facilitate use, thermal imaging equipment will also evolve towards lightweight and portable designs. As China's thermal imaging technology continues to mature, the cost of core components will further decrease, and products will become more affordable and widely available. With the expansion of the thermal imaging technology application market, Chinese thermal imaging product companies will further increase their efforts to expand into international markets, focusing on emerging markets such as Southeast Asia, the Middle East, and Latin America, and increasing their global market share.

5 Conclusion

This article systematically introduces the working principle, technological advantages, and development of thermal imaging technology in China. Through a detailed overview of its application scenarios in fire prevention and control in China, and based on industry development trends, relevant policies, and reports, it analyzes that the demand for thermal imaging equipment will increase by 15% annually. Thermal imaging technology will be deeply integrated with technologies such as artificial intelligence and the Internet of Things to form a more intelligent and efficient prevention and control network. Chinese thermal imaging equipment manufacturers will expand into international markets to increase their global market share.

References

1. Xionghua Wei, “Application of geographic information system in forest fire fighting and its route planning,” Rural Scientific Experiment, (19), 2096-0743 (2025) 19-0156-03(10 Oct. 2025); DOI:10.20264/j.cnki.rse.2025.19.053.
2. Center for Fire Statistics of CTIF. (2025). World fire statistics: Report No. 30. CTIF International Association of Fire and Rescue Services, 2025; https://www.ctif.org/world-fire-statistics
3. Jinlei Wang, “Research on Fire Detection Model Based on Improved YOLOv5”, North University of China, Taiyuan, 2023; DOI:10.27470/d.cnki.ghbgc.2023.001535.
4. Li Zechen, Li Hengchao, Hu Wenshuai, Yang Jinyu, Hua Zexi , “Masked face detection model based on multi-scale attention-driven faster R-CNN,” Journal of southwest jiaotong university, 56(5), : 0258-2724(2021)05-1002-09 (19 Jul. 2021); DOI: 10.3969/j.issn.0258-2724.20210017
5. Shizhen Zhao, “Study on the influence of bearing raceway failure on the bearing temperature of axle box of railway wagon,” Dalian Jiaotong University, Dalian,2025, DOI:10.26990/d.cnki.gsltc.2025.000588.

6. Hu Meng, Yongfu Long, “Application and market analysis of technology on the uncooled infrared focal plane detector ,” Journal of Hunan University of Arts and Science(Science and Technology), 26(02), 1672-6146(2014)02-0074-04 (15 Jun. 2014): DOI: 10.3969/j.issn.1672-6146.2014.02.016
7. Chaolai Wei, “Design and Implementation of Uncooled Infrared Thermal Imagin System for Industrial and Environmental Safety,” Shandong University, Jinan,2024. DOI:10.27272/d.cnki.gshdu.2024.008122.
8. Axel Clouet, “The thermal imaging and sensing market since 2019,” Proceedings Volume 12536, Thermosense: Thermal Infrared Applications XLV; 125360W (2023); https://doi.org/10.1117/12.2664172