SKILLED TO BE A FIRE EXPERT

Co-funded by the Erasmus+ Programme of the European Union

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Fire Detection Systems

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ACKNOWLEDGMENTS

The authors gratefully acknowledge the European Erasmus+ Programme and National agency CMEPIUS “Center Republike Slovenije za mobilnost in evropske programe izobraževanja in usposabljanja” for funding the project No. 2020-1-SI01-KA202-076025 Skilled to be a Fire expert.

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1 Introduction

Effort to increase standard of living, modernization of architecture, innovation and new technologies is reflected to building construction sector. Nowadays, we can see current tendency to build large open spaces for living, production, or storages. Main examples are buildings such as hotels, multipurpose buildings, production halls, storages, hospitals, schools, or malls. Demand on enlarging these spaces bears the risk of higher losses in case of a fire. In this situation, responsibilities in fire safety are given to legal or natural persons, including their employees. Over the last 10 years, the number of people rescued from the fire has increased by about 70 percent. This is a very large proportion, which indicates that the technology in fire protection works.

For fire detection systems design in enclosure fires, hazards need to be identified first. Fires can spread incredibly fast and unpredictably especially in buildings (For more information about fire risk assessment see module 1). Presence of flammable liquids, high utilisation rate of the building or outdated fire alarm system can contribute to increase risk for persons, property and business continuity. To reduce the risk, proper installation and maintenance of modern fire detection and fire alarm systems is mandatory. Fire detection systems can play a pivotal role in mitigating consequences for fire and fire alarm systems are equally important for detection fire as early as possible. Detection is as important as the reactive actions taken right after the fire is identified so early evacuation (see module 4) and fire intervention (see module 7 and module 8) can start.

2 Involvement and coordination of fire safety equipment – actions taken after fire is detected

Fire safety equipment is installed and maintained in buildings as per fire protection guidelines, legislation or as an insurance company requirement. The main goal =is to ensure people or property protection and currently there are several types of fire safety devices available on the market. All these devices cooperate with each other and form a unified fire safety system ensuring the fire safety of the building with regard to the safety of persons during evacuation. When designing systems for effective and fast response to a fire such as evacuation, coordination of all the elements must be a priority. Individual types of fire safety equipment can be divided into individual categories based on the type of protection provided.

The division of fire safety equipment is very extensive, as most common can be listed as follows:

- Fire alarm system
    - Electrical fire alarm
    - Remote Transmission Equipment
    - Equipment for detection of flammable gases and vapours
- Fire or explosion suppression equipment
    - Stable fire extinguishers
- Smoke control device in case of fire
    - Smoke and heat removal equipment
    - Ventilation of protected escape routes
- Equipment for escape of persons in case of fire

  - Evacuation lift
  - Emergency lighting
- Equipment for fire water supply
  - External fire water supply
  - Hydrant systems
- Fire protection devices
  - Fire doors
  - Fire dampers
  - Fire seals
  - Water curtains
  - Fire shutters

The specific equipment of the building with fire safety devices determines the fire safety solution of the building. Fire safety of buildings in general is based on two basic pillars, which are passive and active fire protection.

Passive fire protection

Passive fire protection includes structural and layout solutions to provide ability of the building as a whole to withstand effects of fire. It specifically contains e.g. division of the building into fire sections, the use of suitable products, materials and building structures from their flammability and fire resistance, solutions for escape routes for people or evacuation routes for animals (for more information follow module 2,3,4).

Active fire protection

Active protection represents the ability of a fire safety device as a whole to detect the effects of a fire, to control other fire safety devices in logical sequence and to eliminate or reduce the effect of a fire, i.e. in its initial phase. These are, in particular, electric fire alarms, stable fire-fighting equipment, smoke and heat removal equipment, fire ventilation of escape routes, equipment for autonomous fire detection and signalling and other equipment (for more information follow module 6,7,8).

For proper coordination of the active fire protection systems that detected fire should triggers is usually used a **control system**. Important element of fire detection is the control panel, which is able to control other fire protection systems, forming a comprehensive system with aim to ensure fire safety. Depending on type of the asset building and its equipment with fire safety devices can be as follows:

2.1 Action: safe evacuation and smoke control

Separation of fire sections in a building needs use of fire doors, which perform their function when closed, to prevent the spread of fire and increase the chance of earlier fire extinguishing while ensuring evacuation of people from the building. The door is permanently opened during operation using magnet mechanism attached to the door panels. Coordination is done via the control panel. When the fire is detected, the control panel sends a signal that disconnects the magnets and the self-closing mechanical system, located on the door, resulting in immediate and automatic closure of the door. The door can still be used for people escaping however it is closed automatically after the use to keep heat and smoke in the fire room.

2.2 Action: smoke and heat removal devices

Smoke and heat removal devices are devices that either naturally or forcibly remove combustion products out of the building. The main goal of the smoke and heat removal device is the safe evacuation of people, the creation of acceptable conditions for firefighting and the reduction of property damage.

The main tasks of Smoke and heat removal devices include:

- position of the neutral plane (thickness of the hot layer) - allows the evacuation of people and provides orientation to firefighters (facilitates),
- reduction of the temperature of the upper hot layer - reduces the possibility of flashover, increases the protection of structures, reduces the heat load of people (evacuation, intervention) and reduces the heat load (lower damage),
- reduces the spread of fire outside the fire - lower risk of fire spread and reduction of damage from unnecessarily activated sprinklers.

The complete smoke and heat removal devices system consists of three basic components:

- Smoke and heat removal equipment,
- Smoke barriers to prevent the spread of smoke in the building,
- Equipment for supplying fresh air to the building.

2.2.1 Natural ventilation

The natural method of ventilation uses the so-called chimney effect, where due to the temperature difference between the hot smoke gases and the surrounding air (and thus also the difference in densities) a rising flow is created. So hot air rises and colder air sucks. The intensity of the chimney effect also depends on the height difference between the inlet and outlet openings. Smoke is removed either through openings in the roof (roof smoke flaps) or by means of a piping system. All dampers in the entire smoke section must be opened.

The supply of fresh air must be ensured by a sufficiently large opening (for example, automatically operated doors, windows) located in a suitable place. See figure number 1.

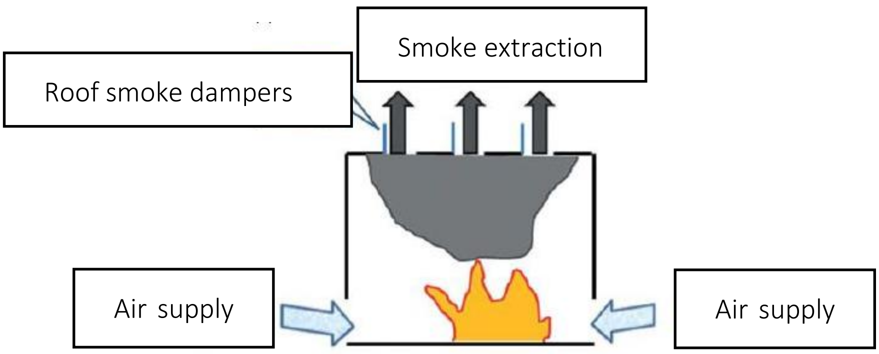

Figure 1: Scheme of natural system for smoke and heat removal

2.2.2 Forced ventilation

For forced ventilation, special electric fans are used, creating a negative pressure. The intensity of the air flow is then given mainly by the fan power. In the case of devices for forced smoke and heat removal, a sufficient supply of fresh air (natural or forced) must also be ensured, as well as air extraction (by means of pressure dampers, exhaust fans, including piping). See Figure 2. Smoke and heat removal devices with forced ventilation is usually installed where, for technical reasons, natural ventilation cannot be used (multi-storey building, underground spaces, etc.).

The forced Smoke and heat removal devices system consists of:

- fan (smoke and heat removal machinery),
- pipes (vents) and shafts for smoke and heat removal,
- energy sources,
- boot device.

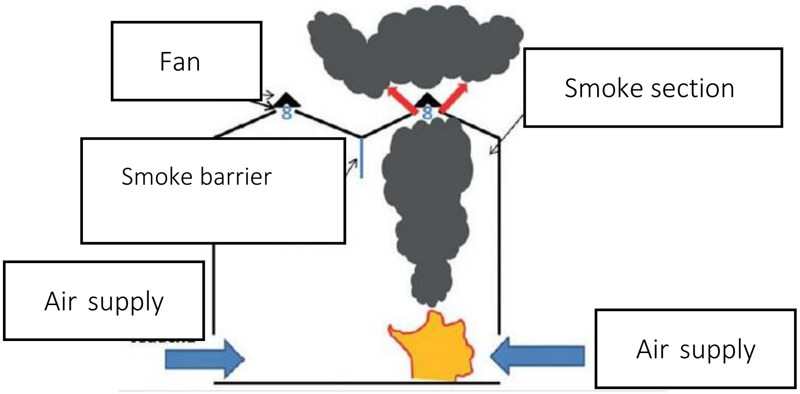

Figure 2: Scheme of forced system for smoke and heat removal

For more information on smoke control please see module 6.

2.2.3 Action: safe and smoke free evacuation

To ensure immediate and safe evacuation of people from the building in the initial phase of the fire, ventilation of protected escape routes takes action. Fire ventilation creates conditions on escape routes that facilitate evacuation for the prescribed time. The main creation of conditions that protect escaping people, that is, before the effect is the target of smoke with heat, which aims to burn oxygen and create combustion and formation. Secondary goal is to create favourable conditions for subsequent firefighting (see module 8).

Ventilation of protected escape routes is divided into three basic types: natural ventilation, forced ventilation and overpressure ventilation.

2.3 Action: extinguishing

Fire detection in buildings is matter of usefulness. It is however even more effective to put out a fire directly in its beginning. The so-called "stable fire extinguishing system" is used for this purpose.

They are designed for automatic firefighting in the event of a fire, in coordination with fire detection systems and evacuation control systems. Types of stable fire extinguishing equipment:

Sprinkler systems automatically respond to a fire and respond to a fire before it can expand. Sprinkler SHZ uses water as the extinguishing medium. It is the oldest and most widespread type of this device.

Their advantage is fast operation, automatic alarm, cheap extinguishing medium, wide range of use, high reliability and long life. Sprinklers take action independently on other automatic detection systems.

Foam fire extinguishers are used mainly in chemical plants, where they reliably extinguish flammable fires. **Gas extinguishing** is environmentally friendly, safe for humans and does not damage equipment, facilities or technology. This gas SHZ technology is mainly used where water, foam or powder SHZ cannot be used, or where these alternatives would cause greater property damage. The systems are environmentally friendly and property friendly and use the properties of inert gases. **Drencher water devices** limit the spread of radiant heat and cool the building envelope and technological equipment. More about automatic fire suppression systems can be found in module 7.

Connection of fire alarm systems and automatic extinguishing systems

The combination of the systems with electric fire alarm brings a further increase in the reliability, speed and efficiency of the intervention. The protection of people and property in the event of a fire is ensured and its consequences are minimized. The fire alarm system detects the occurrence of a fire in the building, transmits the information to the automatic extinguishing control unit and it starts its own extinguishing process.

Alarm monitoring

When smoke sets off a fire alarm, heat triggers a sprinkler head, or someone activates a manual pull station, information about detected fire can in some cases be transferred to the appropriate fire department. Emergency responders dispatch to location of fire event to put out the fire and ensure safety of occupants.

3 Fire Alarm Systems

Electric fire alarm provides early warning of fire. Signals from fire detectors are received by the control panel, which is usually located at the information, gatehouse, reception, security room, etc., accordingly to specific hazards, possibilities and practically. In most cases, the control panel operates in DAY and NIGHT mode. In the DAY mode, a permanent operator is required, who in the event of a fire signal has a certain time to check the situation (find out whether it is burning or not) and, if necessary, to cancel the false alarm. If the alarm is not triggered, the fire alarm system will call the fire protection unit using the remote transmission device. If permanent operation is not on place (NIGHT mode), the reactive actions are taken called immediately.

About installation of fire alarm systems in a building is decided in the project documentation, especially by the fire safety documentation of the building. If the fire alarm is already designed for the building, it can in some cases affect other fire safety systems of buildings and other technological equipment (extinguishing equipment, smoke and heat removal equipment, key safe cabinet unlocking, air conditioning shutdown, escape doors opening, fire shutters closing, sirens and beacons launching, starting visual and acoustic signalisation, evacuation lifts change of operation, etc.).

3.1 Components of fire alarm system

Fire alarm system consists of fire detectors, fire alarm control panel and additional equipment. The detectors use sensors to evaluate certain **physical parameters** and their **changes** accompanying the fire and send the appropriate signal. Individual or zone of detectors send indication of position change to active mode and send information to control panel which activates fire protection systems and audio information via siren. Systems for detection of fire are usually installed in industry, offices, public buildings or tunnels. They can be found at homes as well. Various types of alarm systems such as conventional, addressed, smart or smart wireless are used accordingly to specific requirements.

Main goal of fire alarm system s is to protect property and prevent losses on health and human or animal lives.

Example of addressed fire alarm system represents Figure 3. Each component is connected to the system and has its own unique address. When fire is detected, panel identifies address of the element and therefore position of fire is known.

In contrast to known position in addressed systems, use of conventional system does not provide exact position of the element activated by signs of fire. In this case, only zone is identified as a fire zone represent Figure 4.

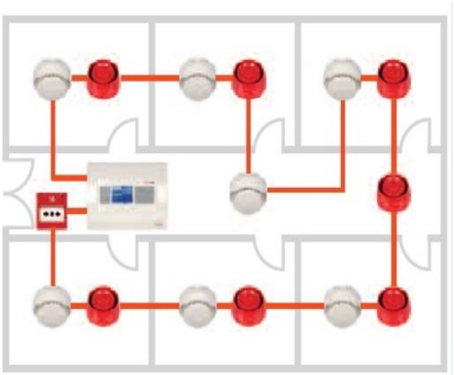

Figure 3: Addressable continuous looped example

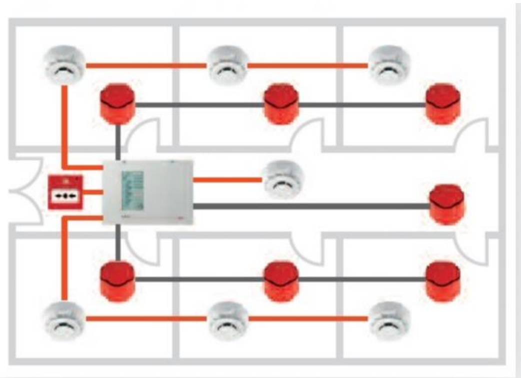

Figure 4: Conventional radial circuit example

4 Types of Detectors

Activation of fire detection system is possible in two main ways. Manual call points react to a human action, represent Figure 5. Detectors react without action autonomously and detects change in environment based on type of the detector, represent Figure 6. According to type of trigger, whereas monitors smoke, temperature, flame or gas, fire detectors can be divided to optical smoke detectors, ionic smoke detectors, heat detectors and gas detectors (such as CO).

Figure 5: Example of a manual call point and automatic detector

4.1 Optical smoke detector

Optical smoke detector is based on the scattering of smoke from burning objects entering in a dark chamber and is there lightened by a small beam of light. The reflection from the particles is catch by a light-sensitive unit which is trigging the alarm as Figure 7 demonstrates.

Figure 6: Optical smoke detectors (CFPA-E No 10:2022)

4.2 Ionic smoke detector

Ionic smoke detector is based on ionisation of smoke particles passing into a chamber with a small radioactive source and thus is electrical loaded. Because some of these chambers are made so that the entering air is part of an electrical circuit, the electrical loaded smoke particles will reduce the intensity in the electrical circuit and the detector will alert. All those detectors shall be marked with an international symbol for radiation and can be recognized in that way. It is however important to follow the national requirements for radiation protection, see figure 8.

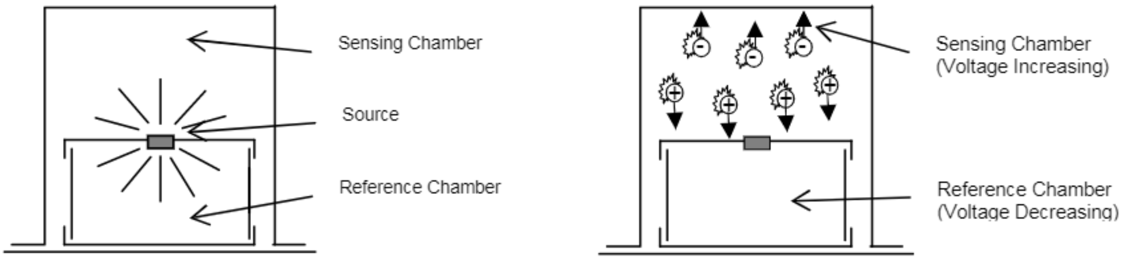

Figure 7: Ionic smoke detector (CFPA-E No 10:2022)

4.3 Heat detectors

Heat detectors react to increase of temperature. Heat detectors are ideal for situations when smoke detectors can have several false alarms due to humid or dusty environment.

4.4 Gas and CO detectors

CO-detectors are not defined as an ordinary smoke alarm and they are only used for special purposes. CO (carbon monoxide) is a colourless and odourless gas. Because it can't be smelled or seen, the gas can affect you before you even know it is there. A detector designed to give an alarm when CO levels reach a certain level in a short time. Gas detection is important in spaces with gas for example monitoring of gas appliances, gas boilers and stored gas bombs. The gas detector informs of faults in the appliance or in the event of a gas leak.

4.5 Flame detectors

The flame detector responds to the infrared or ultraviolet components of the visible flame spectrum. These detectors are suitable for areas where intense flaming can be expected, represented by sufficient light radiation.

Figure 9: Example of a flame detector

5 Frequent false alarms

The vast majority of signals from automatic fire alarms are not real fires. Fire alarm and detection systems respond to increased heat or the presence of smoke. Unfortunately, they can also be triggered by steam, cigarette smoke, aerosol sprays or light cooking smoke. False alarms are occurring - but we should take care to reduce the likelihood and take appropriate action if a false alarm occurs. Tragic cases reveal that people lost their live believing that the real fire was "just another false alarm." Most false alarms are the result of activities such as cooking, smoking or working with hot water, or sometimes simply because the system was not disconnected during testing.

It is important to minimize false alarms. Even if the false alarms occur, it is important not to pass the information to firefighters unnecessarily. Why are false alarms dangerous: Firefighters should be in a real emergency - where they can save lives. Frequent alarms in the building cause employees to become complacent and less willing to act quickly after the alarm is triggered. Unnecessary risk - due to "emergency" calls, we travel at high speed and an accident can occur. False alarms expose the public and our crews to unnecessary risk.

Reduction of false alarms

- There are many measures to reduce false alarms. Much of this is pure common sense - and it is already part of your legal obligations.
- it is decided that the design of the fire detector suits the design and use of the space.
- Usually, the alarm system is properly and regularly maintained
- Investigate false alarms and work with maintenance personnel to implement measures to prevent unnecessary recurrence.
- Establish an appropriate filtering process - a means of safely investigating why a fire alarm has been triggered BEFORE calling firefighters.
- Consult the appropriate experts for relevant advice.

5.1 Required Qualifications

To reduce the likelihood of adverse events related to the operation of fire detection alarms, it is important to perform their inspections and checks. Each user is obliged to perform a default inspection of the device before commissioning. It is also necessary to follow the manufacturers' instructions and local legislation in regular inspections of detectors, control panels, additional equipment, as well as the entire fire detection system.

6 Standards and Guidelines

The fire alarm system should have a user's guide in the present language and respect present legislation. For the design of a fire protection system, requirements are set that describe the types and activities of buildings and prescribe the minimum requirements that must be compiled. The designer works with these requirements and proposes design solutions for specific buildings and situations. For selected equipment that are custom made design and installation should follow standardized methods as provided in the literature.

Design standards provide information regarding detection principles, suitable application fields, placing, inspection, cleaning and when should they be tested.

Some examples of design standards include:

- ISO 7240-14 - international standard for the design, installation, commissioning and servicing of fire detection and fire alarm systems in and around buildings. this standard (published in August 2013; Status, Published; Issue 1; Technical Committee ISO / TC 21 / SC 3 Fire and alarm detection system)
- NFPA 72 - The National Fire Alarm Code is an established and widely used installation standard from the United States. In Canada, ULC is the standard for the fire system (latest version 2019; Status, Published. This code is part of the NFPA family standard)
- EN 54-14 - technical specification (CEN / TS) for fire detection and fire alarm systems – Part 14: Guidelines for planning, design, installation, commissioning, use and maintenance. This document has been prepared by Technical Committee CEN / TC72. It is part of a series of EN 54 standards dedicated to guidelines for fire detection and alarm systems as well as for voice alarms.

6.1 Design

Fire alarms shall be mounted in accordance with the manufacturer's instructions and relevant standards. In general, the most commonly installed smoke alarm is found near the centre of the ceiling. Central placing is the best location for sensing a fire in any part of the room. Wall placing is generally not to be recommended. Dwellings with multiple floors ought to have at least one alarm per floor connected with each other. The best solution in most cases is to place alarms in every room and connect them with each other. In rooms with peaked or sloped ceiling the detector must be mounted away from the highest point of the room. The best placing is about 100 cm from the highest point measured horizontally. Installing an interconnected smoke alarm in the master bedroom can be particularly effective as it helps ensure the alarm will be heard by a responsible person. CO-detectors should be interconnected to the smoke alarms. As the CO-gas roughly has the same weight as air and distributes evenly throughout a room, the detector can be placed at any height in any location if its alarm can be heard.

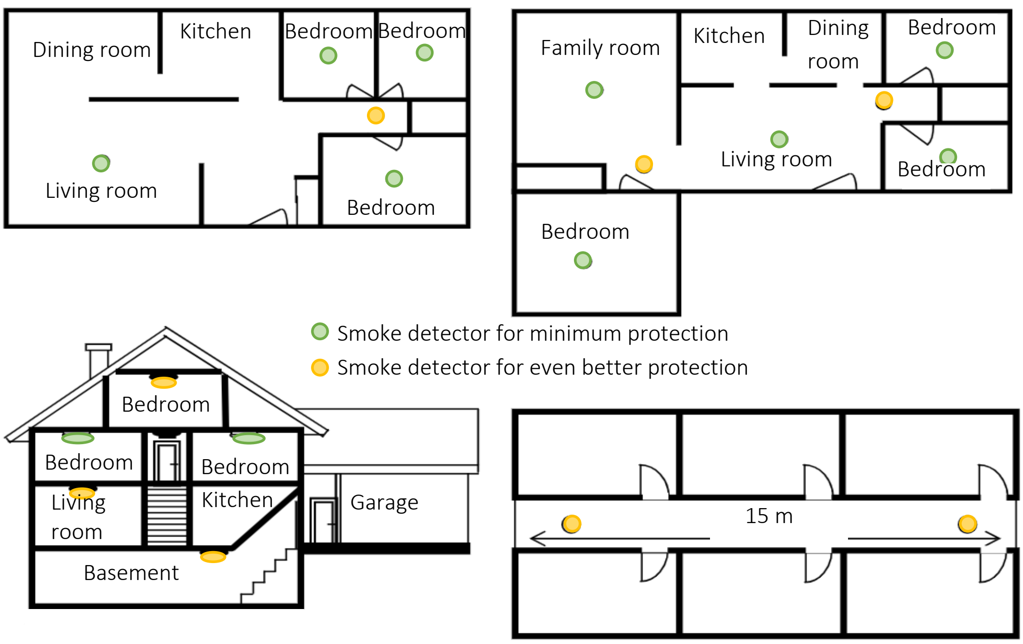

Figure 8: Examples of mounting on a family house – placing of fire detectors (CFPA-E No 10:2022)

6.2 BIM and fire protection engineering

Lately, Building Information Modelling (BIM) tools are widely used in construction, and this also includes the fire protection industry. BIM technology is improving and moving away from structural and architectural models, the fire protection industry as a whole is delivering benefits, fire protection engineering includes not only active and passive suppression systems, but also the overall safety of buildings and occupants. If the model is designed for all systems, the integration can be better applied in its entirety for all design enforcements.

BIM allows designers to create an intelligent environment that gives all users of the model instant access to all available information in the model. Therefore, the ultimate limitation of BIM is the amount of information available in the model and input from designers.

6.3 Maintenance

Inspection of operability, maintenance and repairs of fire safety equipment are authorized to be performed by professionally qualified persons and fire protection technicians. These persons may carry out serviceability checks on any fire safety device, regardless of who is the manufacturer of the specific fire safety device.

The manufacturer of a fire safety device cannot influence by his "act" the authorization of the above-mentioned persons to carry out a check of the operability of the fire safety device.

Check the operability of fire protection systems

The operability of fire safety equipment is checked at least once a year, unless the manufacturer, verified project documentation or fire risk assessment specifies shorter deadlines. Serviceability checks must be performed on all installed fire protection equipment, ie. even those that have been installed beyond the requirements of applicable regulations and which, on a voluntary basis, increase the level of fire safety at a particular entity.

Fire alarm operability check

Fire detectors should be regularly inspected according to the manufacturer's instructions, guidelines (CFPA 2008) or legislation. The detector must be cleaned against dust and checked that the batteries are charged. If false alarms recur, clean the detector, or replace defective detectors with new ones. Changes to the detector or their location must be resolved with a specialist company. These changes for some buildings must be applied to the documentation for firefighters.

Fire alarm is a relatively complex system and persons in charge of operation and maintenance must be trained and familiar with the operation / maintenance of FIRE ALARM SYSTEM. Familiarization and training is provided in most cases by a company that performs regular FIRE ALARM SYSTEM inspections and service. FIRE ALARM SYSTEM checks are performed:

- Once a year - operability check,
- 1 × in 6 months - tests of the activity of automatic fire detectors and equipment controlled by FIRE ALARM SYSTEM,
- 1x per month - activity tests for exchanges and related equipment.

Monthly activity tests are performed by persons in charge of fire alarm system maintenance. The operability check replaces the activity test at the same execution date. A document must be drawn up on the result of the annual serviceability check and the half-yearly inspection and activity test and entered in the fire alarm system operating book, which is part of each fire alarm system. Annual and half-yearly serviceability checks can only be performed by a professionally qualified person in fire protection. For the monthly activity tests, it is sufficient to make an entry in the fire alarm system operating book. If a fault is detected in the FIRE ALARM SYSTEM, it must be rectified quickly.

7 New Technologies and Further Development

With the current trends and growth of innovative technologies (Fig. 5), the specialization of fire protection and its security to produce new methods for dealing with fire-related accidents. These preventive technologies prevent the fire before it starts or inform you at an early stage of the fire. Fire detection can include equipment that detects in time and can extinguish a fire in its early stages (e.g. sprinkler systems).

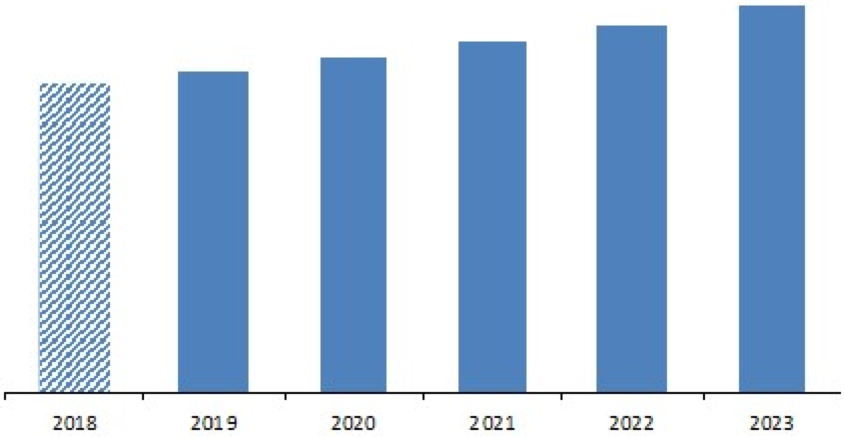

Figure 9: Worldwide fire alarm systems market is growing with increasing modern buildings and environment and requirements on fire protection level (ARC, 2022)

Intelligent control systems are designed as addressable fire alarms, are more sophisticated than conventional fire alarm systems and can provide the exact location of a fire. These systems can contain only one device up to the extremely complex storage of several hundred equipment. Each devices constantly communicates with the control panel. Within a few seconds are alarm, checks and faults of system sent to the control panel and the exact location of the event is displayed.

IoT in fire detection

Internet of things can significantly modernise current versions of fire detection systems. It can provide possibilities for connectivity with wider range of equipment and could in some cases became a part of smart systems. For example, safety warning alerts can be distributed to a number of people in a case of fire and ultimately help to save lives.

Intelligent control systems are also highly flexible. This allows for greater customization depending on the application. These systems may contain various devices offering the required protection, see Figure 10.

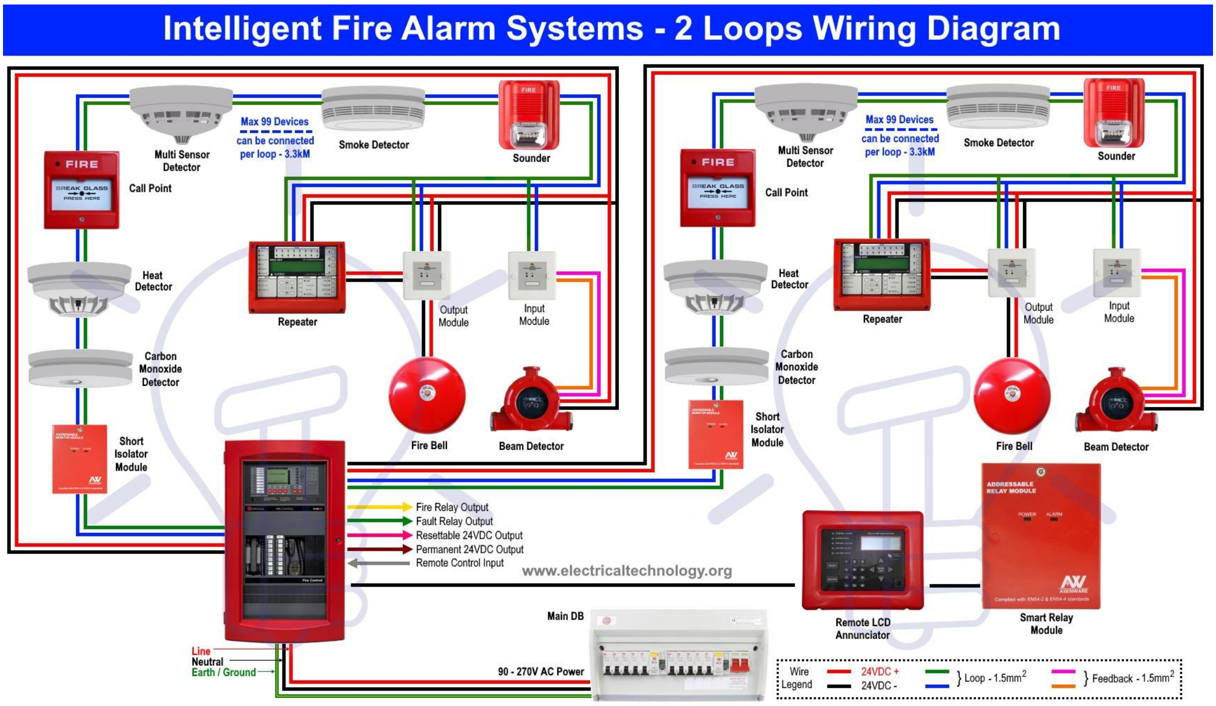

Figure 10: Intelligent Fire Alarm System (Electrical Technology 2019)

A popular and frequently used technology is wireless technology. In the wireless fire alarm system, all detectors and related equipment are connected remotely via radio communication with the fire protection control panel. The most important factor of this technology is the absence of the need for cable installations in difficult spaces, such as finished rooms and historic buildings. Figure 11 shows a system of wireless fire Alarm system.

Figure 11: Wireless fire Alarm system (Electrical Technology 2019)

8 Case Studies – Lessons learned

8.1 Case study – Grenfell Tower Fire

Grenfell Tower, a high-rise residential apartment building in London, ignited June 14, 2017, killing 72 of its 293 present occupants. The high fatality rate is largely due to confusion among occupants about if and when to evacuate.

In a high-rise, fire alarm systems are not designed to notify all occupants at once or signal a mass evacuation. The design intent of the building is to contain the fire within its compartment of origin, so that only occupants within and directly around that compartment need to be notified and evacuate. Other occupants are not alarmed and so they are not evacuated immediately. Therefore, there is place and time to contain the fire in the fire compartment. This policy is applied in the U.K. but is not universally effective. It is inherently and entirely dependent on the performance of the building's passive fire protection measures. If fire compartmentation fails, staying in the apartments should no longer be collectively advised.

The policy was so ingrained as universally practiced behaviour that occupants and emergency personnel alike continued to rely on it for instruction up to an hour after fire compartmentation had failed. The fire breached beyond its compartment of origin and spread across the building exterior, re-entering the interior of the building at multiple levels. Occupants became increasingly endangered, but were left unsure of what action to take. Without notification of the advancing fire and need to evacuate, the original, unchanging instructions were held on to long after they were no longer applicable. By the time they attempted evacuation, many of the building's occupants were left with no survivable path to do so.

Fire alarm systems are designed to signal notification based on zone and building conditions, which can rapidly change in an emergency. These changing conditions are not always observable to occupants or emergency personal. Notification signalling, as part of an automatic fire alarm system, adapts to these changing conditions inherently to send the necessary occupants signals and instructions.

Emergency voice communication systems, most efficiently direct occupants in large or highly occupied buildings. The need for this system is compounded by the increasing reliance on it during other types of emergencies. Beyond meeting code compliance, the building's function, along with its typical occupants, needs to be carefully considered in fire alarm notification design. **Automatic notification and clear instruction are vital to life safety in any emergency.**

Source: Barret 2019, Grenfell tower inquiry

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