

Fire Detection System

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Abstract

Fire detection systems are engineered to identify the presence of fire or smoke and notify individuals of possible hazards. These systems employ a range of sensors, such as smoke detectors, heat detectors, flame detectors, and advanced algorithms, to recognize indications of fire inception or spread. When a fire is detected, alarms are activated, facilitating swift responses to minimize dangers and forestall fire incidents.

Keywords: Fire detection, mitigation, sensors, protection, hazards

INTRODUCTION

Uses of Fire Detection Systems

Early Detection

Timely identification is paramount for curtailing the advancement of fires within industrial settings. Fire detection systems swiftly recognize signs of smoke, heat, or flames, even during their nascent stages, allowing for immediate response measures. Early warning enables evacuation procedures, activates suppression systems, and facilitates the intervention of emergency responders, minimizing the impact of fire incidents.

Risk Mitigation

Industrial plants house various fire hazards, including flammable materials, combustible gases, and electrical equipment. Fire detection systems continuously monitor these environments for signs of fire, providing proactive risk mitigation measures. By detecting potential hazards before they escalate, these systems help prevent property damage, production losses, and personal injuries.

Advanced Security

Guaranteeing the safety of employees stands as a top priority in industrial establishments. Fire detection systems play a pivotal role in fostering a secure working atmosphere by notifying workers about potential fire hazards and aiding in prompt evacuation protocols. Through issuing early warnings and directing evacuation paths, these systems mitigate the likelihood of injuries and fatalities linked with fire emergencies [1].

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Asset Protection

Industrial plants contain valuable assets, including equipment, machinery, and raw materials, susceptible to damage in fire events.

Fire detection systems help protect these assets by detecting fire threats early and initiating suppression measures. Timely intervention preserves assets, minimizes financial losses, and facilitates business continuity in the aftermath of fire incidents.

Why Fire Detection System

Fire has been one of the most crucial discoveries in the history of mankind. It has transcended from being just a tool in ancient times to becoming a vital source of energy in modern society. It wouldn't be an overstatement to suggest that fire is indispensable to the survival of virtually every society [2]. However, when we fail to use fire properly, it can become a cause of immense destruction, as evidenced by countless historical examples (Figure 1).

- The Great Chicago Fire. Date: October 8 to 10, 1871
- Deepwater Horizon Fire. Date: April 20 to September 19, 2010
- Haryana School Blaze. Date: 23 December 1995
- China Zhili Toy Factory Fire. Date: November 19, 1993

History of Fire Detection Systems

Back in the days of the Ancient Greeks and Romans, the earliest fire alarm system was as straightforward as it gets: applying water to extinguish fires quickly. While it may not resemble the sophisticated systems of today, it was the precursor to modern fire alarms (Figure 2).

Fast forward to 1828 in America, where the Pennsylvania State House rebuilt Independence Hall with a new steeple and bell, employing an official fire watchman [2-5]. This signaled the commencement of a more structured strategy towards fire detection and response (Figure 3).

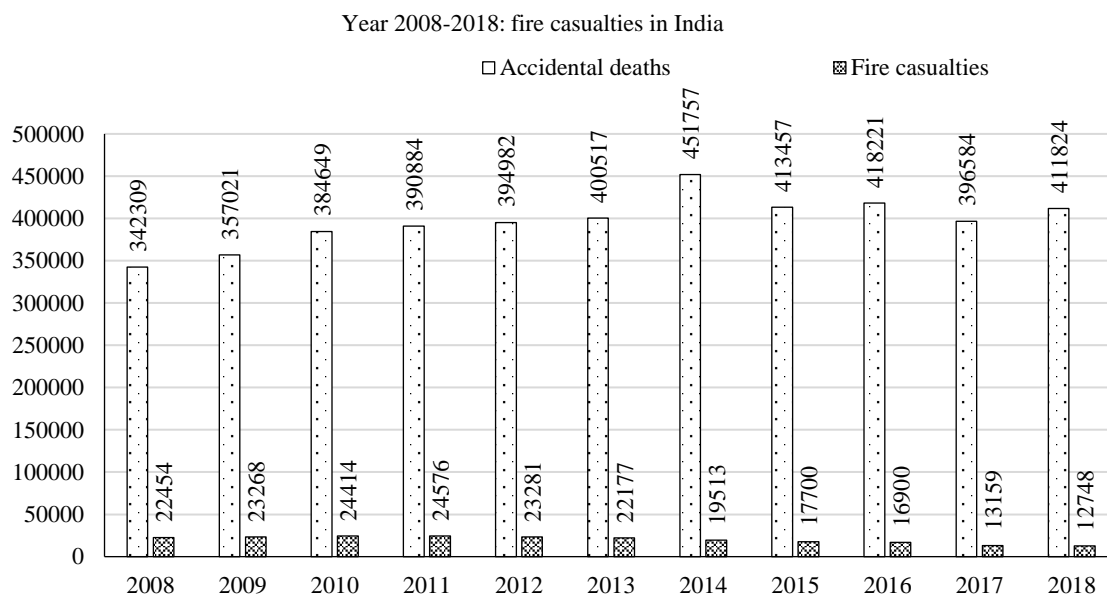


Figure 1. Fire detection system.



Figure 2. Modern fire alarms.



Figure 3. Pennsylvania state house.

The formal invention of the fire alarm system was credited to William F. Channing and Moses Farmer in the mid-17th century. Employing telegraphy and electromagnetism, they devised a mechanism to promptly notify firefighters about the fire's whereabouts. Nevertheless, the initial systems were unwieldy and susceptible to inaccuracies (Figure 4).

It was only when John Nelson Gamewell, a postmaster and telegraph operator, acknowledged the invention's potential and implemented crucial modifications. His streamlined design, incorporating the iconic pull-down lever, transformed fire alarm systems (Figure 5).

Today, we're familiar with the small red boxes containing a handle that, when pulled, sets off sprinklers and alerts nearby fire stations. These modern systems owe their efficiency and reliability to the innovations made over centuries of development (Figure 6).

With the continuous advancement of technology, the future of fire alarm systems holds boundless possibilities [6]. With the swift evolution of the Internet of Things and smart technology, we can anticipate further ground-breaking innovations on the horizon (Figure 7).

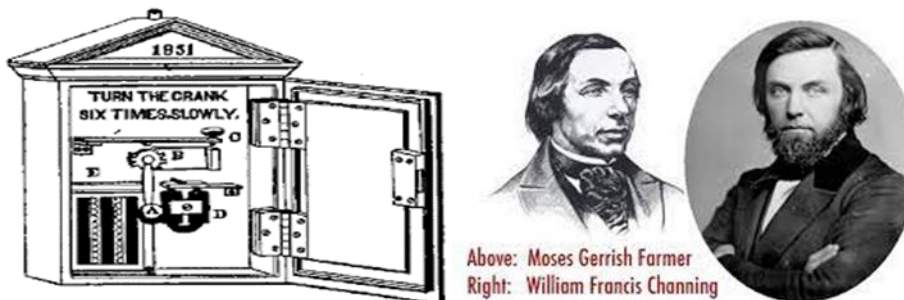


Figure 4. Telegraphy and electromagnetism.



Figure 5. Telegraph operator.



Figure 6. Fire stations.

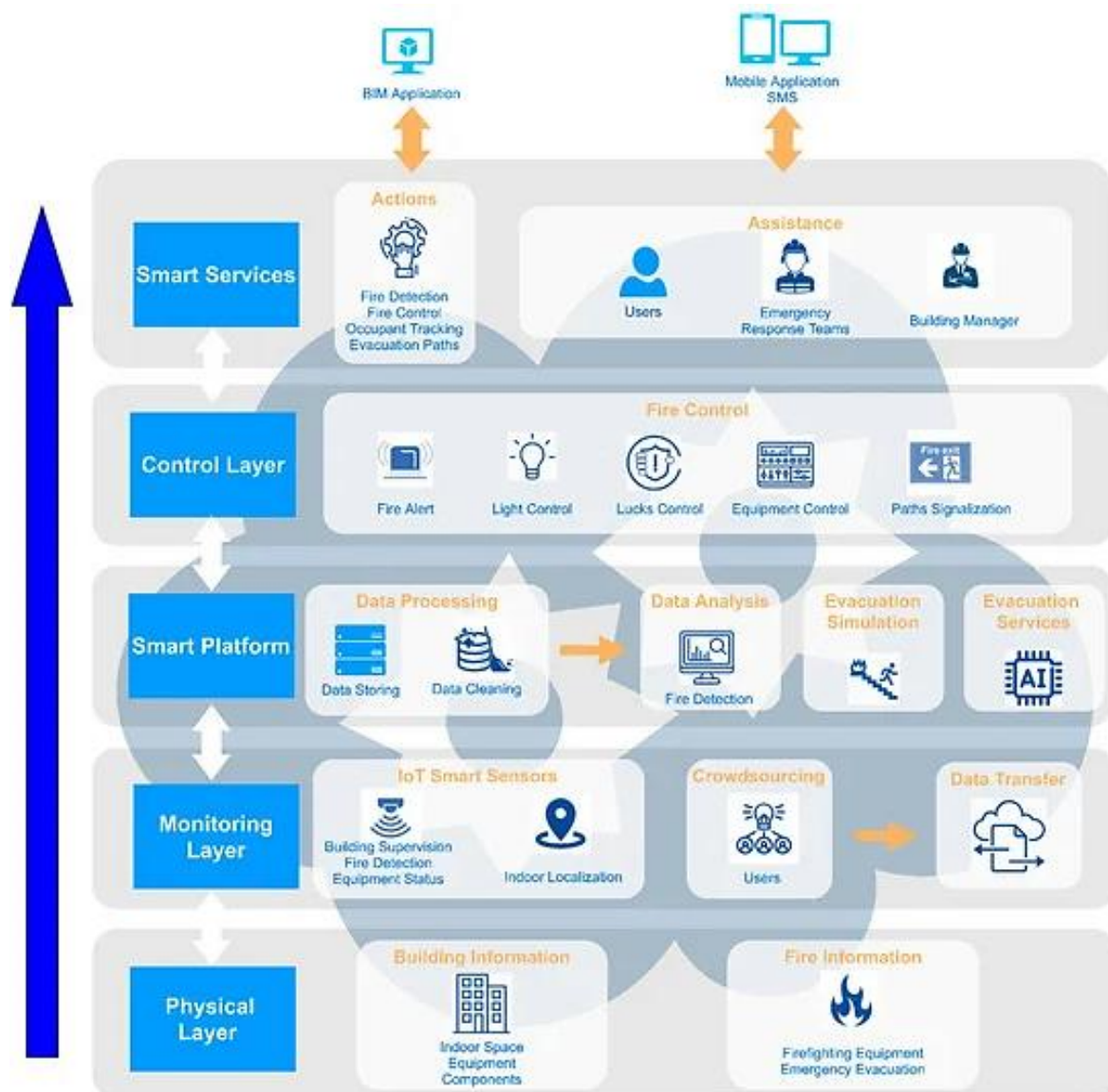


Figure 7. Smart evacuation system.

Modern Fire Detection Techniques

Fire detectors detect one or more of the by-products or indicators of fire, including smoke, heat, infrared and/or ultraviolet light radiation, or gases.

In residential settings, smoke detectors are frequently standalone devices [7]. In non-domestic buildings, fire detection will typically take the form of a fire alarm system, incorporating one or more of the following automatic devices:

1. Heat detector
2. Smoke detector
3. Flame detector
4. Fire gas detector

Heat Detectors

A heat detector serves as a vital component of fire alarm systems, designed to activate when the thermal energy from a fire raises the temperature of a heat-sensitive element. The element's thermal mass and conductivity govern the rate at which heat flows into it, with all heat detectors exhibiting a

thermal lag. These detectors typically fall into two main categories: "rate-of-rise" and "fixed temperature", both aimed at minimizing property damage in the event of a fire [8].

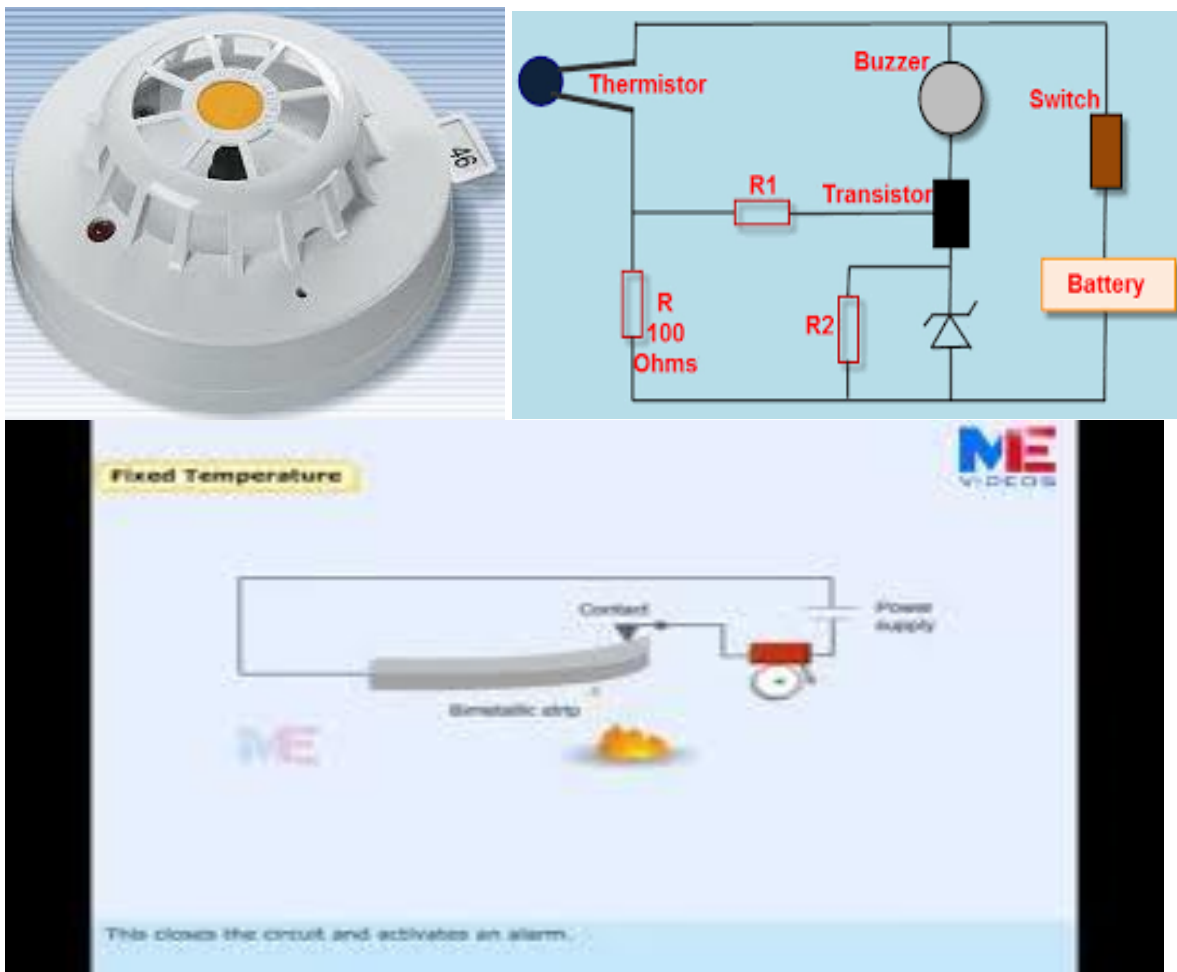
Fixed Temperature Heat Detectors

Among the most prevalent types, fixed temperature heat detectors trigger when the heat-sensitive eutectic alloy reaches its melting point, transitioning from a solid to a liquid state. The thermal lag ensures that these detectors activate after the surrounding air temperature surpasses the predetermined threshold. For electrically connected heat detectors, this threshold commonly lies at 58°C (136.4°F), providing reliable detection in various environments (Figure 8).

Rate-of-Rise Heat Detectors

Rate-of-rise (ROR) heat detectors swiftly respond to rapid increases in element temperature, typically ranging from 6.7° to 8.3°C (12° to 15°F) per minute, regardless of the initial temperature. Equipped with dual heat-sensitive thermocouples or thermistors, one monitors convective or radiative heat transfer, while the other tracks ambient temperature. These detectors activate when the temperature of the first sensing element rises relative to the second, ensuring prompt detection and response to evolving fire conditions [9].

However, rate-of-rise detectors may not efficiently detect fires that develop slowly with low energy release rates. To address this limitation, combination detectors integrate a fixed temperature element, which activates once it reaches the designated threshold, providing comprehensive fire detection capabilities (Figure 9).



Mechanism of Spot Type Fixed Temperature Heat Detector

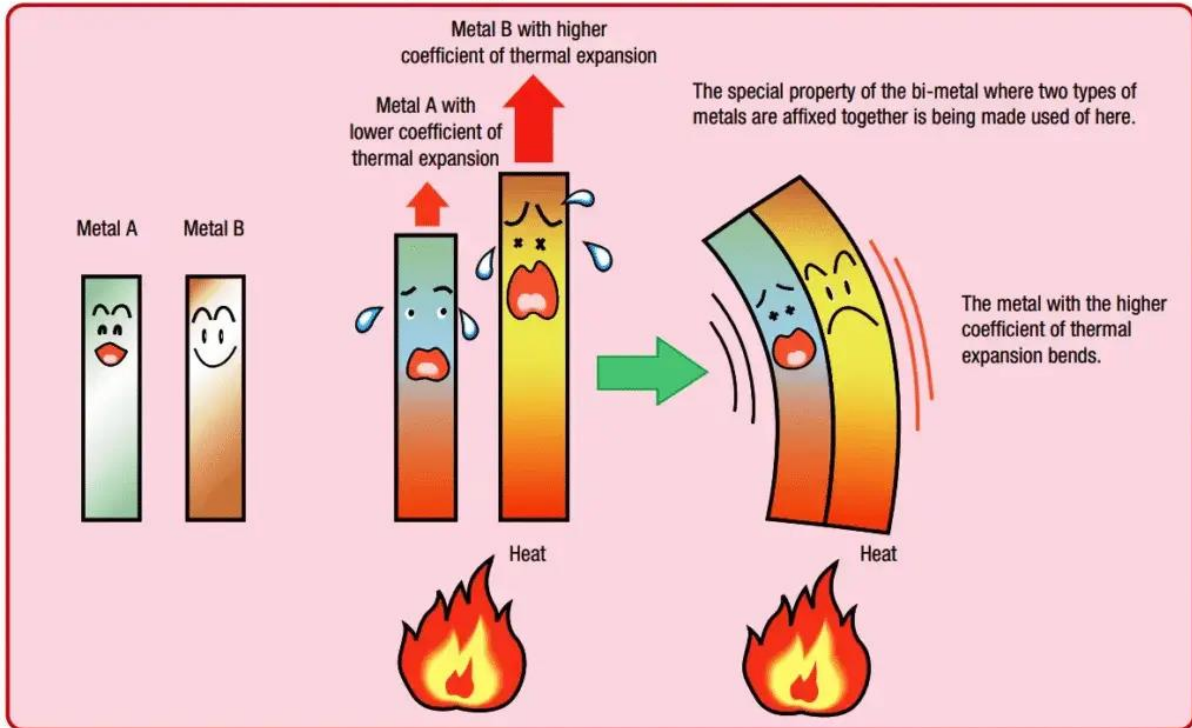


Figure 8. Fixed temperature heat detectors.

Rate-of-Rise Heat Detector

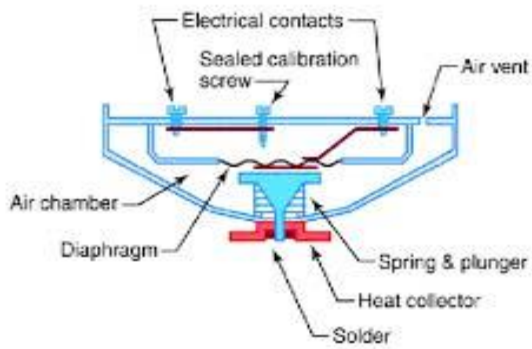


Figure 9. Rate-of-rise.



Figure 10. Smoke detector.

Smoke Detectors

Smoke detectors stand as silent sentinels in the battle against fire, employing advanced technology to detect the presence of smoke particles in the air and provide early warning of potential fire hazards. These devices serve an indispensable role in protecting lives and property, providing dependable detection capabilities across residential, commercial, and industrial environments (Figure 10).

Ionization Smoke Detectors

Ionization smoke detectors utilize a minute quantity of radioactive material to ionize the air inside the detection chamber. When smoke particles infiltrate the chamber, they disturb the ionization process, resulting in a decrease in current flow and activating the alarm. These detectors excel at detecting fast-flaming fires, characterized by rapidly spreading flames and minimal smoke production (Figure 11).

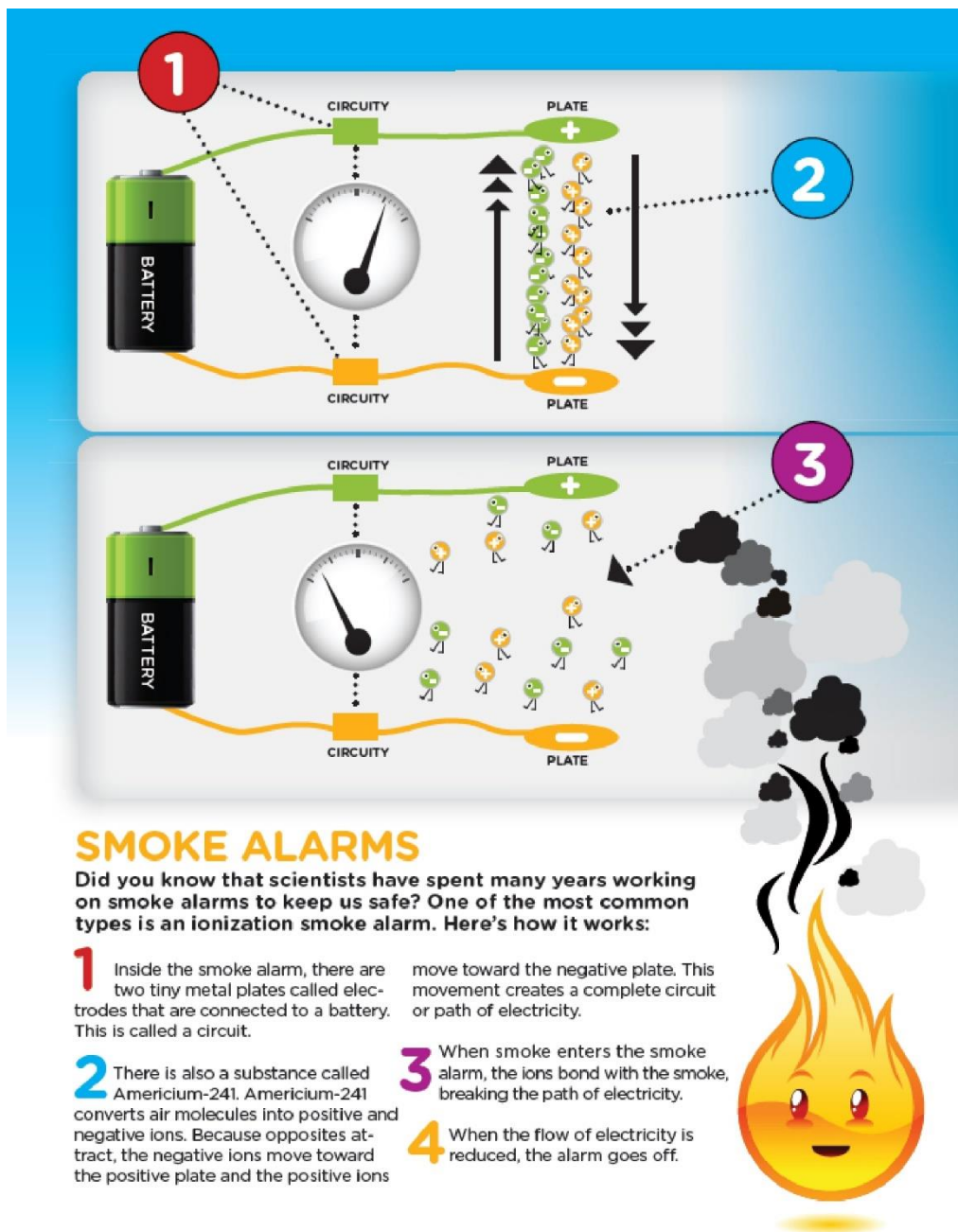
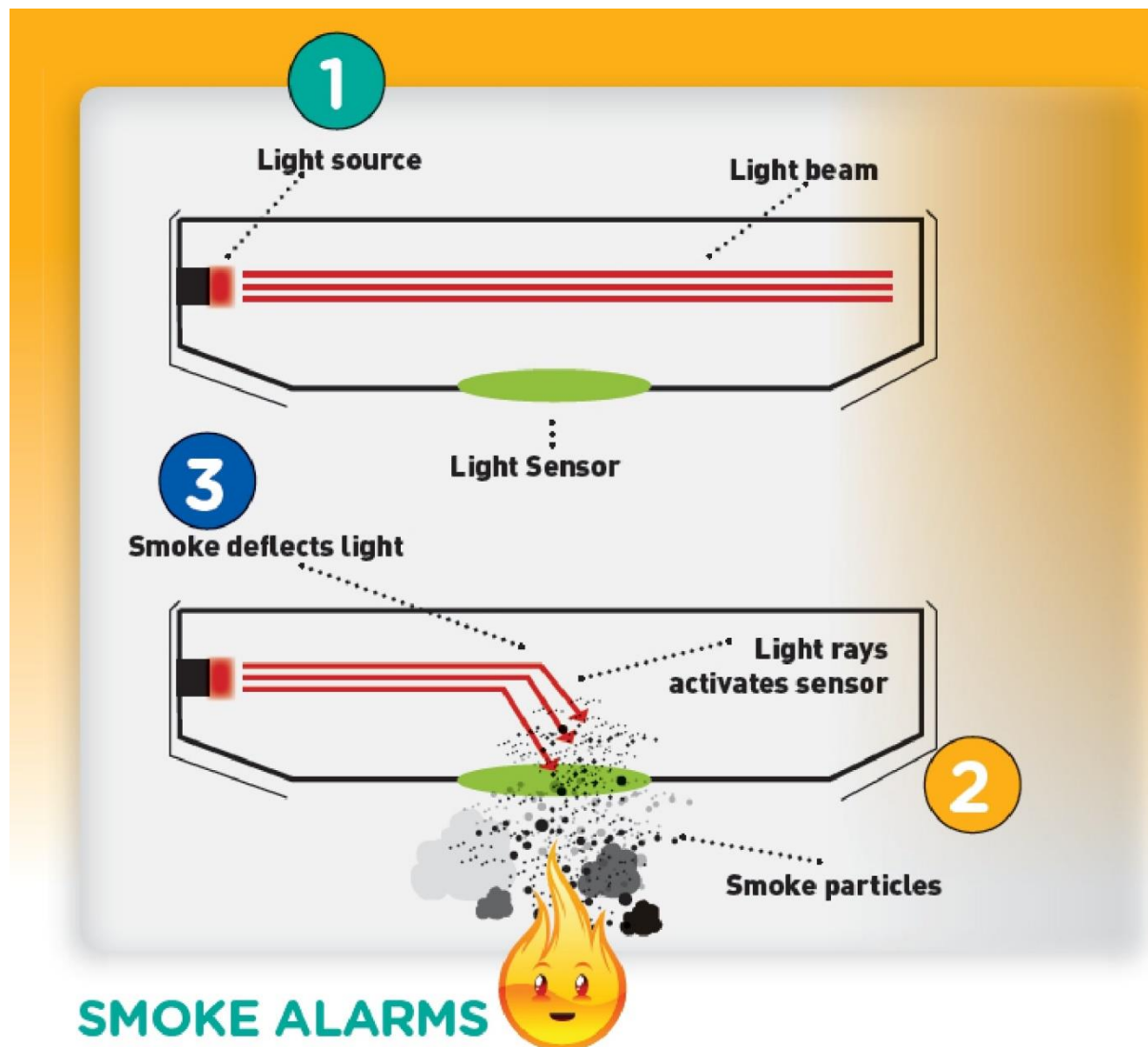


Figure 11. Ionization smoke detectors.



SMOKE ALARMS

Another type of detector is an photoelectric smoke alarm. Here's how it works:

- 1** Inside the smoke alarm, there is an LED light that sends a beam of light (similar to a laser pointer) in a straight line across the chamber. In a separate compartment inside the chamber, there is a photosensor that detects light.
- 2** As smoke enters the detector, the smoke particles interrupt the light beam, scattering it in many directions. Some of the LED light scatters toward the light sensor. When light beams hit the sensor, the alarm will go off!
- 3** When the batteries in your smoke alarm get low, the smoke alarm automatically activates a low battery chirping sound different from the alarm sound so you know it's time to get new batteries.

Some smoke alarm contain both optical and ionization smoke detection systems.

Figure 12. Photoelectric smoke detectors.

Optical Smoke Detectors

Photoelectric smoke detectors utilize a light-sensitive sensor and a light source positioned within a detection chamber. When smoke infiltrates the chamber, it scatters the light, prompting the sensor to

trigger the alarm [10]. These detectors excel at detecting smoldering fires, characterized by dense smoke and potential smoldering over prolonged periods before combustion (Figure 12).

Dual Technology Smoke Sensors

Dual sensor smoke detectors integrate the advantages of both ionization and photoelectric technologies, providing extensive fire detection capabilities. By utilizing multiple detection methods, these detectors can effectively respond to a wide range of fire types, including fast-flaming and smoldering fires, ensuring reliable performance in diverse environments.

Fire Gas Detectors

Gas detectors play a critical role in ensuring safety by detecting the presence of gases in an area, serving as integral components of safety systems. These devices offer timely alerts to operators, enabling them to implement essential precautions and evacuate if necessary, especially in environments where hazardous gases jeopardize organic life.

Types of Gases Detected

Gas detectors have the capability to detect various gases, encompassing combustible, flammable, and toxic gases, while also monitoring oxygen levels. Their versatility makes them indispensable across various industries, from oil rigs and manufacturing plants to photovoltaic facilities and firefighting operations.

History of Gas Detection

Gas detection methods have evolved significantly over time, beginning with primitive techniques like using canaries in coal mines to the development of the first industrial gas detector by Sir Humphry Davy in the 19th century. This historical progression laid the groundwork for modern gas detection technology.

Evolution of Gas Detection Technology

The modern era of gas detection began in the early 20th century with innovations such as catalytic combustion sensors. Subsequent decades witnessed substantial advancements, including the introduction of electronic sensors and the development of sophisticated detection systems capable of detecting multiple gases simultaneously.

Types of Gas Detectors

Gas detectors are categorized based on their operation mechanism and form factors. Portable detectors, commonly worn or carried by personnel, and fixed detectors, installed in specific locations, utilize various sensor technologies such as electrochemical, catalytic bead, photoionization, infrared, semiconductor, and ultrasonic sensors.

Calibration and Maintenance

Regular calibration is vital to maintain the precision and dependability of gas detectors. Both portable and fixed detectors require specific calibration schedules to maintain optimal performance, with daily "bump tests" for portable devices and periodic calibration for fixed systems being common practices.

Applications of Gas Detectors

Gas detectors find widespread use across industries where the presence of gases poses a risk to safety. From industrial plants and refineries to residential settings, these devices play a crucial role in preventing accidents and safeguarding lives by providing early detection and warning of hazardous gas concentrations.

Flame Detectors: Guardians Against Fire

Flame detectors, crucial for fire detection and response, employ various technologies to swiftly detect the presence of flames. These detectors can initiate responses such as sounding alarms, deactivating

fuel lines, or activating fire suppression systems (Figure 13). They outperform smoke or heat detectors due to their specialized mechanisms. Here's a brief overview:



Figure 13. Flame detectors.

UV Detectors:

Detect UV radiation emitted during ignition, offering rapid detection within milliseconds. They include a time delay to minimize false alarms caused by other UV sources.

Near IR Array Detectors

Utilize flame recognition technology to analyse near IR radiation, providing reliable flame detection even amidst water or vapour hindrances. Multiple sensors create near IR images for accurate detection.

Infrared (IR) Detectors

Monitor the infrared spectral band for specific patterns emitted by hot gases. Specialized thermal imaging cameras detect patterns indicative of fire. Some detectors focus on CO₂ resonance for increased sensitivity.

UV/IR Detectors

Sensitive to both UV and IR wavelengths, these detectors compare signals from both ranges to minimize false alarms.

IR/IR Flame Detection

Compares signals in two IR ranges, such as CO₂ emissions and a reference frequency, suitable for different fuel types.

IR3 Flame Detection

Utilizes algorithms and multiple wavelength bands to distinguish flames from non-flame sources, enhancing detection range and reducing false alarms.

Visible Sensors

Cameras or visible light sensors provide image-based flame detection, though they can be hindered by smoke or fog.

Thermocouple Flame Detection

Common in heating systems, they measure heat to verify flame presence and quality, shutting off fuel supply in case of failure. In summary, flame detectors offer rapid and accurate detection of fire, employing various technologies to overcome challenges such as background radiation, water interference, and sunlight. Their diverse capabilities make them essential for applications ranging from industrial furnaces to household gas systems.

INTEGRATED FIRE DETECTION AND ALARM SYSTEMS

Interconnection and Activation Process

In contemporary fire detection systems, a multitude of sensors, including smoke detectors, heat detectors, and other specialized sensors, are linked together in a series configuration to offer extensive coverage and swift response to fire occurrences. These interconnected systems, frequently integrated with alarm sounders or sirens, facilitate instant activation upon detecting fire-related events, guaranteeing prompt alerting and intervention.

Series Connection

The sensors, hooters, and other components of the fire detection system are interconnected in a series configuration, forming a closed loop circuit. This interconnected network enables seamless communication and coordinated response among the system components.

Immediate Activation

When any sensor within the system detects fire-related phenomena, such as smoke or heat, it sends a signal to the central fire alarm panel indicating the presence of a potential fire hazard. The panel then activates the hooters or sirens to alert occupants and initiates appropriate response measures.

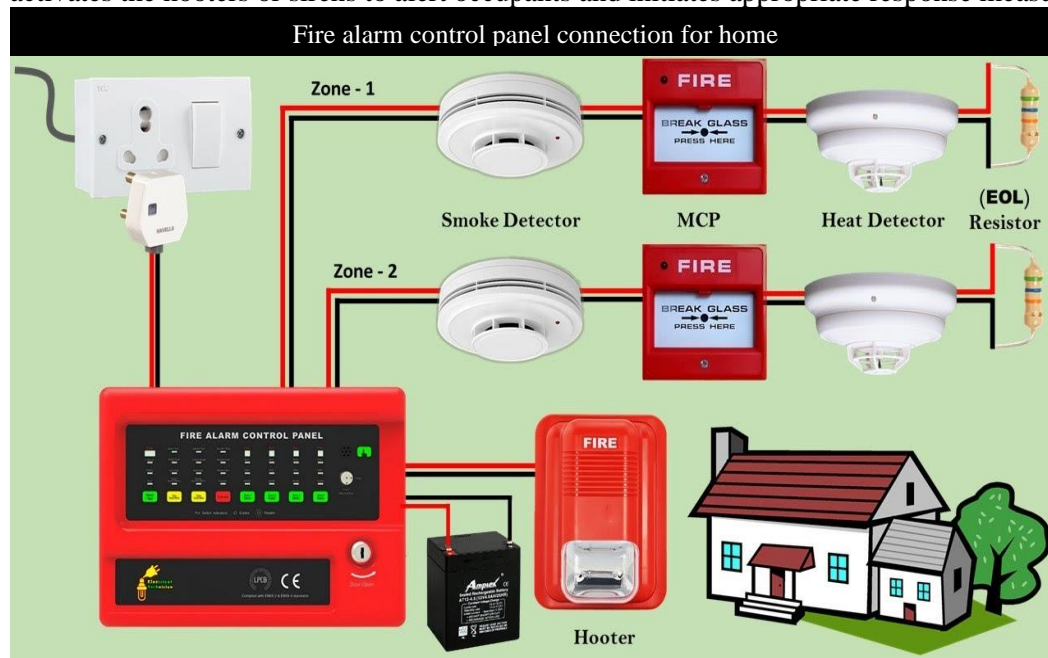


Figure 14. Fire alarm panel.

Zone-wise Alarming

The fire alarm panel is typically divided into multiple zones, with each zone representing a specific area or section of the premises. When an alarm is triggered, the panel identifies the corresponding zone and displays the alarm status, enabling localized response and evacuation efforts (Figure 14).

CONCLUSION

In conclusion, the need for fire detection systems in today's world is crucial. These systems allow us to use fire safely instead of letting it cause destruction. With advancements like IoT, Bluetooth, and Wi-Fi-based sensors, we can detect and prevent fires more effectively. Let's keep improving these systems to make fire a useful tool rather than a danger.

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