Detection systems for fire protection equipment

Fire alarm systems have over a century of existence, ever since Francis Robbin Upton developed the first fire alarm system in 1890 and George Andrew Darby invented the first smoke detector in1902. Further developments were made by Swiss physicist Walter Jaeger and Ernst Meili in the 1930s, which led to the development of smoke detectors operated by the principle of ionization chambers. These first iterations of the smoke detectors were sold in the USA since the 1950s and where used mainly in large commercial and industrial installations due to cost issues and their large size. Further improvements and the invention of integrated circuits, led to the miniaturization of the detectors, the development of modern photoelectric smoke detectors and the gradual obsolescence of the ionization detector, which, in turn, paved the way to the widespread use of advanced fire detection systems that are in use today.
In essence, there are two main fire detection system types: conventional and addressable.
Conventional fire alarm control panels were first developed in the 1970s, when integrated circuits were made small enough to make the panel viable. The initiating devices (smoke detectors, heat detectors, manual call buttons etc) operate by dramatically decreasing the circuit resistance when the environmental influence on any sensor exceeds a predetermined threshold. In a conventional fire alarm system, the information density is limited to the number of such circuits used and today, these types of fire alarm control panels are mostly used in smaller projects such as residences, small schools, and shops.

The addressable fire alarm control panels were introduced in the late 1980s, with the development of microprocessors. These developments led to the design of Signaling Line Circuits (SLC), which enable the connection of devices, each with their own address. Devices that can be connected to SLC, also known as loop circuits or simply loops, include optical smoke detectors, rate of rising heat detectors, beam detectors as well as sirens and input/output control modules. It is standard industry practice that each manufactured develops its own addressable protocol. Depending on the protocol used, a Signaling Line Circuit can monitor and control several hundred devices. Some protocols permit any mix of detectors and input/output modules, while other protocols have 50% of channel capacity restricted to detectors/sensors and 50% restricted to input/output modules. Each SLC polls the devices connected, which can number from a few devices to several hundred, depending on the manufacturer and large systems may have multiple Signaling Line Circuits. This type of control panels is mostly used in large and high-value installations, such as factories, hotels, casinos and airports.

High-value locations such as server rooms are usually protected by aspirating smoke detectors because of the latter’s high sensitivity.

If the fire alarm control panel is the brain of the fire detection system, then the various sensors that signal the presence of fire are the neurons. The automatic fire detection sensors detect fire via responding to any number of detectable physical changes associated with fire, such as convected thermal energy, products of combustion, radiant energy, combustion gases and visible effects of combustion.
A **heat detector** is a fire alarm device designed to respond when the convected thermal energy of a fire increases the temperature of a heat-sensitive element. Heat detectors have two main classifications of operation, "rate-of-rise" and "fixed temperature" with rate-of-rise heat detectors operating on detecting a rapid rise in element temperature of 6.7° to 8.3°C (12° to 15°F) increase per minute, irrespective of the starting temperature, whereas fixed temperature heat detectors operate when the internal heat-sensitive eutectic alloy reaches the eutectic point changing state from a solid to a liquid. Thermal lag delays the accumulation of heat at the sensitive element so that a fixed-temperature device will operate with the preset boundaries. Heat detectors are used in areas where smoke or dust is normally present and, as a result, the use of optical smoke detectors is excluded due to false alarms. They are manufactured according to EN 54-5.
Another type of heat detector that has been used for years, but has recently been included in NFPA code, is the **Linear Heat Detector (LHD)**, which is, in essence, a continuous chain of individual spot heat detectors. They operate based on the principle that when the surrounding ambient temperature meets or exceeds the detector’s fixed temperature, the heat-sensitive polymer casing of the detector melts and an alarm is sent to the fire alarm control panel. Other iterations of LHD consist of panels that measure the conductivity along the detector wire, a process that enables this type of LHD to be used repeatedly, and fiber optics that detect ambient temperature via the oscillations that thermal effect induces on the lattice of the glass quartz. These specialist line heat detectors are used in large installations as well as tunnels and pipelines and are manufactured according to EN 54-22.

Optical smoke detectors sense smoke as an indicator of fire via the scattering that smokeparticles cause on infrared, visible or ultraviolet light and are further separated in three main categories: optical smoke detectors, beam detectors and aspirating smoke detectors. Spot optical smoke is the most widely used type of detector world-wide, due to its low cost and ease of installation and,according to NFPA studies, the risk of a person dying in a home fire is cut in half in homes with working smoke alarms. Beam smoke detectors are mainly used in large installations, such as warehouses and hangars, due to their wide range (up to 1800m2 can be covered by a single beam smoke detector) and their operation is based on the same principle that the spot optical smoke detectors operate, but they consist of a separate receiver and transmitter (or a transmitter/receiver and a reflector) that operate with the same principle like the spot optical smoke detectors, but on a much greater range. Aspirating Smoke Detectors (ASD) sample the air of the room via specialized tubes. The sample is then sent into a specialized chamber inside the ASD control panel that tests the scattering that smoke particles cause on the light source. This type of detectors are characterized by very high sensitivity but also a limited range, high installation costs and complexity. Spot optical smoke detectors are manufactured based on EN 54-7, beam smoke detectors on EN 54-12 and Aspirating Smoke Detectors on EN 54-20.

Fires on other installations such as oil refineries are detected by outdoor flame detectors.

A **flame detector** is a sensor designed to detect and respond to the presence of flame or fire, based on the visual effects that open flames produce. Ultraviolet flame detectors work by detecting the UV radiation emitted at the instant of ignition and they operate with wavelengths shorter than 300nm and, even though they are capable of producing an alarm within 3-4 milliseconds, a time delay of 2-3 seconds is introduced to minimize false alarms. Near-IR flame detectors operate in the 0,7 to 1,1 μm and they use a Charge-coupled device (CCD) to monitor flame phenomena, without hindrance from water and water vapor. Furthermore, by observing the flicker frequency of fire (1 to 20Hz) the detectors are made less sensitive to false alarms caused by heat radiation. Infrared (IR) or wideband Infrared detectors operate in wavelengths from 1,1μm and higher, monitoring the spectral band for specific patterns given off by hot gases. For example, hot CO_2 produced during hydrocarbon burning will emit radiation within its resonance frequency of 4,3 to 4,4 mm. This radiation can be detected by specialized thermal imaging cameras (TIC) with very high accuracy, with the drawback of very limited range due to water and water vapor absorbing almost 100% of the radiation wavelengths from 3,5μm and higher. Flame detectors are mainly used in polluted environments or locations with high ceilings as well as outdoors in locations such as oil refineries or shipyards and they are manufactured according to EN 54-10.

Two recent introductions to the fire detections sensors range are combustible gas detectors and visual flame detectors via CCTV cameras. Combustible gas detectors operate by detecting the concentration of gases that are produce of combustion, such as Carbon Monoxide or Dioxide. Due to the difficulty of gas detection, NFPA standards decree that gas detectors shall be placed based on engineering evaluation and various types of detectors are being developed, such as acoustic detectors or point detectors. CCTV detectors consist of two parts, a regular CCTV camera and a complex algorithm that analyses in real-time the video feed of the CCTV, monitoring for the presence of flames or smoke. It is characteristic that no EN 54 standards exist for both of these types of detectors and combustible gas detectors mainly appear as a combination of carbon monoxide and optical smoke detectors, mainly for home use.

Fire detection is an ever-evolving field, using recent technologies and having to face advancements in structure manufacturing and material technologies. Furthermore, the advancement of microprocessor technology and algorithm integration, enable the development of smaller and more sensitive detectors, which are also more affordable and easier to install. This, in turn, leads to a demand from legislators worldwide for automatic fire detection to be included in an increasing number of installations, mostly in tandem with Building Management Systems and Cloud real-time monitoring, to minimize loss of life and property due to urban fires.

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