DEVELOPING FIRE DETECTION SYSTEM FOR CHEMICAL LABORATORIES

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RESEARCH REPORT SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF ENGINEERING

FACULTY OF ENGINEERING

UNIVERSITY OF MALAYA

KUALA LUMPUR

2014

UNIVERSITI MALAYA
ORIGINAL LITERARY WORK DECLARATION

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Name of Degree: Master of Engineering (Safety, Health and Environment)

Title of Project Paper/Research Report/Dissertation/Thesis ("this Work"):

DEVELOPING FIRE DETECTION SYSTEM FOR CHEMICAL LABORATORIES

Field of Study: Safety, Fire Protection, Fire Detection

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ABSTRACT

Fire detection system as a key component of fire protection and safety plan in chemical laboratories, aim to detect the unwanted presence of fire in order to provide responses to a deemed threat to people, property and environment. This project describes the system in detail from detectable fire products to implementation of a fire detection system for a chemical laboratory.

The literature review discusses various factors that impact the reliability and accuracy of the fire detection system. It further explores the operation principals and applicability of system components to provide a method to properly select and design of fire detection systems.

The concept of this project is to develop a fire detection system for chemical laboratories to minimize the risk and maximize the safety. To achieve these objectives, a step-by-step approach introduced and the system was implemented.

ABSTRAK

Sistem pengesanan kebakaran dijadikan sebagai komponen pelan perlindungan dan keselamatan kebakaran di makmal kimia, bertujuan untuk mengesan kehadiran kebakaran yang tidak diingini dan dianggap untuk memberikan maklum balas ancaman kepada orang, harta benda, dan alam sekitar. Projek ini menerangkan sistem secara terperinci daripada produk kebakaran dikesan untuk pelaksanaan sistem pengesanan kebakaran bagi makmal kimia.

Tinjauan berikut membincangkan tentang pelbagai faktor yang memberikan kesan kepada kebolehpercayaan dan ketepatan sistem pengesanan kebakaran. Ia juga meneroka prinsip operasi dan penerapan komponen sistem untuk menyediakan satu kaedah untuk memilih dengan betul dan mereka bentuk sistem pengesanan kebakaran.

Secara keseluruhannya, konsep projek ini adalah untuk membangunkan satu sistem pengesanan kebakaran untuk mengurangkan risiko dan memaksimumkan kadar keselamatan bagi makmal kimia. Justeru itu, untuk mencapai objektif-objektif ini, pendekatan langkah demi langkah yang diperkenalkan dan sistem telah dilaksanakan.

ACKNOWLEDGEMENT

I like to give my deepest appreciation to my supervisor, Dr. Brahim Si Ali, for his time, ideas, advices, and support throughout the period of this project progress. His guidance, patience, encouragements and comments throughout the project have been very inspiring and indispensable for the success of this project.

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Chapter one: Introduction

Chemistry forms a major constituent of human knowledge; Chemical sciences and technology have significantly improved human society. As a sequel to the scientific-technological progress of chemistry, there has been enormous increase in the number of application and complication of chemical facilities of all categories, including chemical laboratories.

The scientific and technological advances on all fronts of chemical knowledge, factor of susceptibility to hazards, and complexity of fires and the related hazards in which chemical facilities are exposed had increased.

Attempting to tackle these hazards has been result in developing and evolving improved methods for fire protection system in order to mitigate such losses. Fire protection systems are constantly improving to tackle more complex fire safety issues.

Fire detection as a crucial part of fire protection system, is designed to detect the unwanted presence of fire signatures by monitoring environmental changes associated with fire products.

The early detection of fires, is to provide responses to a deemed threat to people, property and environment. To develop a fire detection system, it is important to consider its reliability, and how it could be applied.

Reliable fire detection systems are essential to all facilities including chemical laboratories; first for a rapid and safe evacuation and second as a means to initiate manual or automatic fire suppression and control.

Various fire detection systems are available, to provide early detection and warnings of heat, flame, smoke and gas.

1.1 Problem Statement

Experience has proven that, it is impractical to expect that prevention of fires can be achieved 100%. Several unpredictable factors, including vagaries of nature and acts of human commission and omission are bound to occur.

The enhancements of fire safety standards continue to mitigate losses of lives and property due to fires. The possible way to achieve this objective is to develop an integrated system that balances between fire prevention, fire detection and response to fire.

1.2 Objectives

Reliable and early fire detection systems results in significant reduction in losses. The sooner a fire is detected, the lesser the losses and damages. This work aims to provide guidance to properly select, design and operate fire detection systems.

Selecting an appropriate detection method, mechanism and design, the correct installation and maintenance of detectors increase the reliability of the system and prevent failure and unwanted nuisance alarms. Either situation negates a detector's potential lifesaving benefit, making the proper operation of an early warning detection system indispensable.

In developing fire detection system for chemical laboratories the following objectives have to achieved

- To study fire detection systems and related characteristics, factors and methods.
- To develop an approach for the fire detection system design.

1.3 Scope of Study

The study is divided into two parts. The first is a review of fire science and fire detection methods, different fire detection systems, technologies, codes, standards, mechanisms and designs.

The second is a step-by-step approach to develop a fire detection system, providing a framework for the design of different fire detection methods for chemical laboratories. This part provides an insight into the aspects of a successful detection of different fire hazards.

1.4 Approach

Study approach included a relevant literature review dealing with fire protection and detection, technical and engineering literature, data for various detection methods and technologies. To identify how different system designation can apply to develop a reliable fire detection system for chemical laboratories.

In this study, textbooks, handbooks, papers and commonly used standards in detection system used and referred.

Chapter two: Literature Review

2.1 Introduction

A chemistry laboratory can be defined as a site where chemical experiences are carried out. Chemical laboratories include numerous varieties of facilities, equipment and materials intended for testing, sampling, handling and working on different chemical substances.

The variety of tasks and use of equipment and substances in chemical laboratories, involves different hazards. Chemistry or chemical laboratories require various and sophisticated methods to design and implement a fire detection system.

The major factors for fire detection implementation are the building layout, processes, equipment and substances used, within the facility. Hazards and risks associated with these factors impose the existing of a fire detection system to be designed and implemented within the facility. Related codes, regulation and standards shall be considered within the implementation.

2.2 Fire science

To understand the principals of fire detection systems, it is beneficial to possess a basic knowledge of fire development and behavior. The purpose of this section is to introduce the physical and chemical transformations associated with a burgeoning fire and to understand the fire products that can be sensed, detected and measured. The essence of fire detection is the measurement of this response through direct or indirect means. With this information, the role and interaction of detection systems can then be better realized.

2.2.1 Combustion

Fire is a chemical reaction. A material, mixes with oxygen, and heated to a point where flammable vapors are produced to cause ignition.

Equilibrium thermodynamic is incapable of predicting the exact composition of gases or the rate at which they are produced, or other secondary effects of the heating; rather, one must rely upon chemical kinetics and analyze the dynamics of the process to gain insight into what is likely to occur in the early stages of a particular fire Transfer

Heat transfer is classified into various mechanisms, including conduction, convection and radiation. The temperature and concentration of chemical species at any point within a fire are the resultant of a balance among sources of energy, mass and momentum, the diffusive and convective processes responsible for the dispersion.

During the early stages of a fire, heat and smoke are small relative to the space of the facility and can be neglected. The source of energy is confined to radiation effects which are relatively small compared to conduction and convection. The momentum source is influenced by the gravity and pressure gradients at the boundaries, these effects cannot be neglected in detection considerations (Grosshandler, 1995).

2.2.2 Fire Products

Heat, flame, smoke and gas are four products of combustion. The products formed from the combustion of different substances vary depending upon the oxygen available, the heating rate, the moisture content and the geometry of the combustible load.

The concentration of a particular species in a fire is dictated by the boundary conditions surrounding the event, the fire location, and the period of ignition (Joshua Dinaburg, 2012).

2.2.3 Fire Signatures

No two unwanted fires are alike in all aspects, the quantities and rates of production of heat and chemical species vary significantly. Developments in early fire detection are incumbent upon knowing the fire type as well as the means to measure its characteristics. The concept of a "fire signature" was defined by Custer and Bright (1974) in their description of the state of fire detection (Grosshandler, 1995). Knowledge and measurements of fire signatures can be used for developing detection systems and evaluating their performances under realistic and unbiased conditions.

The signature of two identical fire sources will differ in magnitude and rate of change if they occur at different locations relative to the detector. Because unwanted fires are highly stochastic, the fire detection system must respond in a timely fashion independent of where the ignition occurs. There is a hierarchy of measurement methods which is inverse to the complexity of the combustion system.

Even for the major products of combustion the amount of time-dependent cannot be predicted to a high degree of certainty. For trace species and compounds that are formed or destroyed slowly, one must rely on measurements using model systems to estimate what is likely to be formed in an actual fire (Grosshandler, 1995). The results from laboratory experiments provide a starting point for identification of possible signature species and conducting full-scale tests will undoubtedly lead to the acceptance of numerical modeling as an essential tool for the detection system design.

2.3 Fire Hazard Analysis

Fire Hazard Analysis (FHA) is scientific methods to estimate the possible events, outcomes, potential impact, and consequences of fire in a specific set of conditions. FHA methods can be divided into two categories: risk-based and hazard-based. It is essential to perform a FHA to develop a fire detection system.

Hazard-based methods including fire hazard evaluation which is an organized effort to identify and analyze the significance of hazardous situations associated with the contents, process or activity and it is an important step in fire risk assessment and fire hazard analysis.

Risk-based methods analyze the likelihood of fire event and outcome, whereas hazard-based methods do not. Risk analysis requires knowledge of both the probability (frequency or likelihood of occurrence), and the consequence (impact, damage, or injury level) of the event. Risk assessment is the process used to determine how to manage the risk identified by the analysis.

The combination of hazard evaluation and risk assessment is an organized effort to pinpoint weaknesses that could lead to chemical releases, fires or explosions. Analysis can be made by experts, probabilistic methods using experimental data and deterministic methods such as model including empirical correlations, computer programs, full-scale and reduced-scale fire models, and other physical models (Leggett, 2012).

FHA can be used as part of the design process to determine a suitable, applicable and reliable detection system to improve fire response times and potential to fight fires and to reduce the overall consequences. FHA also required for evaluating the existing detection system to determine whether they achieve a set of fire safety goals.

2.3.1 Hazards Identification and Evaluation

Hazard identification involves determining credible failure scenarios that could lead to a fire incident. A hazard evaluation is used to identify, analyze the significance of hazardous situations associated with a process or activity. In this step estimation of the consequences and likelihood of the incident with both qualitative and quantitative methods would assist the design criteria.

Surveys, Checklists, What-If analysis, Fault Tree Analysis (FTA) and HAZOP analysis procedures are valuable at this stage. These techniques could be modified to suit the chemistry laboratory environment and to shift the focus to the chemicals, equipment, and the common procedures.

2.3.1.1 Checklist

The technique relies on lists of chemicals that share a particular property or producing peer fire products, which has the potential to cause a fire incident such as flammable hydrocarbons. These lists are searched to determine if the chemicals stored or to be used or produced in the synthesis are found in these compilations.

2.3.1.2 What-If

What-If hazard identification approach is a systematic technique that relies on a structured brainstorming. It requires a basic understanding of the chemistry science and procedures, along with the ability to combine possible deviations that could result in an ignition, release, or explosion accident. This knowledge helps in deciding on which adequate detection system that could be used.

2.3.1.3 Hazard and Operability Analysis

The HAZOP procedure involves taking a full description of processes taking place in the lab, and systematically questioning every part of it to establish deviations (Leggett, 2012). Once identified, decide if such deviations and their consequences can result in a fire incident. If so then consider what detection system and devices would be applicable for this situation.

2.3.2 Risk assessment

The risk to the laboratory personnel, and its environment could be estimated. The objective is to reliably identify those events which present fire related risk in order to design a proper fire protection system that detects and respond to the incident. Skills are needed to use this approach. An experienced chemical engineer is helpful in this situation. The majority or severity of the risk may result in fire protection priorities review. The fire risk assessment process can be summarized as follows:

i. Fire hazard identification;
ii. Identification of the recipients (people, properties and environment);
iii. Evaluation of the risks arising from the hazards; and
iv. Record, review and revise the assessment and findings of actions taken as a result of the above

Additional data may also be needed. The facilitator, manufacturer, a safety officer or member of Safety, Health and Environmental (SHE) department, and past incidents report and investigation can provide these data.

2.4 Fire Hazards in Chemical Laboratories

Laboratories are potentially dangerous work environments, often containing a wide variety of hazardous products. Most hazards encountered fall into three main categories: chemical, biological, or physical. Common chemical hazards found in a laboratory are volatiles, reactive substances, flammables and combustibles, explosives, oxidizers, toxic materials and corrosive materials. Common physical hazards present in laboratories are electrical, high temperature and high pressure vessels. Many of chemical and physical hazards associated with fire incidents. Fires cause fatalities, injuries, property loss, serious disruption to normal work activities and environmental damage (Sudha, 2010).

Fire hazards in laboratories arise from the storage and use of flammable and combustible, explosive and oxidizing substances and fuel gases, and from undertaking hazardous operations.

2.4.1 Flammable substances

Flammable and combustible chemicals are the most commonly used hazardous chemicals and there is a high potential hazard of fire in many laboratories because of the storage and use of flammable substances, which may be in solid, liquid or gaseous form (EHSC, 2013). Flammable and combustible substances can mix with air and burn if they contact an ignition source. Vapors from flammable liquids are denser than air and thus tend to sink to ground level where they can spread over a large area. This behavior can challenge the detection system.

The hazard of a flammable or combustible chemical is based on their flash and boiling points. For a liquid the auto-ignition temperature, explosive limits, vapor density, and ability to accumulate an electrostatic charge are all important. The possibility of such hazards being accentuated through oxygen enrichment should also be considered.

Flammable or combustible solids that are often encountered in laboratories include alkali metals, metallic hydrides, some organometallic compounds, phosphorus and sulphur. Almost all of the gas now used in laboratories as burner fuel is natural gas (methane) although propane and butane from cylinders may also be encountered. Acetylene, hydrogen and nitrous oxide are also used in atomic absorption spectroscopy equipment (EHSC, 2013).

2.4.2 Explosive substances and mixtures

Explosions can occur when flammable vapors are mixed with oxygen or air in proportions within a critical value known as the Lower and Upper Explosive Limits (LEL and UEL). Explosions can also occur when flammable substances are mixed with solid or liquid oxidants.

2.4.3 Oxidative substances

Oxidative substances promote combustion in other materials, but are harmless themselves. They have a risk of fire hazard when in contact with suitable material. Such as Sodium iodates, Mercuric oxides, Organic peroxides.

2.4.4 Other Combustible Materials

A range of combustible materials such as paper, cardboard, plastics and other packaging are often found in laboratories. In the event of a fire these materials, along with furniture and construction materials such as hardboard and chipboard, will contribute significantly to the spread of the fire and producing different fire production and signatures.

2.4.5 Gas release

Toxic gases produced at fires or in non-fire related processes are responsible for a large number of fire threats to human which result in adverse effect on body functions, serious irreversible damages and death. Reports indicate that more victims are claimed by the gas and smoke than by burns.

Many of Toxic gases and vapors can cause death if they are present in sufficient quantities and for a sufficient time. While many hazardous gases are unrecognizable for human like carbon monoxide, many of them like hydrogen chloride are causing immediate symptoms such as irritation. Although irritants may serve as warning agents and alert occupants to fire, under certain circumstances they can prevent victims from finding an exit even before reduced visibility from smoke traps them.

CO is considered the primary toxic agent in chemical fire analysis due to its copious generation by all fires. However, there are many more gases produced by fires which are notably more toxic including nitric oxide, hydrogen sulfide and hydrogen cyanide (K. Sumi, 1971).

CO poisoning can result from faulty furnaces or other heating appliances and portable generators. Small concentrations of products such as hydrogen chloride and ammonia cause direct irritation of the respiratory tract and the eyes.

2.4.6 Hazardous Equipment and Operations

A number of hazardous equipment and operations may be undertaken in laboratories that could result in fire risks. These include reactions at either high temperature and/or high pressure and oxidation reactions. Fire ignition hazards in laboratories include naked flames of Bunsen and other burners, hot plates, ovens, furnaces, electrical devices, wiring and non-flame proofed equipment (EHSC, 2013).

2.4.7 Laboratory Fire Incidents Review

Advance in chemical studies and industry practices have significantly increased the number, and complexity of chemical facilities including chemical laboratories. The major hazards with which the chemical industry is concerned are fire, explosion, and toxic release (Mannan, 2014). Of these three, fire is the most common however explosion is particularly significant in terms of fatalities and loss.

There have been numerous minor and major fires in chemical laboratories. In the United States, since 1985 there have been 114 serious fires in laboratories each of which incurred losses in excess of £50,000. Since 2009 there have been 8 serious fires in academic laboratories. The estimated financial cost of these incidents totals £16,848,700. Of these fires, 4 were started deliberately, 3 were accidental and the circumstances of the last one were unknown. There have been 113 chemical-related fires since 2009, costing £74,527,953. There have also been numerous unrecorded minor fires in chemical laboratories (EHSC, 2013).

Reported data indicates that the accident rate in academic chemistry laboratories is 10 to 50 times higher than that in industrial laboratories (Leggett, 2012). Investigation findings of accidents in academic laboratories often point to the absence of a reliable fire protection program based on hazards that led to the accident.

In Taiwan, it was reported that 49% of campus accidents (2004-2007) were related to improper use of chemicals. In Malaysia, chemical related fire incident in laboratory were reported at University Malaya chemistry department (2001), University Putra chemical engineering laboratory (2002) and University Kebangsaan Malaysia applied physics laboratory (2005) (Sarifah Fauziah Syed Draman, 2010).

Rapid increase of industrial and academic laboratories has made previous detection technologies out of date. These facilities require a determination of the contents and inventory, processes and equipment, existing fire safety system, ` tactics, as well as the proper fire detection system to provide proper response.

The proper detection system protects laboratories incidents to become large fire events. Conversely, adequate fire detection and protection design have still resulted in events with significant fire losses. Many of large fire events are the result of inappropriate design in the detection system. Analysis of fire incidents confirms that detection and notification was a key element in protection (Joshua Dinaburg, 2012). It was observed that manual fire protection attempts often failed and cost the fire department valuable response time.

2.5 Fire Detection System

The essence of fire detection system is to sense and measure of fire products and fire signatures through direct or indirect means. Generally fire detection is a key component of fire protection system.

Fire detection system employs several methods, principle and technologies. These systems broadly defined as:

- Conventional Systems
- Addressable Systems
- Analogue Addressable Systems

2.5.1 Conventional Systems

A conventional or point wired system is a two-state alarm system that gives one of two states relating to either ‘normal’ or ‘fire alarm’ conditions. In a conventional system one or more circuits are routed through the protected space and provide a number of two wire circuits onto which conventional detectors and call points are connected. Similarly, separate two wire circuits are also provided for the purpose of connecting sounders (or alarm bells) to the system.

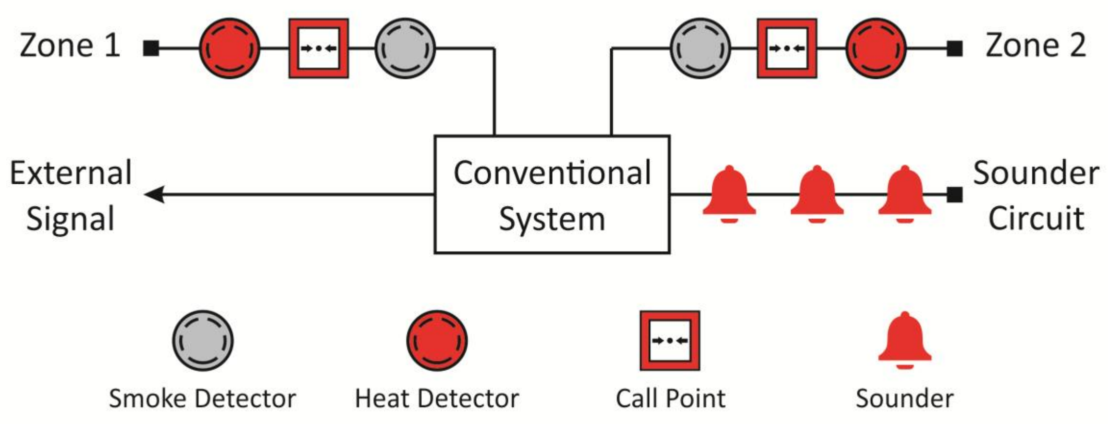


Figure 2.1: Conventional Fire Detection System Model

To indicate precisely the location of a fire, the detectors are grouped into zones with each zone being connected to the fire controller using a separate circuit that has a separate indicator on the control panel. Each detector includes an integral light or voice indicator which illuminates when the device is in the ‘fire alarm’ mode. If an indicator on the control panel indicates a fire in a zone, the zone must be physically located.

If zoning was to be extended to the limit, each circuit would have only one detector connected, and the exact location of the fire could be established at the fire controller without the need to physically search the zone.

Conventional fire systems are relatively simple and do not require a large amount of specialized training for installation. With a conventional system, there is no accurate way of determining which detectors are in need of servicing. Consequently, each detector must be removed and serviced, which can be a time consuming, labor intensive, and costly endeavor (Artim, 1999).

In conventional systems all the detectors on a zone circuit communicate continuously with the control panel. When one detector goes into the ‘fire alarm’ mode, the voltage in the circuit drops and all other detectors on that zone become disabled as result no further information about the zone can be obtained (NFPA, 2003).

2.5.2 Addressable Systems

In An addressable detection system, signals are individually identified at the control panel. The fire controller can provide a number of two wire circuits onto which addressable detectors and call points may be connected. The two wire circuit should be connected to form a loop in order to provide circuit integrity.

Essentially addressable detectors operate as conventional detectors; they only have two active modes (‘normal’ and ‘fire alarm’) and the zoning requirements of the addressable system are the same as for a conventional system.

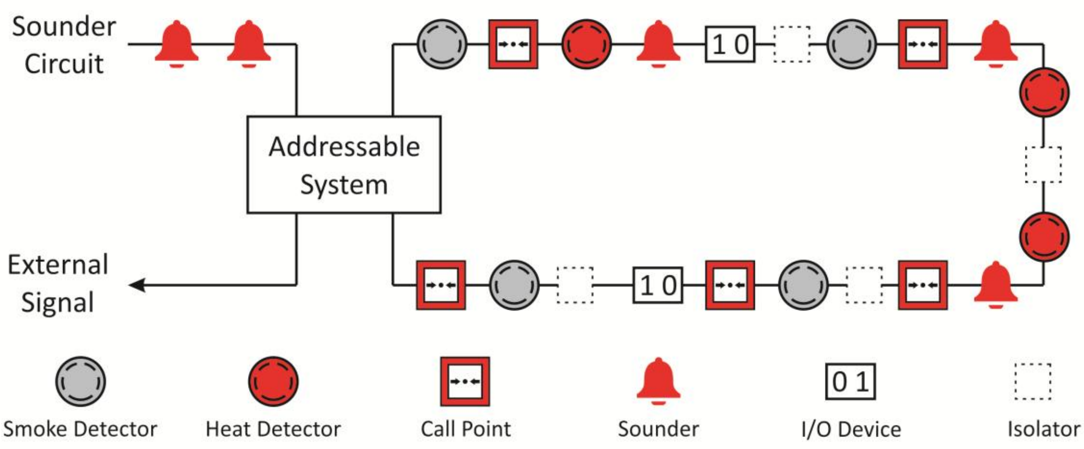


Figure 2.2: Addressable Fire Detection System Model

In an addressable system, multiplex communication techniques allow each detector to independently signal its status back to the control panel. Since each detector has its own identity (or address), can also be configured to send additional information.

Besides handling input devices, that is, detectors and call points, addressable systems can also handle output devices on the zone circuits. A typical application would be a sounder module used to drive a number of sounders (or bells), or a plant interface module used to shut down a piece of electrical plant (NFPA, 2003).

2.5.3 Analogue Addressable Systems

In an analogue addressable system each analogue addressable detectors give an output signal representing the value of the sensed phenomenon, such as smoke or heat. The output signal may be an analogue signal or a digitally encoded equivalent of the sensed value. The system design elements of analogue addressable systems, is the same as that of an addressable systems.

This system offers a number of performances over both conventional and addressable type. The analogue addressable detectors relay the received information sensed parameters such as temperature, smoke density, etc. to the control panel. Control panel interprets the received analogue value and decides whether or not to indicate an alarm, pre-alarm, normal or fault condition.

This system provides solution to reduce false alarms without causing an excessive delay in actual alarm. Unlike conventional or addressable fire detectors where the sensitivity is set, each analogue addressable detector can be made to emulate a normal, low or high sensitivity (NFPA, 2003). This option can be useful in several situations. It is possible to reduce the sensitivity level of detectors in selected zones for certain times. This feature allows the settings to be manually switched to low sensitivity for occupied zones which result in reduction of the possibility of a false alarm. It can then switch back to normal sensitivity when the premises are again unoccupied.

2.6 Fire Detection devices

Various technologies available that have been used or could potentially provide fire detection for laboratories. Due to the high potential for fire incidents in chemical labs, the fire detection methods should be capable of detecting fires early enough to provide an adequate response time to prevent large fire loss events. Available technologies may be capable of faster detection times and may reduce the overall fire fighter response times.

In this section the basic operating principles of these technologies and general laboratories environment, the benefits and limitations are discussed.

A fire can be detected simply by an individual, employing manually actuated devices or by automatically actuated devices. Automatically actuated devices can take many forms to respond to any number of detectable physical changes associated with fire: Thermal convection energy; heat detector, products of combustion; smoke detector, radiant energy; flame detector, combustion gasses; gas-sensing detector, and release of extinguishing agents (sprinkler); water-flow detector. The advanced detection systems can use imaging devices and IT algorithms to analyze the visible effects of fire. Sprinkler actuation serves as a form of heat detection, as the sprinkler is activated by excessive heat and the sudden flow of water can be monitored and used to provide notification of a fire event. In the absence of automatic detectors, fires are often detected by the visible presence of smoke or flames.

The suitability of certain types of detection depends on the size of fires, the duration of the incipient period of the fires, the fire growth rate after incipient development, and the size and configuration of the space they are designed to monitor (Joshua Dinaburg, 2012).

2.6.1 Manual Call Points

Manual call point system is simple but important for every fire detection system. A Break Glass Call Point is a device that enables personnel to raise the alarm by breaking the frangible element after detecting fire. The design has to ensure that any call points in the circuit remain operational in the event of a fault occurring; ring and loop circuits are normally used to facilitate this requirement.

Manual Call Points should be located at exit routes to open air mounted 1.4 m from the floor and sited on the floor landings of stairways. The greatest travel distance from any point in the building to the nearest call point must not exceed 30 m. Where necessary, extra call points should be sited, a greater number of Call Points may be needed in high risk areas or if the occupants are likely to be slow in movement.

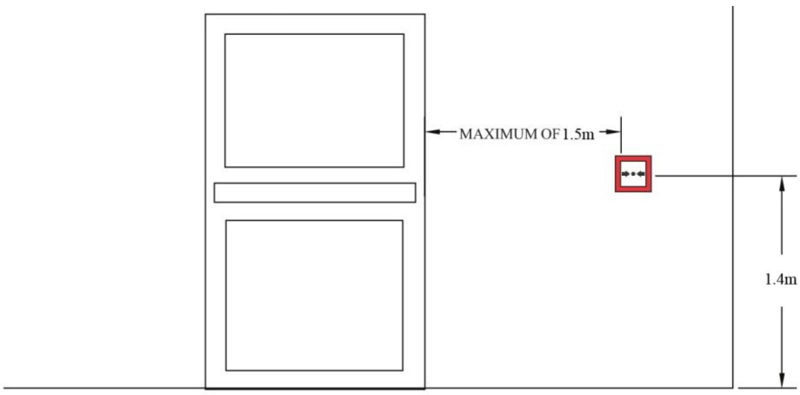


Figure 2.3: Manual Call Point Siting

Break glass/impact type call points must not be installed in areas where flammable or explosive atmospheres are likely to be present such as chemical storages. They should be mounted free of any obstructions and against a contrasting background.

Manual call points and automatic detectors can be incorporated into a single alarm system. It should be remembered, that people escaping from a fire will not necessarily operate the manual call point nearest to the fire. So to prevent misleading indication of the position of the fire, it may be preferable for manual call points to be indicated separately from detectors (NFPA, 2003). If manual call points are sited, in a multi-zone building, their indication of the position of the fire may be misleading; it is preferable to be arranged in a separate zone.

2.6.2 Smoke detection

Smoke is produced in the early stages of fire development, often long before the initiation of rapid flame spread. Smoke is released from the source of ignition and can travel through heat-induced buoyancy or forced air flow.

Smoke detection is often considered a reliable option for early fire detection warning. These systems use devices that respond to smoke particles produced by a fire and may use in conjunction with fire alarm systems (Joshua Dinaburg, 2012).

Traditional smoke detection systems involve the use of spot- type smoke detectors. Spot detectors refer to devices that can be mounted to ceilings or walls and measure the concentration of smoke at a single point.

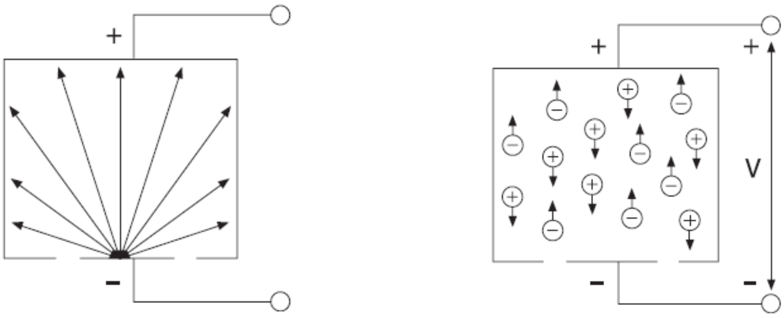
Spot-type smoke detectors use either the ionization principle of operation or the photoelectric principle. These systems are intended for early warning. Some are designed to be installed in ventilation ducts (ORRProtection, 2009).

Line-type smoke detectors refer to devices in which detection is continuous along a path. Examples include projected beam smoke detectors and laser smoke detectors.

For use in applications where spot-type and line-type detectors cannot be used, specialized detector types such as air aspirating detector, are also available.

2.6.2.1 Ionization Smoke Detector

Smoke ionization detectors are sensitive to smoke with small particles. The principle of smoke ionization detector is using a small amount of radioactive material to ionize the air between two different charged electrodes to sense the presence of smoke particles.



a) Particle Radiation Pattern **b) Ion Distribution**

Figure 2.4: A Typical Ionization Chamber (SystemSensor, 2013c)

As particles from combustion enter an ionization chamber, collide with the ionized air molecules. Some become positively charged and some become negatively charged. As these relatively large particles continue to combine with many other ions, the total number of ionized particles in the chamber is reduced. This reduction in the ionized particles results in a decrease in the chamber potential that is sensed, a threshold is crossed and an “alarm” condition is established.

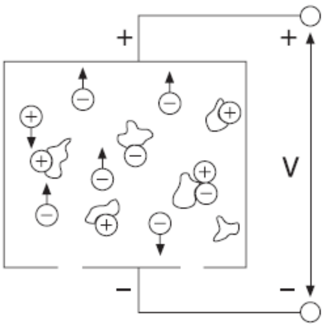


Figure 2.5: Ion and Particles Distribution (SystemSensor, 2013c)

Humidity and pressure have adverse effect on sensing chamber. To compensate for these effects, the dual ionization chamber was developed.

A dual-chamber detector utilizes two ionization chambers; one is a sensing chamber, which is open to the outside air. The other is a reference chamber, which is partially closed to outside air and is affected only by humidity and atmospheric pressure. Electronic circuitry monitors both chambers and compares their outputs. When combustion particles enter the sensing chamber decreases its current, while the reference chamber current remains unchanged. The resulting current imbalance is detected by the electronic circuitry.

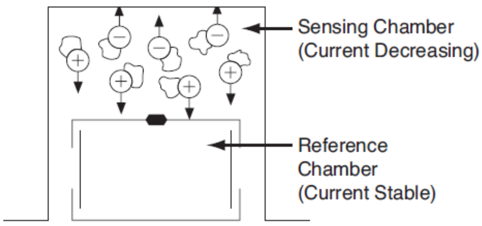


Figure 2.6: Dual Chamber with Particles of Combustion (SystemSensor, 2013c)

There are a number of parameters that can affect dual-chamber ionization detectors such as dust content, excessive humidity (condensation), significant air currents, and tiny insects.

2.6.2.2 Photoelectric Smoke Detector

Photoelectric smoke detectors are designed to sense smoke using these effects of smoke on light. Smokes from fires affect the intensity of a light beam passing through air and cause the light to scatter or obscure. Most photoelectric smoke detectors are of the spot type and operate on two principles, light scattering detection and light obscuration detection.

In ***Photoelectric Light Scattering Smoke Detector,*** a light-emitting diode (LED) is beamed into an area not normally "seen" by a photosensitive element. When smoke particles enter the light path, light strikes the particles and is reflected onto the photosensitive device causing the detector to respond.

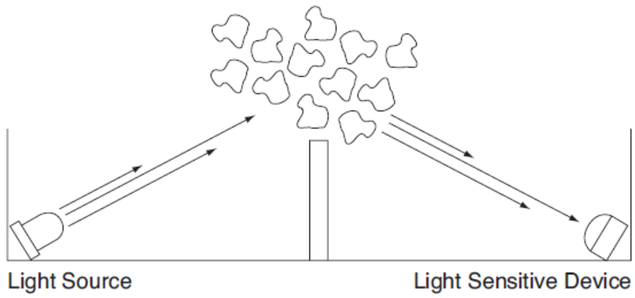


Figure 2.7: Light Scattering Detector with Smoke (SystemSensor, 2013c)

In ***Photoelectric Light Obscuration Smoke Detector***, when smoke particles partially block the light beam in an area normally "seen" by photosensitive element, the reduction in the light intensity reaching the photosensitive device alters its output signal and an alarm is initiated. Obscuration type detectors are usually of the projected beam type where the light source spans the area to be monitored.

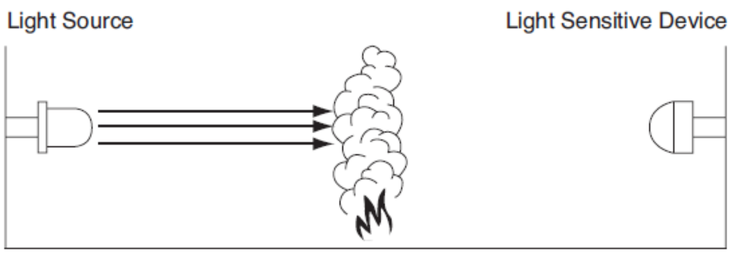


Figure 2.8: Light Obscuration Detector with Smoke (SystemSensor, 2013c)

2.6.2.3 Beam smoke detectors

Beam smoke detectors are line-type smoke detector that can be an important component of a well-designed automatic fire alarm system.

The detector works on the principle of light obscuration. Reflected beam smoke detectors consist of at least one light transmitter and one receiver (transceiver) unit that projects, monitors, and receives a beam reflected across the protected area.

The photosensitive element intercepts light produced by the transceiver unit in a normal condition. The transceiver unit is calibrated to a preset sensitivity level based on a percentage of total obscuration (SystemSensor, 2013a). This sensitivity level is determined by the manufacturer which is based on the length of the beam, the distance between the transceiver unit and reflector. The detector senses the cumulative obscuration by smoke and respond.

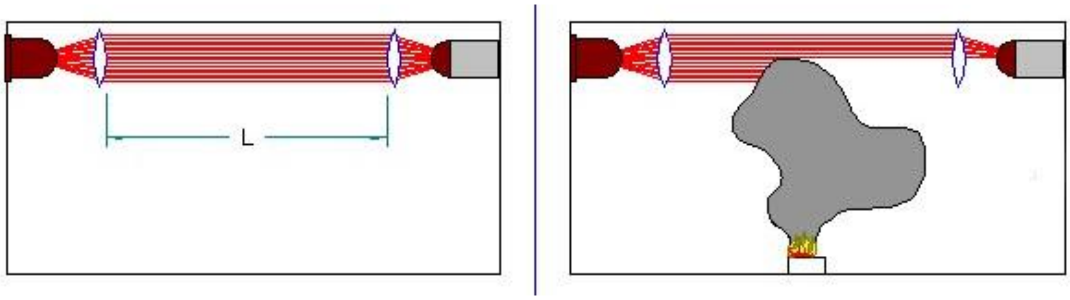


Figure 2.9: Beam Obscuration

Due to the situation and environment condition different setting of beam detector can be applied.

An ***End-to-End beam detector*** has a separate light transmitter and receiver. They are used in applications where there is little available space to install a wide area detector. as the receiver is on a separate element each individual unit is quite small. The small size of the detector is also an advantage for aesthetic installations.

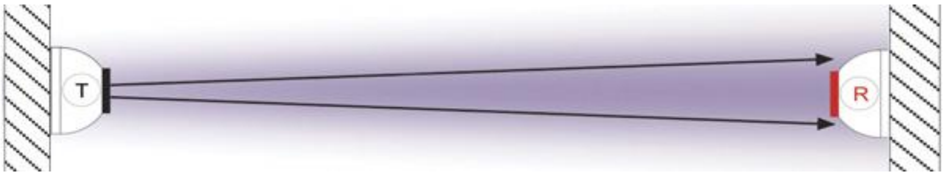


Figure 2.10: End-to-End Beam Detector

Reflective beam detector incorporates a light transmitter and the detector on the same unit. The light path is created by reflecting light emitted from the transmitter off aretroreflector that is placed opposite the detector.

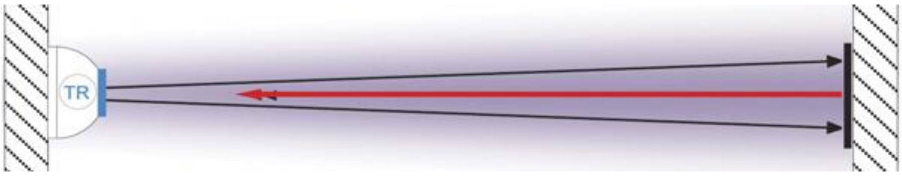


Figure 2.11: Reflective Beam Detector

Motorized beam detector automatically aligns itself during installation and can compensate for alignment 'drift' i.e. where the optical path of the light beam changes over time. Both end-to-end systems and reflective systems can be motorized.

Heaters allow the optical surface of the beam detector and reflector to maintain a slightly higher temperature than the surrounding air. This helps to minimize condensation in environments that experience temperature fluctuations.

2.6.2.4 Laser Smoke Detectors

Laser technology smoke detectors are designed to extremely early detection of fire. They are designed to detect the earliest particles of combustion making them ideal for monitoring and control rooms, and computer lab, or any area with mission critical operations.

The principal of operation is similar to beam detectors, however, Laser-based smoke detectors are ultra-sensitive to smoke and particles, as much as 100 times more sensitive than standard detectors. So care and judgment of application is needed to prevent unwanted alarms.

2.6.2.5 Air Sampling Smoke Detectors

An Air Sampling Detector or Aspirating Smoke Detector (ASD) consists of a central detection unit which draws air through a network of pipes to detect smoke. The sampling chamber is detects the presence of smoke particles suspended in air. In most cases aspirating smoke detectors require a fan unit to draw in a sample of air from the protected area through its network of pipes.

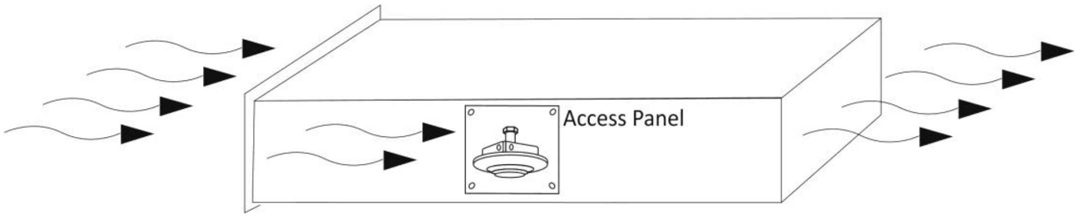


Figure 2.12: Duct Smoke Detector

ASD use a pipe system and fan to draw smoke particulates back to the detection chamber. The pipe configuration, hole placement and hole diameter are designed from algorithms which take into consideration air flow, room size, sensitivity requirements (speed of detection) and other parameters to determine the optimal set up (SystemSensor, 2013c).

2.6.3 Gas detection

Gas sensing devices measure and indicate the concentration of certain gases in the environment via different methods. Techniques are available for measuring almost any gaseous species produced prior to or during combustion.

Gas detectors are categorized by the type of gas they detect: combustible or toxic. Within this broad categorization, they are further defined by the technology they use: catalytic and infrared sensors detect combustible gases and electrochemical and metal oxide semiconductor technologies generally detect toxic gases. The tradeoffs in choosing a gas sensor involve time response, selectivity, sensitivity, complexity, and cost. Potentiometric, solid-state, electrochemical sensors have been constructed for oxygen, hydrogen, water vapor, carbon monoxide, carbon dioxide, chlorine, and hydrogen sulfide, with detectable partial pressures as low as one part in a million. Organic thin film sensors have the potential to measure low concentrations of combustion products (Grosshandler, 1995).

Gas detection devices are applicable for chemical substance storages with stable environment including as safe boxes and tank farms, and processes and operations including volatile substances or may result in chemical release

2.6.3.1 Carbon monoxide detector

A carbon monoxide detector or CO detector is a device that detects the presence of the carbon monoxide gas in order to prevent carbon monoxide poisoning. CO detectors are designed to measure CO levels over time and sound an alarm before dangerous levels of CO accumulate in an environment, giving people adequate warning to safely ventilate the area or evacuate (SystemSensor, 2013b). Some system-connected detectors also alert a monitoring service that can dispatch emergency services if necessary.

While CO detectors do not serve as smoke detectors and vice versa, dual smoke/CO detectors are applying. Smoke detectors detect the smoke generated by flaming or smoldering fires, whereas CO detectors detect and warn people about dangerous CO buildup caused.

2.6.4 Heat detection

In addition to smoke detection and gas sensing, fires can be detected by measuring the temperature of hot gases or surfaces exposed to fires. Heat detection system is less sensitive alternative for mentioned detection system; however, it is acceptable for specific substances or environment which smoke detectors cannot be used. It should be noted that the ambient temperature which heat detector senses is always higher. However, heat detection will only detect developing flaming fires and may not provide notification during incipient periods prior to rapid flame growth (CSAA, 2011).

There are generally two types of heat detection methods utilized, *spot-type detection* and *linear detection*. Traditional heat activated sprinkler protection systems with water flow monitors can be considered as a form of spot heat detection.

Spot-type heat detection methods such as the Rate of Rise and Fixed Temperature types are designed to sense the conditions near a fixed point. Linear detectors are designed to sense the conditions in the vicinity of the line.

Heat detectors are designed to respond when the operating element reaches a predetermined temperature (fixed temperature detector), when the temperature rises at a rate exceeding a predetermined value (rate-of-rise detector), or when the surrounding environment’s temperature reaches a predetermined level, regardless of the rate of temperature rise (rate compensation detector). Some devices incorporate both fixed temperature and rate-of-rise detection principles.

Heat detectors can be addressable or conventional, and can be used to provide audible notification to occupants and electronic notification to monitoring stations and fire departments. It is possible with some addressable detectors to also monitor temperature, which could be used as a pre-alarm condition for lower level temperature increases (Joshua Dinaburg, 2012).

2.6.4.1 Fixed temperature heat detectors

Fixed Temperature Heat Detectors or Static Heat Detectors react at a pre-determined temperature. Fixed temperature detectors operate when the 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 reach its operating temperature sometime after the surrounding air temperature exceeds that temperature. This type of technology has been available for decades without the use of batteries or electricity.

These detectors are ideally suitable for use in areas where sudden large changes in temperatures are considered normal, such as laboratory furnace or electrical oven.

2.6.4.2 Rate of Rise heat detectors

Rate-of-Rise (ROR) heat detectors react to abnormally high rates of change in temperature and operate on a rapid rise in element temperature, irrespective of the starting temperature. This type of heat detector can operate at a lower temperature fire condition than would be possible if the threshold were fixed. It has two heat-sensitive thermocouples or thermistors. One thermocouple monitors heat transferred by convection or radiation. The other responds to ambient temperature. Detector responds when first's temperature increases relative to the other. Rate of rise detectors may not respond to low energy release rates of slow developing fires.

These detectors are ideally suitable for use in areas where any large change in ambient temperature will signal an alarm condition to the control equipment such as lab furnace chimneys. ROR detectors should not be used in areas where large sudden changes in temperature are normal, otherwise false alarms will occur.

2.6.4.3 Linear Heat Detectors

Linear heat detection (LHD) describes a general type of cable or tube based detector that can measure heat along the length of the device. There are several principles of operation for linear heat measurement. The physical operating principles of each type vary, but in general they are extended wires or tubes that are capable of sensing elevated temperatures anywhere along an extended path. Two major type of LHD are non-integrating and integrating.

The ***non-integrating*** LHD usually consists of a stretched wire, of fixed melting point, which is suspended over the area to be protected. If one small section of the wire is heated up (due to fire) and the temperature of the section is greater or equal to the melting point of the wire, the line will break and cause the system to go into alarm.

The ***integrating*** LHD is similar to the non-integrating version except here the average temperature is taken over the whole length of the wire rather than just sections of it (NFPA, 2003). Consequently, a large amount of heat in a small area would need to be generated in order to create an alarm.

Linear heat detection is often advantageous for chemical storage facilities because it can be run in storage racks and between storage levels. Linear heat detection devices can be very rugged, resistant to environmental conditions and low maintenance. Placement on or near storage provides linear heat detection with the benefit of much faster alarm times compared to ceiling mounted detection devices.

They are ideally suited for such applications as risers, high rack storage areas, thatched surfaces and ducts. To allow for easy location of alarm or fault conditions, it is recommended that the maximum length of the sensing wire be limited (Joshua Dinaburg, 2012).

2.6.4.4 Sprinkler System

Sprinkler systems automatically detect and then control, suppress, or extinguish fires. Sprinkler serves as a form of heat detection, as the sprinkler is activated by heat and the flow of water can be monitored and used to provide notification of a fire event.

2.6.5 Flame detection

Heat detection devices measure the convective output from hot gases in a fire, the presence of flames can also be measured by the radiative components. Flame detection can be performed through optical visualization of protected spaces by measuring emitted thermal radiation or through resolved imaging technologies (Gottuk, Peatross, Roby, & Beyler, 2002). As heat radiated in the form of wave and with light speed, these detectors can be used to protect large open areas with extremely high speed of response to flaming fires. In order to ensure full coverage however, flame sensors do require direct line of sight to all parts of the area to be protected.

2.6.5.1 Optical flame detectors

Optical flame detectors (OFD) measure radiant energy emitted by flames at the speed of light and specific wavelengths indicative of fires.

Various OFDs are designed to detect ultraviolet (UV), infrared (IR), or combinations of various wavelengths of the radiative spectrum. The wavelengths detected can be tailored to detect specific types of flames and reject other forms of background or nuisance sources.

OFD devices can be used to monitor a large area for the presence of flames. Such devices could be used to protect a large area, such as a gable frame labs. The primary limitation of OFDs is due to the presence of obstructions (Joshua Dinaburg, 2012). The devices must be able to see the flames, and labs generally present a fairly dense viewing environment.

2.6.5.2 Flame ionization detector

A flame ionization detector (FID) is operating based on the detection of ions formed during combustion of organic compounds in a flame.

The generation of these ions is proportional to the concentration of organic species in the sample gas stream. Hydrocarbons generally have molar response factors that are equal to number of carbon atoms in their molecule, while oxygenates and other species tend to have a lower response factor. Carbon monoxide and carbon dioxide are not detectable by FID.

2.6.6 Advanced Detection Systems

The recent generation of detectors employs a series of sophisticated and high-tech detection measures in order to detect the fire with high level of accuracy and rapidity in challenging environments and conditions.

2.6.6.1 Video Image Detection

Video image detection (VID) systems consist of video-based analytical algorithms that integrate cameras into advanced flame and smoke detection systems. The video image from a camera is processed by proprietary software to determine if smoke or flame from a fire is identified in the video (Gottuk et al., 2002). The detection algorithms use different techniques to identify the flame and smoke characteristics and can be based on spectral, spatial or temporal properties; these include assessing changes in brightness, contrast, edge content, motion, dynamic frequencies, and pattern and color matching (Joshua Dinaburg, 2012).

2.6.7 Multi-Criteria detection

Multi-Criteria detection contains multiple sensors that separately respond to fire products such as heat, smoke, flame or fire gases. An alarm signal is determined through advanced algorithms based on input from these sensors. Several types of multi-criteria detection systems are introduced. An advanced Multi-Criteria detector combines four signals: photo, thermal, carbon monoxide and infrared. Combination Carbon Monoxide and Smoke detectors are also available. This device type provides separate signals for each event. In this device the CO sensor may or may not be used for determining the presence of smoke/fire depending upon the type of device.

The combination of sensors offers better immunity to nuisance alarms in challenging environments with faster response times to real fires. Hence, combining multi functions into one device improves installation time and cost as well as offering a more aesthetically pleasing final product.

2.6.8 Control Panel

The control panel is the brain of the fire detection and alarm system. It is monitoring the various input signals of devices such as manual and automatic detection components, analyze the input and then activating output devices such as warning lights sounders, alarms, extinguishing system, emergency communication system and building controls. The control panel also monitors the functionality of system and reports the trouble. Control panels may range from simple units with a single input and output zone, to complex computer driven systems that monitor several buildings (Artim, 1999).

2.6.9 Additional Fire Safety Functions

Often fire detectors are utilized to control auxiliary devices and equipment. Detectors should be utilized in such a manner to approve for their intended purpose.

The fire detection and alarm system may need to interface with other existing devices or alarm systems. In these cases information should be obtained relative to these devices before the system is designed including voltage compatibility, addresses, and contact compatibility. Often additional interface modules are required to activate, de-activate or otherwise monitor existing devices.

2.7 Detection system design

The process of fire detection system design is complying with a set of prescribed or prescriptive design features implemented which specifies how the detection system is to be designed. These features have been derived from the analysis of simulations, real-scale tests and past experiences. Prescribed design features have been evolved from past experiences. While performance-based design relies on the ability of the designer to achieve certain performance objectives through modeling and engineering methods. To apply performance-based design method an understanding of all the fire protection features is critical.

Although fire detectors are based on simple concepts, certain design considerations need to be observed to achieve the objectives. The design should ensure that the detection system performs maximum efficiency and reliability. System should produce an early alarm, but should minimize the impact of an unwanted signal which can arise from a variety of causes.

The process of design, including zoning, siting and spacing, shall be the result of an engineering evaluation and should consider several factors which may have significant impact on the fire protection. Consideration includes but not limited to:

- Structural features
- size and layout of the facility
- ceiling height and shape
- surface and obstructions
- ventilation
- ambient environment
- burning characteristics of the combustible materials present
- the configuration of the contents in the area to be protected
- Pre-stratification as a predominant factor
- occupancy and uses of the laboratory

2.7.1 Detectors Selection

Each type of detectors can detect different types of fires, but their respective response times will vary depending on the type of fire scenario. It is often difficult to predict what particle size will be produced in a developing fire because chemical facility normally contain a variety of combustibles. Many factors affect the performance of smoke detectors. The laboratory area and architecture, type and amount of combustibles, the rate of fire growth, the proximity to the fire, ventilation and environmental conditions are all important considerations. The fact that different ignition sources can have different effects on a given combustible further complicates the selection. Before the selection of the detectors, they should be assessed in terms of performance, efficiency, capability and limitation.

Because fires develop in different ways and are often unpredictable in their growth, neither type of detector is always best. A given detector may not always provide significant advance warning of fires when fire protection practices are inadequate, nor when fires are caused by violent explosions, escaping gas, improper storage of flammable liquids such as solvents, hydrocarbons, etc.

Spot-type detectors only sample smoke and heat at their particular spot. The smoke which enters the chamber may be diluted below the level of smoke needed to activate an alarm. Facilities with high ceilings present special problems for the installation and maintenance of spot-type detectors (SystemSensor, 2013c). High air movement areas are challenging for spot-type detectors, because the propagation of smoke developing in sensing chamber may not occur.

The characteristics of an ionization detector make it more suitable for detection of fast fire flames that are characterized by combustion particles in the range of 0.01 to 0.4 micron such as solvents. Dust and dirt can accumulate on the radioactive source and causes it to become more sensitive.

Photoelectric smoke detectors are better suited to detect slow smoldering fires that are characterized by particulates in the 0.4 to 10.0 micron range. Insects, dirt, drywall dust, and other forms of contamination as well as reflected light from the light source may be result in false detection.

Beam smoke detectors can cover an area which would require a dozen or more spot-type detectors. A beam smoke detector's sensing range can be 100 meters (330 feet), as result beam smoke detectors are suited for high ceiling applications and the devices can be mounted on walls, which are more accessible than ceilings. Beam smoke detectors impractical in most occupied areas with normal ceiling heights because as line-of-sight devices, they are subjected to interference from any object or person which enters the beam's path. However, appropriate sensitivity setting minimizes the possibility of nuisance alarms (SystemSensor, 2013a). Since the sudden and total obscuration of the light beam and as the same very small, slow changes in the quality of the light source are not typical of a smoke signature. The detection system will see this as a trouble condition, not an alarm.

In high ceilings laboratory building, beam smoke detectors may be more responsive to slow or smoldering fires than spot-type detectors because they are looking across the entire smoke field intersecting the beam.

Since high air movement does not have as great an effect on beam detectors, they are not typically required to be listed for this type environment. Stratification needs to be considered, since it is a predominant factor in buildings with glass or metal ceilings. Stratification occurs when smoke is heated by smoldering or burning materials and becomes less dense than surrounding cooler air (J.N.Vakil, 2005). The smoke rises until there is no longer a difference in temperature between the smoke and the surrounding air. Stratification, therefore, may occur in areas where air temperature may be elevated at the ceiling level, especially where there is a lack of ventilation. The heat from the fire can further add to this hot air layer and increase its depth.

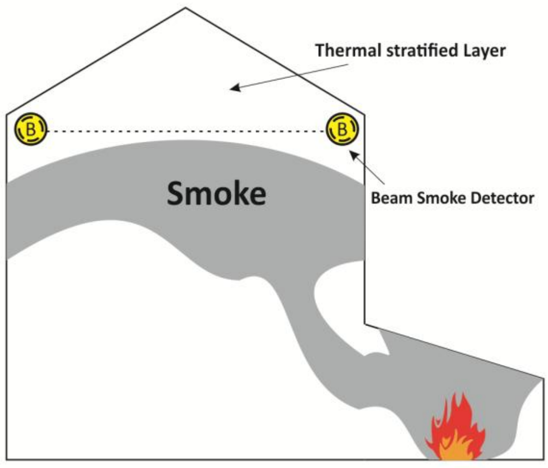


Figure 2.13: Thermal Stratification

One of the major limitations of spot-type smoke detectors for chemical facilities is their inability to survive in hostile environments, such as temperature extremes, dirt, humidity, and corrosive gases. Although beam smoke detectors may be subject to some of these debilitating elements, they are a good alternative in many instances because their operating temperature range may be much wider than spot-type smoke detectors. Possible beam detectors applications for chemical laboratories include freezers, cold storages and enclosed burning facilities.

Beam detectors, however, should not be installed in environments where there is no temperature control and condensation or icing is likely. If elevated humidity levels and rapidly changing temperatures can be expected in those areas, then condensation likely will form, and the application is not acceptable for the beam detector. Also, the beam detector should not be installed in locations where the transceiver unit, the reflector, or the optical pathway between them may be exposed to outdoor conditions such as rain, snow, sleet, or fog. These conditions will impair the proper operation of the detector (SystemSensor, 2013a).

2.7.2 Coverage

The system design should be based on the purpose of protection system and priorities for earlier warning with higher risk premises. The categories of protection coverage are as below:

- **Property Protection (Type P)**: The purpose of protection is the building and its contents which is divided into P1 and P2;
- **Life Protection (Type L):** The purpose of protection is enhancing the safety of the occupants which is divided in to L1, L2, L3, L4 and L5; and
- **Type M:** A system which provides manual alarm only.

2.7.3 Zoning

The faster the source of an alarm can be pinpointed, the faster action can be taken. The most effective way of pinpointing and limiting fire spread within a building is to subdivide the area into the smallest practicable compartments; such a compartment is known as a zone. One major function of a fire control system unit is to indicate the location of a fire as precisely as possible. To this end, the detectors are grouped into zones.

It is always advisable to zone any system that contains more than a small number of detectors and minimize the number of detectors in each zone (OH&S, 2010). Fewer detectors on a zone will speed up locating the fire and simplify troubleshooting. The site shall be zoned in accordance with the code and standards.

For conventional systems, each zone is connected to the controller by a separate circuit. For addressable systems however, one circuit may connect to several detectors and protect several zones. In either case each zone should have a separate number of visual indicators on the controller.

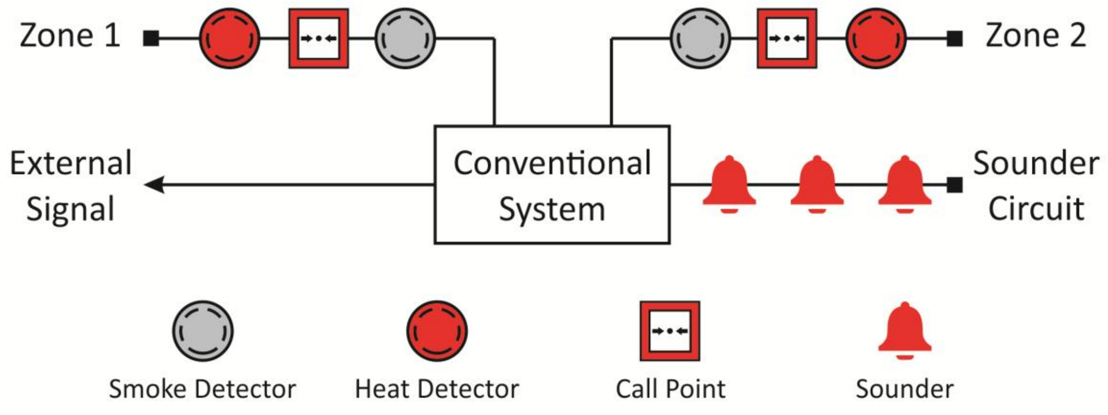


Figure 2.14: Conventional Detection System Zoning

Ability of addressable systems to identify any detector or call point which is in the alarm condition, regardless of how many devices are connected to that circuit is major benefit to precisely locate the origin of the fire. This ability made it suitable for multi-purpose facilities.

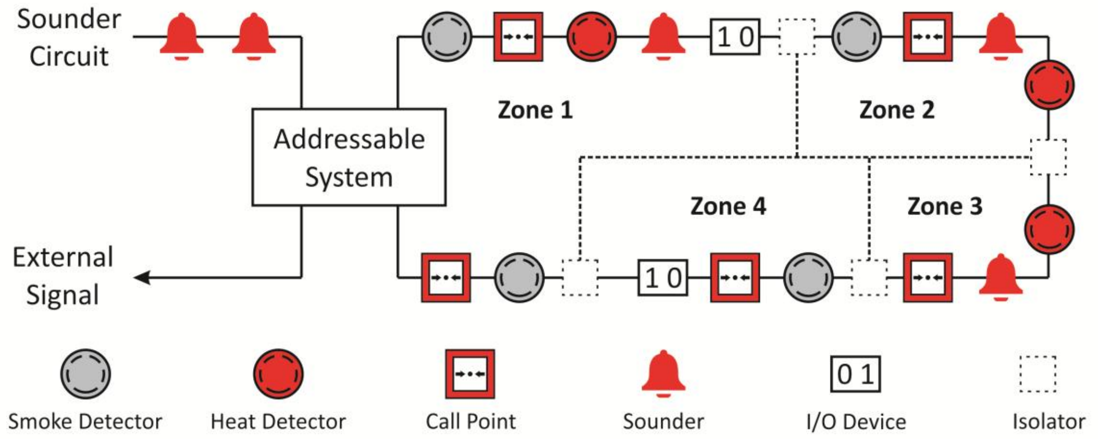


Figure 2.15: Addressable Detection System Zoning

There are several guidelines to the size and configuration of a zone that are common to both conventional and addressable fire systems:

1. The maximum floor area of a zone should not exceed 2000m^2.
2. The search distance should not exceed 30m.

3. For multi-purpose buildings, such as chemical laboratories inside a faculty building, zone boundaries should not cross occupancy boundaries or split between them.
4. A single zone may extend to cover several fire compartments. An example of this is that a specified section of the lab (e.g. control room or office) may designed to have adequate fire resistance to be considered as compartments but may be considered to be on the same zone as a larger adjacent compartment. Zone boundaries, however, must lie along compartment boundaries i.e. walls and doors.
5. If manual call points are sited, in a multi-zone building, their indication of the position of the fire may be misleading. To prevent misleading indication of the position of the fire, it may be preferable for each to be arranged in a separate detection zone. If the call points are connected in a staircase zone, then misleading information becomes less likely.
6. There are advantages and disadvantages of having individual spurred wiring for each zone and having a complete loop.

A color code zoning presented in figure 2.16

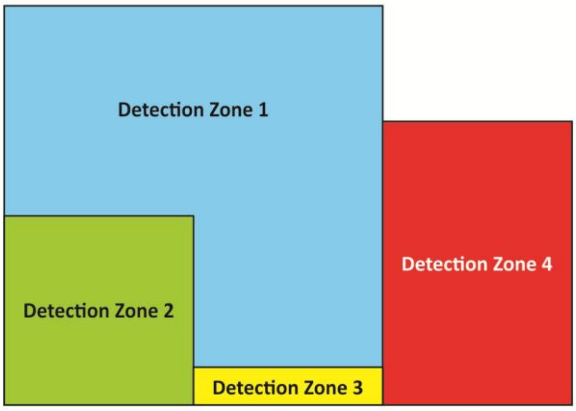


Figure 2.16: Zoning a One-Floor multi-purpose Building

2.7.4 Locating

The coverage area of different detection devices vary depending on the type of detection and device technical specifications. In cases there is a requirement for more than one device in an area, which result in overlap in different device's coverage, as well as probable blind spots, theses coverage area must be determine by the designer to ensure that there are no blind spots in the area without excessive overlap.

Some fire protection codes specify detector spacing on a given center-to-center distance between detectors under ideal conditions. Guidelines are based on ideal conditions that do not exist in the majority of buildings. Designers and installers usually have to deal with a variety of problems, such as uneven ceilings, beams and joists, equipment, storage racks, partitions; air flow, peaked or sloped ceilings, or localized heating or cooling from HVAC systems; and extensive variability in the value and combustion characteristics of building contents. Locating and spacing parameters are recommending by manufacturers due to application (SystemSensor, 2013c).

The spot-type smoke detectors should normally install within the range of 25mm to 600mm from the ceiling, and for heat detectors within the range of 25mm to 150mm.

For spot detectors the coverage of a detector is a circle centered on the detector and having a radius of specific limit due to the type and technology of the detectors which is designated by manufacturer. This coverage limited by regulated codes and standards.

Spot smoke detectors have an individual coverage of a 7.5m radius. The individual coverage can be represented by a square measuring 10.6m x 10.6m giving coverage of 112m² per device, which is usually approximated to 100m². Maximum center-to-center distance between two spot-type smoke detector is 10.6m.

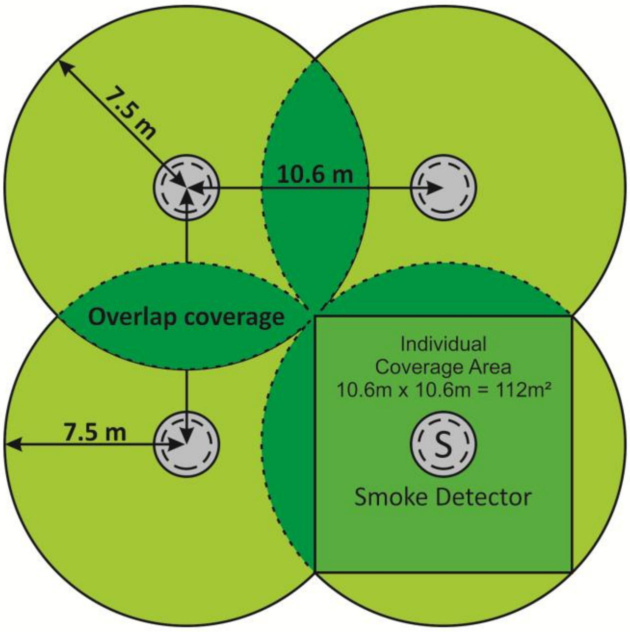


Figure 2.17: Spot-Type Smoke Detector Coverage and Spacing

Spot heat detectors have an individual coverage of a 5.3m radius. The individual coverage can be represented by a square measuring 7.5m x 7.5m giving coverage of 56m² per device, which is usually approximated to 50m². Maximum center-to-center distance between two spot-type smoke detector is 7.5m.

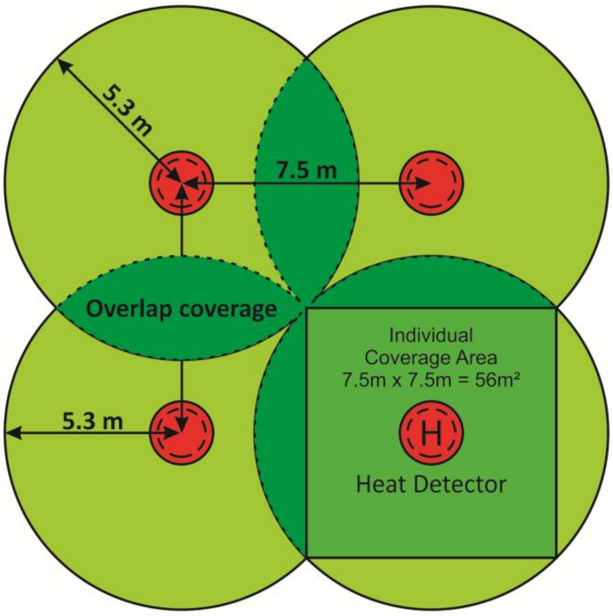


Figure 2.18: Spot-Type Heat Detector Coverage and Spacing

In a corridor less than 2m wide, the individual coverage of spot detectors do not need to overlap, as shown in figure 2.3.14 maximum center-to-center distance can be spaced 15m apart for smoke detectors and 10.6m for heat detectors.

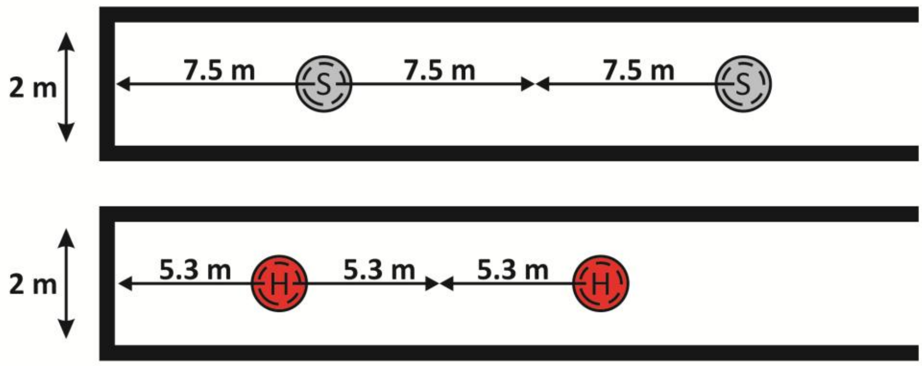


Figure 2.19: Spot-Type Detector Spacing in Corridor

Minimum distance between detector and wall or partition should be 50cm and the minimum distance between the detector and HVAC Panel should be at least 1m. if there is any racking or partition less than 30cm from the ceiling, it consider as a wall.

For a semi cylindrical arch, the radius of cover of a detector in the center can be calculated as 8.93m for a smoke detector and 6.31m for a heat detector. For the pitched roof less than 6m deep, the design is same as flat ceiling. For deeper than 6m, at least one row of detector should be in the top 6m.

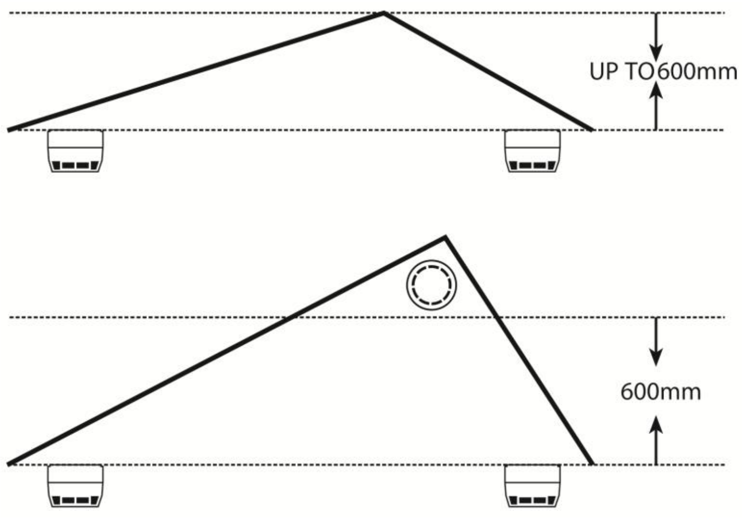


Figure 2.20: Spot-Type Detector Spacing for pitched roof

For siting beam detectors, the maximum height of floor is 25m and minimum is 2.7m and the distance of optical beam from the ceiling is 30cm. the length of the optical beam is 100m.The beam detector should not pass less than 50cm to a wall or partition, and not closer than 60cm to an obstruction.

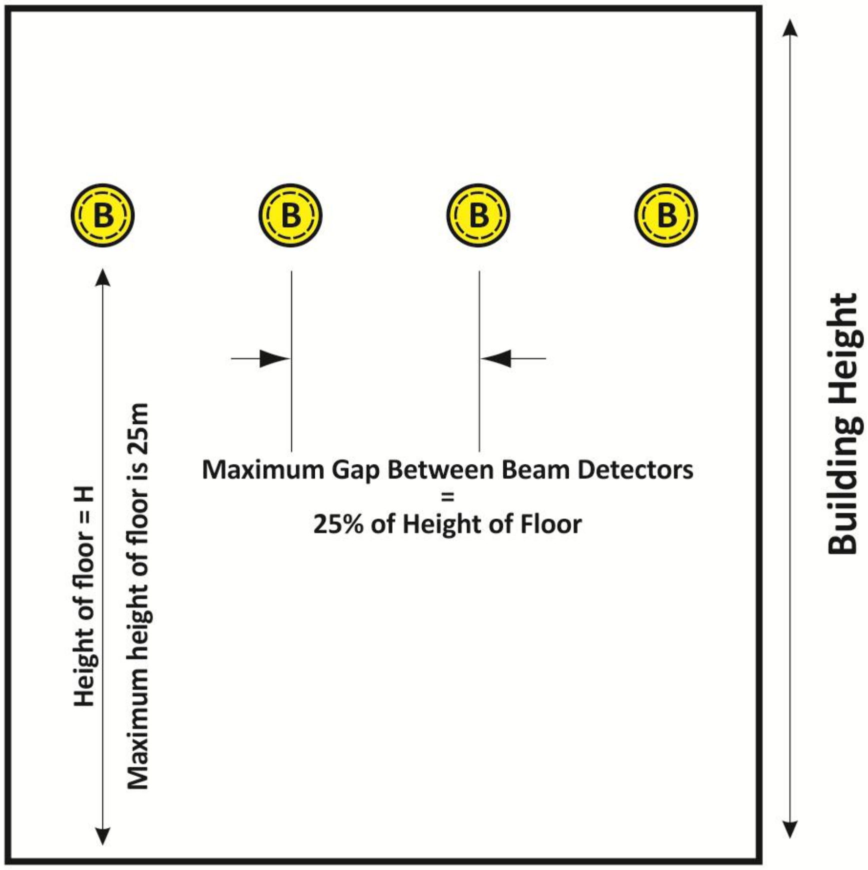


Figure 2.21: Beam Detector Spacing

The coverage should be taken as extending of the beam length on both sides of the center line of the beam. Where high ceilings are present, additional beam smoke detectors mounted at different heights may be required to detect smoke at lower levels.

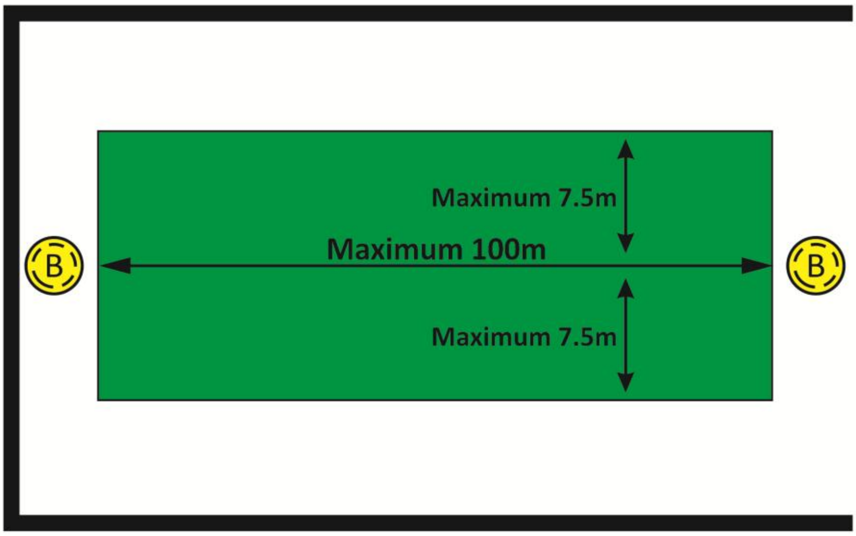


Figure 2.22: Linear Beam Detector Length and Coverage

Beam detector should be installed within the minimum and maximum beam length allowed by the manufacturer’s instructions, which are limited by the standards and codes. Beam detectors require a stable mounting surface for proper operation. Farther installation from the ceiling and at different levels defeats the effects of stratification or other obstructions. There must be a permanent clear line of vision between the detector and the reflector. Reflective objects must not be near the line of vision between the detector and reflector. Operation of the detector through panes of glass should be avoided. Intense lights source such as windows, can result in detection fault and should be considered.

In applications where reduced spacing is required, care should be taken to keep two parallel beams at a minimum distance so that the receiver from one detector cannot see the light source from another detector (SystemSensor, 2013a). Where two or more detectors are installed with their respective beams at angles, care should be taken that the receiver of each detector can sense only the light from its own transmitter. It is important to follow the manufacturer’s testing procedures in the manual.

2.7.5 Installation

Detector placement is critical to early warning functions. The location, quantity, and zoning of detectors should be determined by desired objectives that meet the minimum requirements of all local codes or ordinances. Fire safety planner should weigh the costs against the benefits of installing a complete fire detection system when any detection system is being installed.

2.7.6 Wiring

Smoke detectors are generally categorized as either 2-wire or 4-wire detectors. Smoke detectors should be connected to supervised installation wiring to ensure electrical supervision of the device. Regardless of the method, removal of the smoke detector or a single installation wire must open the initiating circuit and send a trouble signal to the control panel.

Wireless smoke detectors do not require any field wiring as the power for the initiating devices is contained and incorporated within the device internal batteries. Supervision of the internal battery power source is incorporated within the smoke detector circuitry.

All fire alarm system installation wiring should be installed in compliance with local codes, the manufacturer's instructions, and the requirements of the agencies having jurisdiction.

2.7.7 Inspection and Maintenance

Smoke detectors are designed to be as maintenance free as possible; however, dust, dirt, and other foreign matter can accumulate inside a detector's sensing elements and change its sensitivity (NFPA, 2003). They can become either more sensitive, which may cause unwanted alarms, or less sensitive, which could reduce the amount of warning time given in case of a fire. Both are undesirable; therefore, detectors should be tested periodically and maintained at regular intervals. The supervisor should therefore ensure that the following Daily, Weekly, Monthly and Annual checks are carried out on the system.

2.7.8 Troubleshooting

No detection system is impervious to unwanted alarms. Unwanted alarms can result from a wide variety of causes, including improper environments, temperature extremes, excessive dust, dirt, humidity, excessive air flow rates, or the normal presence of combustion particles in the air streams surrounding the detectors. Improper installation and inadequate maintenance will increase the nuisance alarms.

2.8 Codes and Standards on Safety and Fire Protection

Fire detection systems must be in compliance with the fire safety codes and standards. Therefore, it is mandatory to review applicable fire codes before and during the fire detection development.

Safety codes and standards developed for protection of people, property and environment. Fire safety code is a set of rules prescribing minimum requirements to prevent fire and explosion hazards arising from hazardous materials and conditions.

A typical fire safety code includes administrative sections about the rule-making and enforcement process, and substantive sections dealing with equipment, hazards, and specific rules for specific building such as laboratories.

The fire code is aimed at preventing fires and ensuring the necessary prevention. The fire code also addresses inspection and maintenance requirements of fire protection equipment in order to maintain optimal fire protection measures.

All fire alarm systems shall be designed, installed in accordance with the ordinances, and all codes and standards as established by the officials. A number of codes and standards may be applicable depending on condition. Although users, designers, manufacturer and installers often established their own requirements, the minimum Code requirements must be met.

There are two types of codes. Specification Codes which spell out in detail and Performance Codes which establishing criteria for determining if the objective has been achieved.

In many countries, where the power of regulating construction and fire safety is vested in local authorities, a system of model codes is used. Model code is developed and maintained by a standard organization independent of the jurisdiction responsible for enacting the code. Normally, model building codes have a 3-5 year update cycle.

2.8.1 International Fire protection code

The widely recognized model code and organizations include but not limited to:

International Fire Code by International Code Council or **ICC IFC:** contains regulations to safeguard life and property from fires and explosion hazards. The purpose of this code is to establish the minimum requirements for providing a reasonable level of life safety and property protection from the hazards of fire, explosion or dangerous conditions in new and existing buildings, structures and premises, and to provide safety to fire fighters and emergency responders during emergency operations. IFC section 907 covers the application, installation, performance and maintenance of fire detection systems and their components (IFC, 2012).

The **National Fire Protection Association** (NFPA) is a United States trade association, albeit with some international members, that creates and maintains fire safety standards and codes for usage and adoption by local governments.

Some of NFPA codes and standards which pertains fire detection in chemistry laboratories are:

NFPA 1: Fire Code: Cover the full range of fire and life safety issues from fire protection systems and equipment and occupant safety in new and existing buildings to fire hazards.

NFPA 45: Fire Protection for Laboratories Using Chemicals: This standard shall apply to laboratory buildings, laboratory units, and laboratory work areas whether located above or below grade in which chemicals, as defined, are handled or stored.

NFPA 72: Fire Alarm and signaling Code: Cover the application, installation, location, performance, inspection, testing, and maintenance of fire alarm systems, supervising station alarm systems, public emergency alarm reporting systems, fire warning equipment and emergency communications systems (ECS), and their components. Federal, state, and local municipalities across the United States have adopted the NFPA 72 as a standard in the enforcement of fire code regulation. Municipalities often adopt revisions of the code after years of review and amendments, making many local fire codes specific to their governing authorities.

NFPA 720: Standard for the Installation of Carbon Monoxide (CO) Detection and Warning Equipment

EN 54: Fire detection and fire alarm systems: is a standard developed and approved by European Committee for Standardization. This standard specifies requirements and laboratory test for every component of fire detection and fire alarm system.

BS 5839-1:2013: Fire detection and fire alarm systems: is a Code of practice produced by British Standards Institution (or BSI) for design, installation, commissioning and maintenance of detection systems in non-domestic premises.

2.8.2 Malaysia Codes

In Malaysia, historically the fire protection acts and regulations started in 1883 and later in 1946 the Malayan Union Services (MUS) was formed. On January 1976 the fire and rescue service was integrated as a federal-level department. On May 1981, the department was changed as the Malaysian Fire Service Department.

FIRE SERVICES ACT 1988 (Act 341) established to make sure of effective and efficient application and implementation of the fire safety provisions for the protection of occupants, buildings and property from fire hazards arising from the equipment, operations and processes. The Fire and Rescue Department or BOMBA Malaysia is the authorized body for the enforcement

The fire protection codes and standards of Malaysia are developed and established under the Malaysian Standard (MS), which had been reviewed and approved by the Building and Civil Engineering Industry Standards Committee and endorsed by the Board of the Standards and Industrial Research Institute of Malaysia (SIRIM) which are published under the authority of the SIRIM Board in 1996. These standards are subject to periodical review and amendments in order to keep update to progress in the industries and premises concerned.

Some of MS codes and standards which pertains fire detection in chemistry laboratories are:

- ***MS 1176:1991:*** Specification for components of automatic fire detection systems
- ***MS 1471:1999*** Vocabulary on fire protection.
- ***MS 1471:1999*** Part 3: Fire detection and alarm
- ***MS 1745:2004*** Fire detection and alarm systems

Chapter three: Methodology

3.1 Introduction

Fire detection and alarm systems are designed to provide warning of the outbreak of fire and allow appropriate responses to be taken before the situation gets out of control. This role is significantly greater in hazardous areas such as laboratories. As all systems are designed primarily to protect life, property and environment, this places a great responsibility on the designer because each lab will present a different set of problems in relation to the risk of fire, explosion and chemical releases. Each fire detection system therefore must be specifically designed to meet the requirements for each facility.

In designing a system, particular consideration must be given to the type and purpose of facility, building construction and type and quantity of the equipment and contents, so in the event of a fire, the fire detection system, combined with appropriate fire prevention procedures, will keep risk to both personnel and property to a minimum.

3.2 Methodology overview

Distinctly different fire hazards exist within the laboratories and various detection methods may be employed to detect fire events arising from these hazards. Chemical laboratories containing substances and instruments present a particularly challenging environment and it is important to select the correct method to ensure reliable detection in the early stages of the development of a fire whilst minimizing nuisance alarms.

The purpose of this method is to provide a step-by-step approach to developing a fire detection system. And intended to provide a performance-based framework for design and develop a new or existing fire system with different detection technologies for chemical laboratories in the presence of common fire events. This approach provides insight into key aspects for successful detection of the fire hazards in this demanding application.

To assist with designing procedure, flowchart shown in Figure 3.1 has been produced to provide a logical guide. This flowchart provides a systematic approach to the main activities which should be considered in planning and designing a fire detection system.

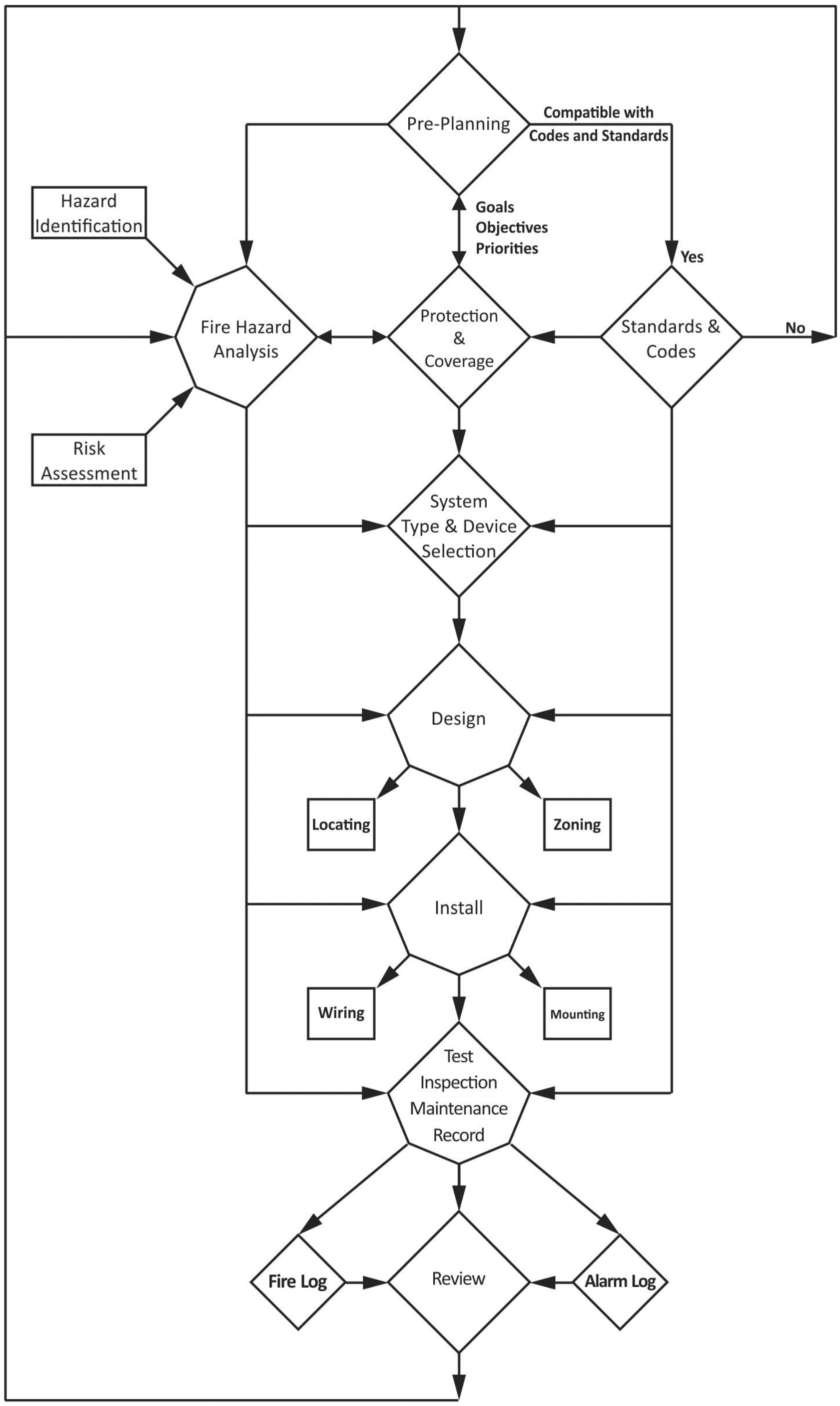


Figure 3.1: Fire Detection System Development Flowchart

3.3 Pre-Planning

Once the decision is made that a fire protection system is to be installed in a facility, whether the system is required by a code or not, the type of system and required equipment must be determined. This determination should consider the specific safety codes in force as well as fire safety requirements of the organization.

The employer must determine fire protection goals, objectives and priorities and communicate that information to the fire protection system designer. These goals must meet the codes and standards (CSAA, 2011). Compliance with the applicable codes and standards may not meet protection goals. Codes often provide less protection than the employer expects. Thus consultation should be provided with experts to develop protection strategy for the specific facility or application.

This task is probably the most important of all because mistakes made here may have a fundamental effect on the type and operation of fire system. The specification of the system therefore should be prepared with great care, thus ensuring that all requirements of the system are covered. A thorough review of the existing facility and the existing system should be made.

In case of upgrading an existing fire alarm system, the location and type of all devices should be noted during the review of the facility. All spaces should be reviewed to determine what devices and what quantity of devices will be required. This approach will require complete hazard identification and risk assessment process. Existing system shall be maintained fully operational until the new system has been activated.

The designer should discuss the fire detection and alarm system with the user or facility maintenance personnel to determine their preferences and proficiencies. Options should be discussed with the employer and other stakeholders including the maintenance unit or facility architect.

The selection of a fire alarm system should take into consideration the following:

- The purpose of the system
- The fire protection goals, objectives and priorities
- The type and characteristics of facility to be protected
- The type and quantity of the contents to be protected
- The existing and potential hazards and risks
- The applicable fire alarm system codes and standards
- The other fire protection systems that must be interfaced
- The required response time of the system and the fire department
- The basic function of the system
- The availability of the system
- Compatibility with ancillary equipment
- The effects on other facilities and occupants

The system may also be used to actuate suppression systems or shut down equipment and manufacturing processes or activate other safeguards.

A survey should be made to determine application, equipment and facilities, the type and quantity of the contents, layout and vicinity with neighbor facilities to ensure that the appropriate system are used for the application.

The modification must also fit within the budget constraints placed on the overall project. The system should be sized to the facility. Expensive, highly responsive system may be of little use to the user. Future expansion and flexibility should be considered when designing the system.

3.4 Codes and Standards

Fire alarm systems must, be selected, designed and installed in compliance with the applicable requirement of the fire safety codes and standards. System type, coverage, devices and appliances must be in compliance with the minimum requirements of the applicable codes and standards (NFPA, 2003). There is no shortcut to a thorough investigation of all applicable codes prior to beginning a project.

The intent of the system shall meet the minimum code requirements, but in addition, shall meet the specific level of life safety and protection as required by the employer (CSAA, 2011). In almost all cases, these minimum requirements will require a higher degree of protection and workmanship than that specified by the referenced codes.

3.5 Fire Hazard Analysis

Due to the nature of chemicals and application of chemical laboratories, different fire hazards exist within them and various detection methods may be employed to detect fire events arising from these hazards (Mannan, 2014). The fire hazards in lab environment require the system developer to carry out a Fire Hazard Analysis or FHA, to implement fire protection precautions and to apply appropriate detection and response system to hazards. The choice of fire detectors depends on the nature of hazard and the rate of risk.

It is helpful to model the fire incident process in order to understand more clearly the factors that contribute to incidents and the steps that can be taken to avoid them in terms of detection.

3.6 Purpose, Priorities and Coverage

After identifying the existing and potential hazards and analyzing the risk associated to them, the purpose and priorities of the system should be established. That is whether the priority is to protecting the building and its contents (Property Protection) or enhancing the safety of the occupants (Life Protection).

After assigning the priorities, the degree of coverage should be established. This allows fire detection system designs to be specified according to purpose and the extent of protection to be afforded.

Another important element to consider is the impact of time in the design of a fire detection system. Time is a deterministic factor in the detection of a fire, response and suppression as well as in evacuation of occupants. As each type of detector responds to a particular fire product, the relative speed of response of the detectors is therefore dependent upon the type of fire being detected.

In terms of priority; For life safety applications, the main objective is to ensure that the occupants have time to evacuate safely before the conditions in the protected premises reach intolerable levels of smoke, heat, and gas (CSAA, 2011). For property protection, the design should take into consideration the response time of extinguishing devices and the fire department as well as their capabilities and availability of supplies.

3.7 Detection System Selection

Three types of fire alarm detection systems described in section 2.5. Each system has its own applications. The proper system should be selected due to protection type, coverage zones and applied detectors.

The dirtier the environment and the more compartmentalized a facility is, the more preferable addressable or analogue addressable becomes. Conventional systems are relatively simple for small to intermediate size separate laboratories but for large buildings and multiple laboratory facilities, they can be expensive to install because of the extensive wiring.

3.8 Detector Selection

Once the type of fire protection and alarm system decided, type of detectors are to be used to protect the different areas (zones) within the premises should be selected. To develop an efficient fire detection system, consideration must be given to the types of detection devices that will meet the employer fire protection preferences and the system goals as well as comply with applicable standards (CSAA, 2011).

There are several types of detector, each of which responds to a different product of combustion (smoke, gas, heat, flames). Detector Selection is based upon the goals of the protection system; hazard identification and risk assessment and must be in compliance with fire detection codes and standards.

As each type of detector responds to a particular fire product by a specific method and in defined condition, the selection of the detectors is therefore dependent upon the fire hazards being identified or anticipated.

Detector’s response times will vary depending on the type of fire scenario. It is often difficult to predict what particle size will be produced in a developing fire because chemical facility normally contain a variety of combustibles. By making use of the detectable effects of the products of combustion, the protection against different fire scenario can be achieved. Before select and apply the detectors, they should be assessed in terms of performance, efficiency, capability and limitations.

Special application rules can compensate for the limitations of detectors. In certain circumstances where smoke detectors are unsuitable or not enough to provide reliable detection, special-purpose detectors, such as flame detectors, heat detectors, and other detection devices may be used. The application of detectors should be based on an engineering survey and used in accordance with the codes and manufacturer’s installation instructions (SystemSensor, 2013c). Consideration must be given, as well, to the need for a rapid response due to Fire Safety Plan Including life safety factors or the high value of the assets being protected.

3.9 Design

The design of a fire detection system varies considerably depending on the objectives and priorities, detection system type and devices, level of protection and type of premises to be protected. In addition to deciding the type of controller and detectors, there are also other aspects which need to be considered such as, area under consideration, compartments and the height of installation.

Although smoke detectors are based on simple concepts, certain design considerations need to be observed. The design should ensure that the detection system performs maximum efficiency and reliability. Environmental conditions, the type of combustible material, facility characteristics and layout, site structure and reactive safety guards all affect the ability of the detector system to provide the expected protection.

Appropriate zoning is the most effective way of detecting and responding to fire spread within a building. For siting the detectors, Smoke tests are helpful in determining proper placement. Special attention should be given to smoke travel directions and velocity, since either can affect detector performance.

3.10 Installation

System components and all devices shall be installed in accordance with applicable standards and manufacturer recommendations. Contractor and installation personnel shall be qualified and experienced.

Whenever new devices are to be placed in an existing facility, wall or ceiling openings will need to be created. Location of access panels, as well as location of devices should be carefully coordinated with the construction, layout, contents and process which performed within the lab.

Correct operation of a fire alarm system depends on the interconnections between the control equipment, detectors, call points and sounders. Unless these interconnections operate correctly when required the system will not fulfill its intended functions.

The components of most fire detection and alarm systems are connected by cables and wiring. Selecting and wiring of cables for a fire alarm system should be based on system type, devices, environment, manufacturer instruction and codes and standards. Strongly recommended to apply color-code wiring for detection system. For specialized applications where cabling cannot be used, wireless devices, fiber optics and/or radio links are used.

3.11 Test, Inspection and Maintenance

Routine test and maintenance of fire detection system is critical for the reliability and performance of the system. To ensure continued trouble-free and effective operation of the system under normal circumstances, routine attention is essential. Routine attention may perform at regular intervals by daily, weekly, monthly and annual checks. Special attention should take in after a fire and after a false alarm.

The zone or system undergoing maintenance should be disabled to prevent unwanted alarms and possible dispatch of the fire department. It should be noted that undergoing maintenance of fire detection system, result in temporarily disabling the system and may result in risk.

Test, inspection and maintenance must always follow the manufacturer's specific recommended practices for maintenance and testing. Manufacturer or installing contractor shall be responsible for retraining supervisory personnel of the employer for the inspection, testing and maintenance of the system.

3.12 Improvement

Thorough documentation of all steps of procedure is essential to revise and improve the developed fire detection system. The recording is critical since many details must be noticed during the review of detection system operation.

Identified hazards and associated risk, the fire detection system design, and the codes and standards which considered for the development should be fully described and accurately addressed. The manufacturer shall prepare and provide design documentation including drawings, parts lists, circuit diagrams, and the signal processing principle. Documentation should be available for inspection and investigation of any fire incident in the laboratory

An integrated system for documenting will assist in the assessment of the reliability and efficiency of the system for different conditions and will also provide a basis for evaluating the effectiveness of the systems in laboratory environment.

A fire log should be maintained to record all fire incidents, and the response of fire detection system to them. All declared alarm should be inspect and record, to determine the reasons and rate of nuisance alarms by the system.

These records will use to identify the uncharted hazards and associated risk to them and clarify that if there is a need for modification in the system. Also it will result in pervasive future FHA.

Ultimately, all system weakness can be identified to improve the reliability of the detection system or define new objectives and priorities for the fire safety program to develop state-of-the-art detection systems in lab environments.

Chapter Four: Results

4.1 Introduction

The expected outcome of this study is an approach to develop a fire detection system for a chemical laboratory. The result of this project is a step-by-step approach to apply a fire detection system.

This approach concentrated firstly on fire hazard analysis to characterize the fire hazards and risk likely to be present in chemical laboratory which may result in development of initiating lab fire incidents; and secondly on evaluating the performance of detection technologies to these fires including consideration of related codes and standards.

4.2 Findings

In this study various sources of information including textbooks, handbooks, papers, reports and standards used and referred. Several fire hazards and detection systems were reviewed to identify the suitability of fire detection system to respond at earlier stages of a fire in chemistry laboratory environment. Therefore, technical specifications, capabilities and limitation of existing methods and techniques were reviewed as to whether detection systems could provide accurate sensing, reliable detection and early notification to affect a significant difference in fire response.

Above mentioned data and analysis have been used to introduce a comprehensive approach to develop fire detection system for chemical laboratory as shown in the following process flowchart.

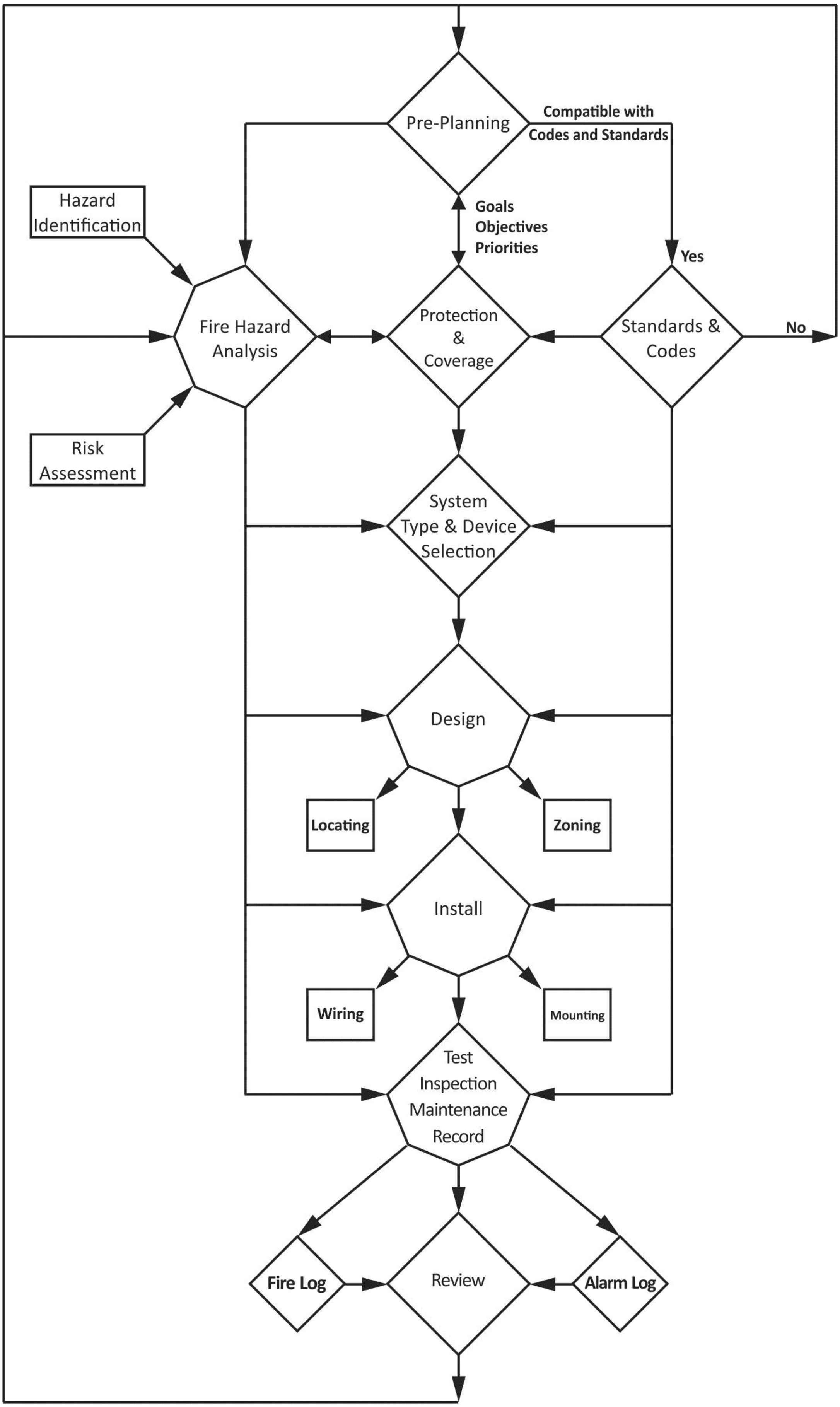


Figure 4.1: Fire Detection System Development Flowchart

The fire hazard analysis has indicated the potential impact of detection technologies to reduce risk of laboratory fires. Fire detection system is an important factor to eliminate and control fire damage and the interruption of operations. The impact depends upon the rapidity of sensing and the ability to detect conditions.

As noted, fire detection is particularly instrumental when fires can be detected sufficiently before the fire transitions to an accelerated growth phase. The potential impact of detection system is directly related to the duration of the initial fire stage and the additional information provided by the system such as fire location. Detection system presents the greatest benefit when it allows an effective manual response.

If detection system is able to provide early enough notification, the impact of fire response actions such as automatic suppression system or fire department, to limit the damage will increase significantly. In the event that there is manual suppression system or on-site trained personnel for fire response, fire detection will have a larger impact.

In addition to improving the response time, early warning detection can also provide additional benefits. It is possible that detection equipment can provide information to the fire department during setup and assessment, such as the internal temperatures in the space, the depth and visibility of the smoke layer, the location and extent of the fire spread, or even visual images of the conditions inside the space. This information can be extremely valuable when the response team is making an assessment of taking actions. If more information is available, they may determine that safe entry and firefighting could be conducted in incidents.

4.3 Implementation of the approach

In this section the collected data and developed procedure come together, and the presented approach will be implemented to a typical chemistry laboratory.

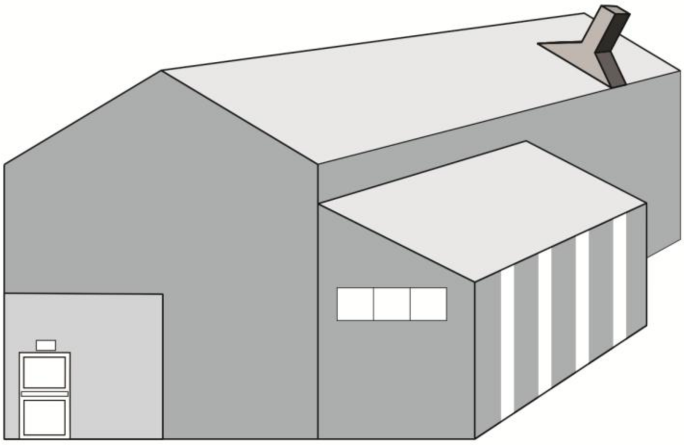


Figure 4.2: Typical Gable Structure Chemical Laboratory With a Control Room and Side Storage of Gas Cylinder

Front section, floor plan, contents, detail and dimension of this hypothetical laboratory is illustrated in the following figures.

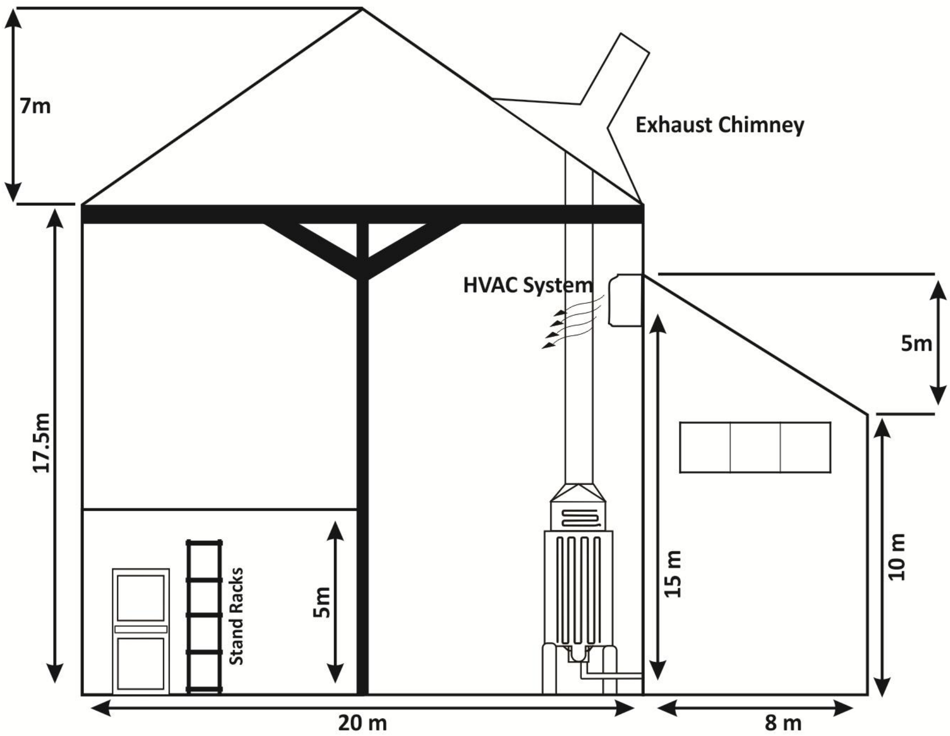


Figure 4.3: Front Section

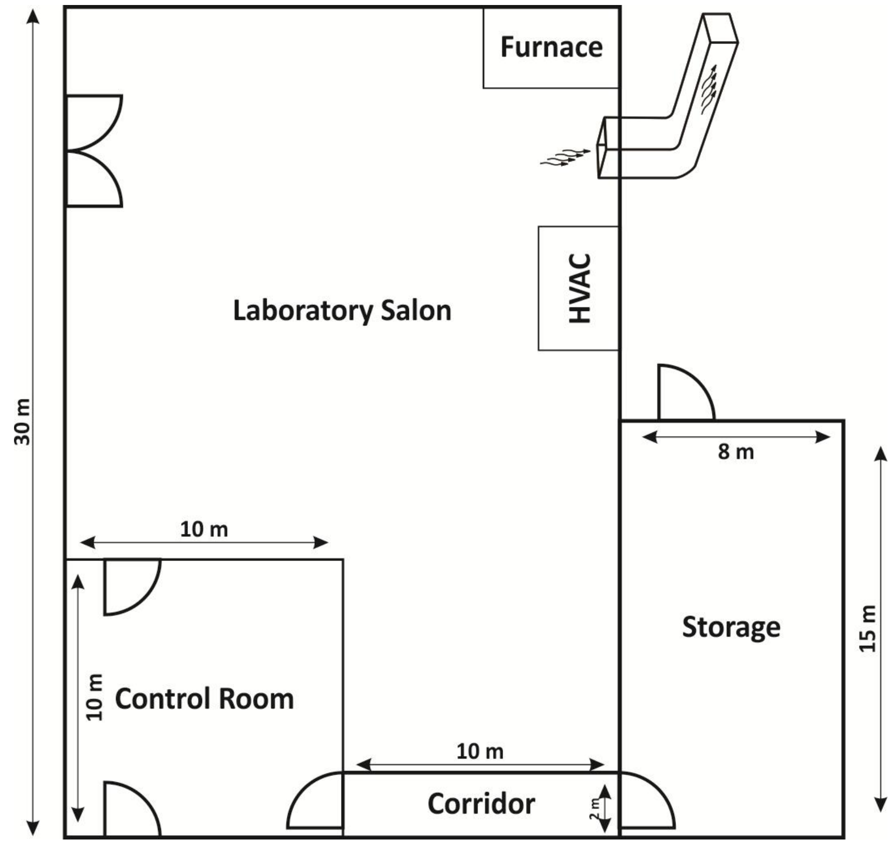


Figure 4.4: Front Plan

The potential fire hazards present in chemical laboratories is shown in table 4.1.

Table 4.1: Fire Hazards in chemical Laboratories

No.	Type of Hazard	Source in Lab	Detection method
1	Fire	• Hydro carbon • Metallic hydrides, • Furniture and construction materials	• Smoke Detection • Heat Detection • Flame detection
2	Explosion	• Reactors • Tanks	• Gas Detection
3	Gas release	• Faulty furnaces • Heating appliances Generators	• Gas Detection • Smoke Detection
4	ignition	• Bunsen and other burners, hot plates, ovens, furnaces, electrical devices, wiring.	• Flame Detection • Heat Detection • Smoke Detection

Goals, objectives and priorities of this system are to maximize the protection for building and its contents and minimize the risk for inside people and surroundings. The design complies with ***MS 1745:2004: Fire detection and alarm systems.***

Selection of detection system type and specifying the coverage is based on the survey and evaluation of building structural characteristics, layout and vicinity with neighbor facilities and with regards to overall health and safety program and emergency response plan. For this hypothetical laboratory the analogue addressable system selected based on the advantages of this system and its performance abilities.

The table 4.2 illustrates the detectors types and their suitability associated with identified fire hazard in different environment condition.

Table 4.2- Detector Suitability

		Environment Condition	
Fire Hazard type	**Hazard Source**	**Clean**	**Dirty**
Overheating	Electrical Equipment Furnace Body	**Heat Detector**	**Heat Detector**
Slow Smoldering	Fabric Plastic	**Photo electric Smoke detector**	**Heat Detector Beam Detector**
Flaming	Hydrocarbons	**Ionization Smoke Detector**	**Heat Detector Beam Detector**
Clean Burning	Solvent Fuel Gases	**Flame Detector**	**Flame Detector**

Zoning, Spacing and locating of the manual call points and detectors are carried out due to type of the MS standards, fire hazard analysis, building layout, contents and selected detectors.

In addition, environmental conditions, operations and processes, number of the occupants, working schedule and pattern, existing safety devices, HVAC system, and auxiliary devices are important factors which should be considered in the design process.

The zoning of the premises and the siting layout of spot type detectors is depicted in the following figures.

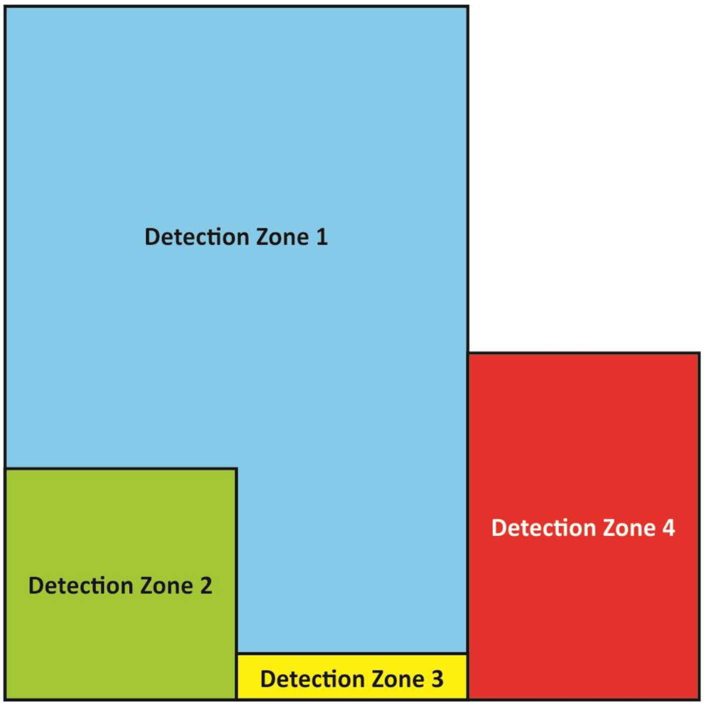


Figure 4.5: Zoning

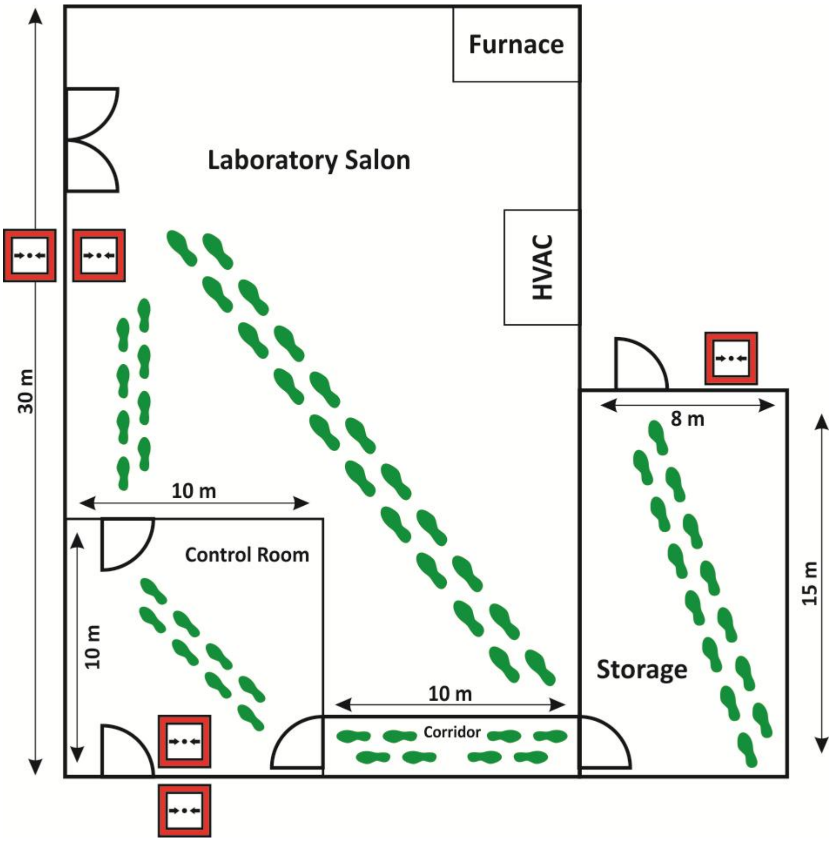


Figure 4.6: Manual Call Points Siting

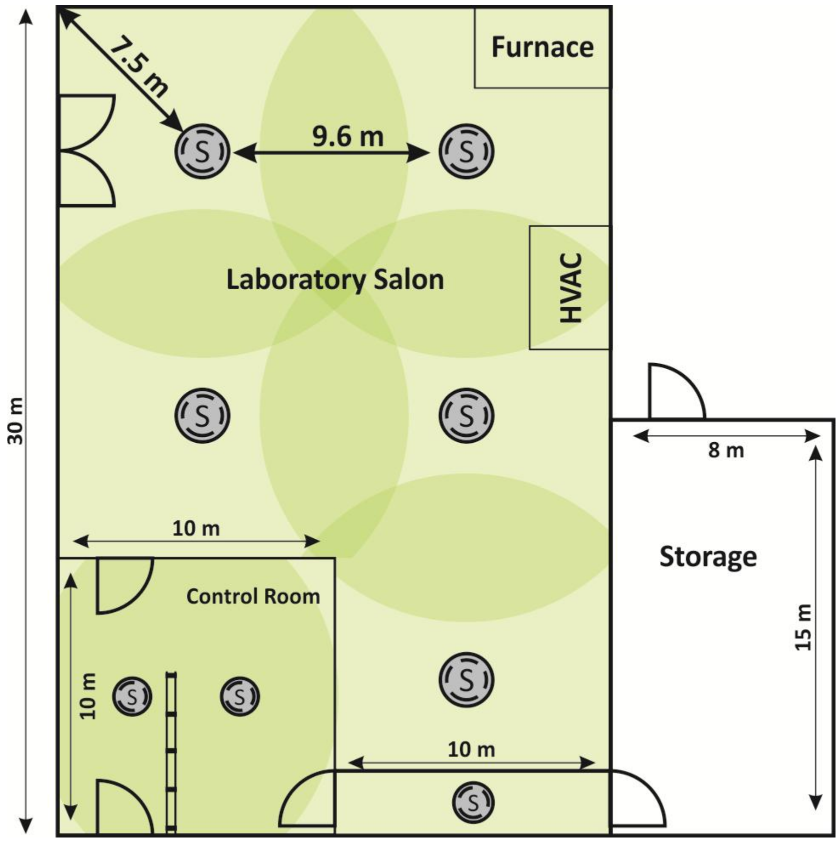


Figure 4.7: Spot-Type Smoke Detectors Siting

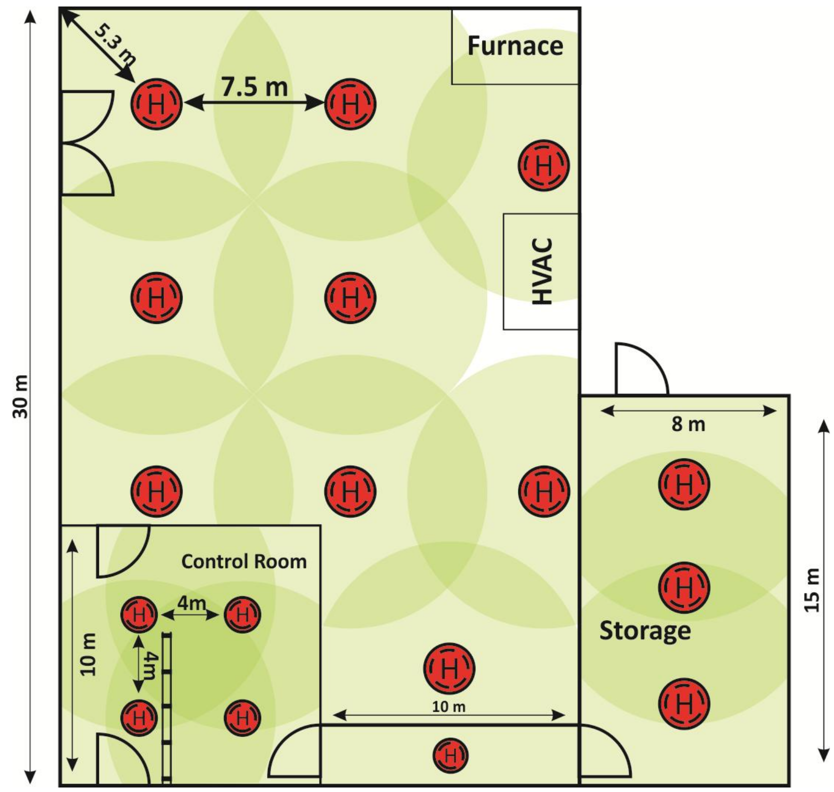


Figure 4.8: Spot-Type Heat Detectors Siting

Based on the present hazards in the laboratory salon, linear beam detector, CO detector and duct smoke detector, were predicted and sited.

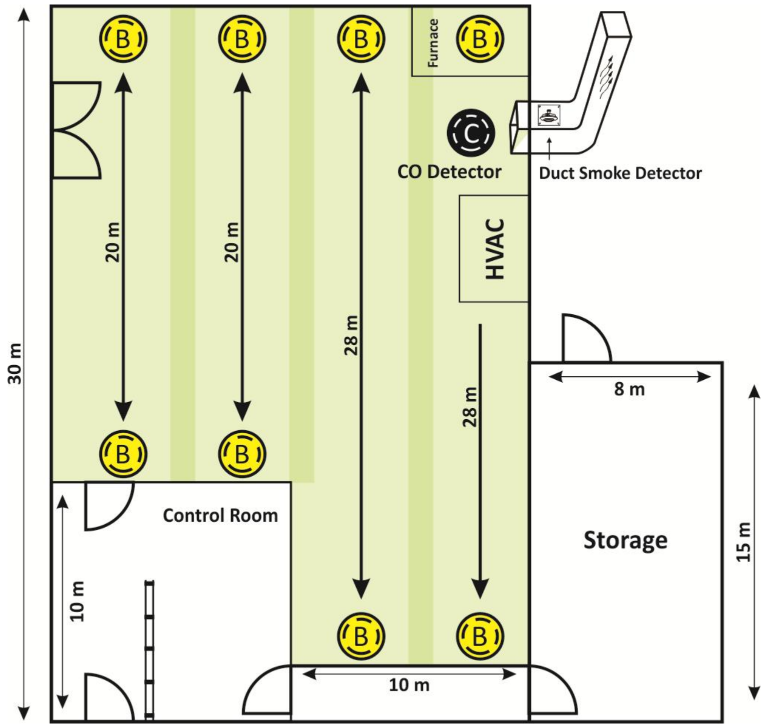


Figure 4.9: End-to-End beam detectors, CO Detector and Duct Detector Siting

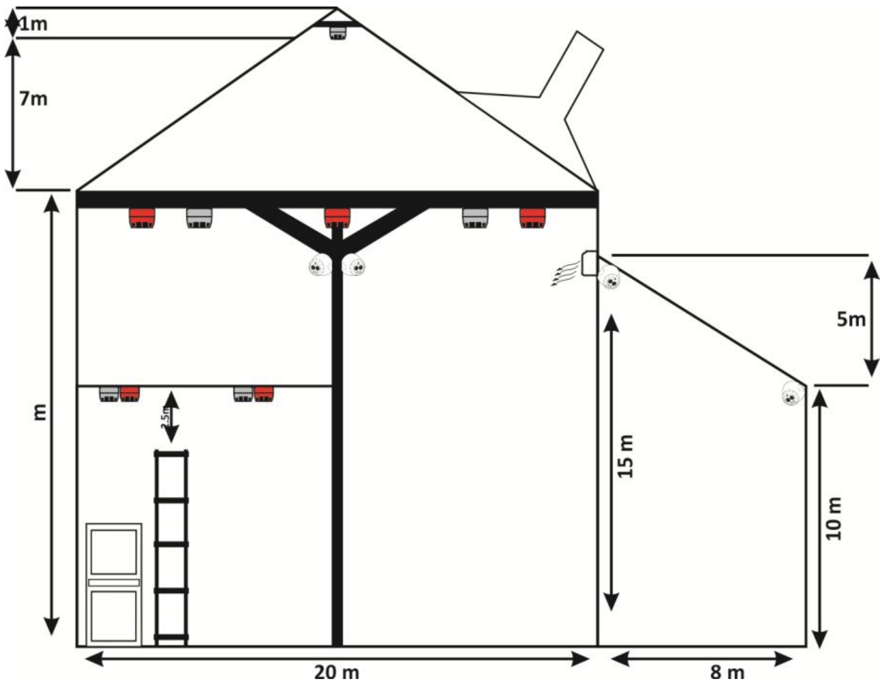


Figure 4.10: Reflective beam detectors and Roof Detectors Siting

Building's height and pitched roof of the laboratory requires additional heat and smoke detectors on the upper layer (Figure 4.10).

Complete detection system design with maximum protection for chemical laboratory presented in figure 4.11.

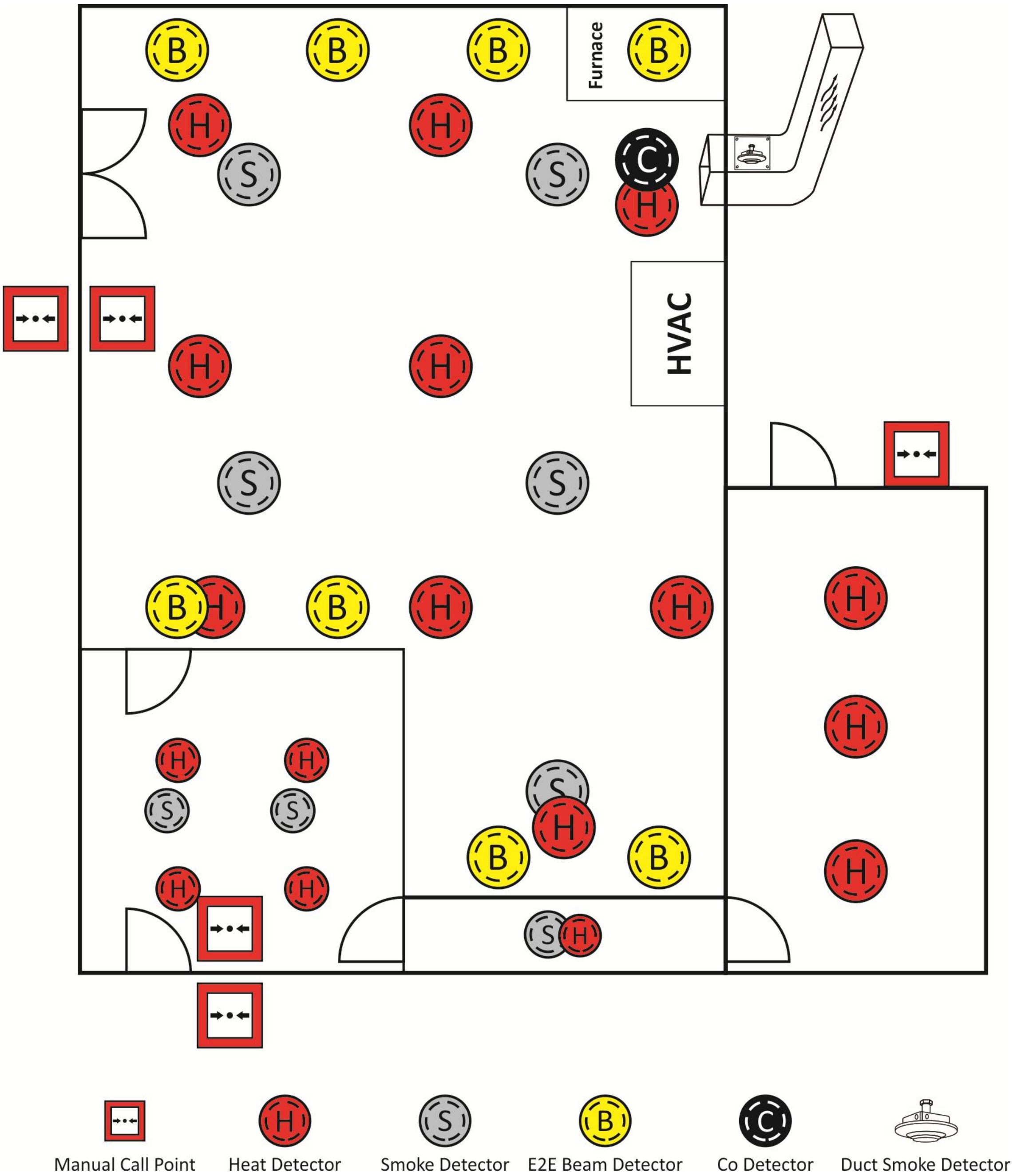


Figure 4.11: Detection System Design

As discussed, adherence to ***MS 1745:2004: Fire detection and alarm systems*** should be considered as key factor. However, the manufacturer's specifications and instructions is the vital factor beyond the abovementioned factor.

4.4 Conclusion

This method offers a comprehensive approach to develop a fire detection system. The developed procedure proposed method of fire detection as an important part of fire safety program for each type of laboratory facing chemical hazards. It is not specified to any specific chemistry laboratory. As showed in the typical case study it can be extended as a general approach to fire detection system development for other facilities as well. However, the method should be modified in terms of objectives, priorities, codes and standards. Fire hazard analysis shall be performed for every specific environment to determine the type of detection system, equipment and design to maximize the reliability which results in higher protection and safety.

Chapter Five: Discussion

5.1 Introduction

In this chapter, the findings of the study are discussed based on the results obtained from the literature review and methodology.

The aim of this study was to develop a fire detection system for chemical laboratories. This project has summarized fire detection systems data with discussion of the relative factors to these systems. Application and principals of each introduced and described how these systems can integrate to develop a reliable fire detection system for a chemical laboratory. Factors which are involved in development of system reviewed in order to identify the role and effect of these factors on the fire detection system design and operation. Several standards and manuals are considered and a number of common detection devices.

5.2 Outcomes

Based on the literature review, developed method and implementation of the method, this study has identified and met the objectives that were previously stated:

Objective 1: To study fire detection systems and related characteristics, factors and methods.

This objective is divided into three parts. The first part touches on the fire science to understand the characteristics fire and fire products that can be sensed, detected and measured. The second part discusses aspects of fire hazard analysis to estimate the possible events, and outcomes of fire in a chemical laboratory. This is followed by the review of the applicable fire detection systems and devices and analyze of relative criteria and designs.

Objective 2: To develop an approach for the fire detection system design

This objective is divided into two parts. First, introduce a step-by-step practical approach to design a fire detection system for chemical laboratories. Secondly the proposed approach implemented to a typical chemical laboratory and the outcomes presented.

The choice of the correct detection system for a specific fire hazard is therefore determined by the suitability of the detection of the anticipated fire event within the environment in which it is required to operate.

This should assist in the task of choosing the best options, which help in preparing the specification of the fire protection system, and assist designers, engineers, safety officers and emergency planners in providing the most effective system that meets the needs of the user in terms of feasibility, performance, efficiency, reliability and cost.

A set of vector graphical symbols prepared for the illustration of the designed system for this study, which can use for future design or develop a simulation interface to design fire detection system layout.

5.3 Limitations

Fire Hazard Analysis is not fully determines the real fire incidents outcome. Consequently, real-scale testing is needed to determine the performance of detection system.

To determine reliability of developed fire detection system, function of the system should be assessed in several fire scenarios and real-scale experiments. The fire science literature provides limited insights into incipient growth times and detector responses to realistic fire scenarios. Also, the lack of real-scale test results for developed system precludes determining the effectiveness of fire detection system design.

Chapter Six: Conclusion

Analysis of fire incidents confirms that detection and notification was a key element in protection. The proper detection system protects laboratories incidents to become large fire events. The research and literature review of fire detection system has highlighted a general lack of fire protection system for chemical laboratories.

Fire detection system reliability would be assessed based on the ability of a system to detect the fire and, secondly, the time of suitable response. Fire detection is reliable when fires can be detected sufficiently before the fire transitions to an accelerated growth phase. The potential impact of detection system is directly related to the duration of the initial fire stage. Improving the understanding of incipient phase for more fire hazards and typical fire incidents in variable laboratory environment would improve the assessment of developed fire detection system performance and provide a foundation for performance-based fire detection design.

In most fire scenarios it is impossible to assign a single cause as the incident has arisen from a particular combination of circumstances. It is helpful to model the fire incident process in order to understand more clearly the factors that contribute to incidents and the steps that the designed system can be taken to avoid them in terms of detection. There are several types of models to determine the contributing factors including Houston model, Fault Tree Analyze (FTA) model, Management Oversight and Risk Tree (MORT) model and the ACSNI model.

6.1 Recommendations

The presented step-by-step approach and related flowchart for fire detection system design can be used to develop visual software which can assist the safety professionals in order to manage, design, and review the fire detection system for laboratories. This software can be efficient tool for fire safety programs that save time and resources.

Another potential application of introduced method is to apply for development of fire detection and response system in University Malaya chemical laboratories.

Following, a model system can be applied to a selected laboratory to evaluate detection system performance for a range of designed fires test and representative lab conditions. Characterization of the tested fire scenarios will include measurements of the times of response, heat release rate, the smoke development, and the radiant heat output. The results for the different fire scenarios will serve to establish a database of characterized design fires that can be used in future system development as inputs to fire models.

Initial testing would be conducted for a single isolated premise, but further evaluation into the impact of building size and environmental conditions (i.e., ventilation and temperature).

The fire hazard analysis of fire scenarios and the response times would be the basis for detection system design. The response times would be deemed as representative of developed detection system effectiveness and reliability. Also, the results of the tests will assist in the evaluation of detection system for other chemical laboratories.

Further information about the role of building design, fire detection and suppression equipment, and fire emergency response plan can be determined from the analyzed fire incidents.

In addition, early detection technology could be conduct to more successful suppression and extinguishment systems. Applying an early detection system in laboratory could be used for development of advanced suppression and extinguishment systems.

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