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Design and Technical Analysis of an Automatic Extinguishing System for the Safety of Flammable Liquids Service Stations

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ملخص

يتناول هذا البحث تصميم وتقييم نظام إطفاء حرائق أوتوماتيكي باستخدام غاز ثاني أكسيد الكربون (CO_2)في محطات الخدمات الصناعية، مع دراسة حالة خاصة بشركة **سوناطراك**. يبدأ المشروع بتحديد أهمية السلامة في محطات الخدمات، مشيرًا إلى المخاطر المرتبطة بالسوائل القابلة للاشتعال، مثل الحرائق والانفجارات، والتأثيرات الصحية والبيئية المترتبة عليها.

يستعرض الفصل الأول السياق النظري والمعايير الدولية المعتمدة مثل معايير **NFPA**و**ISO**، بالإضافة إلى تقنيات الإطفاء الحالية) غاز CO_2 ، الرغوة، المسحوق(، مع تحليل نقاط القوة والقيود لكل منها.

في الفصل الثاني، يتم التطرق إلى الجوانب التقنية لتصميم النظام، بما في ذلك أنواع الكواشف (الحرارية، اللهب، والغاز) وأنواع العوامل المطفئة، مع أخذ القيود البيئية والاقتصادية بعين الاعتبار.

يركز الفصل الثالث على تطبيق عملي لنظام الإطفاء الأوتوماتيكي بغاز CO_2 في محطة كهربائية تابعة لسوناطراك، متضمنًا تقييمًا للأداء، منهجية الحسابات، ومخططًا وظيفيًا للنظام، بالإضافة إلى توصيات لتحسين الكفاءة والسلامة.

يمثل هذا المشروع مساهمة مهمة في تطوير حلول فعالة لمكافحة الحرائق في البيئات الصناعية الحساسة، مع مراعاة المعايير العالمية ومتطلبات السلامة المحلية.

الكلمات المفتاحية: نظام إطفاء أوتوماتيكي، ثاني أكسيد الكربون، السلامة الصناعية

Résumé

Cette recherche porte sur la conception et l'évaluation d'un système d'extinction automatique des incendies utilisant du gaz carbonique (CO_2) dans les stations-service industrielles, avec une étude de cas de Sonatrach. Le projet commence par souligner l'importance de la sécurité dans les stations-service, en mettant l'accent sur les risques associés aux liquides inflammables, tels que les incendies et les explosions, et leurs impacts sur la santé et l'environnement.

Le premier chapitre passe en revue le contexte théorique et les normes internationales telles que NFPA et ISO, ainsi que les technologies d'extinction actuelles (gaz CO_2, mousse, poudre), en analysant les points forts et les limites de chacune d'entre elles.

Le deuxième chapitre aborde les aspects techniques de la conception des systèmes, notamment les types de détecteurs (thermiques, à flamme, à gaz) et les types d'agents d'extinction, en tenant compte des contraintes environnementales et économiques.

Le chapitre 3 se concentre sur une application pratique du système d'extinction automatique du CO_2 dans une centrale électrique de Sonatrach, y compris une évaluation des performances, une méthodologie de calcul, un diagramme fonctionnel du système, ainsi que des recommandations pour améliorer l'efficacité et la sécurité.

Ce projet représente une contribution importante au développement de solutions efficaces de lutte contre l'incendie dans des environnements industriels sensibles, en tenant compte des normes mondiales et des exigences locales en matière de sécurité.

Mot clé : Système d'arrêt automatique, dioxyde de carbone, sécurité industrielle

Abstract

This project explores the **design and evaluation** of an **automatic fire extinguishing system using CO_2** for industrial service stations, with a specific case study focusing on **SONATRACH**. It begins by emphasizing the importance of safety in service stations and the risks posed by flammable liquids, including fire hazards, explosions, toxic vapor exposure, and environmental pollution.

Chapter one outlines the theoretical background and international safety standards such as **NFPA** and **ISO**, while also reviewing existing extinguishing technologies (CO_2, foam, powder) and assessing their strengths and limitations.

Chapter two delves into the technical aspects of system design, detailing types of fire detectors (heat, flame, gas), extinguishing agents (FM-200, sprinklers, foam), and addressing both environmental and economic constraints.

Chapter three presents a practical application of the CO_2 extinguishing system in an electrical substation at SONATRACH. It includes system performance evaluation, CO_2 quantity calculations, schematic diagrams, and recommendations for improved efficiency and safety.

This work provides a valuable contribution to the development of effective fire suppression systems in high-risk industrial environments, aligning with international safety standards and local operational needs.

Key words: Automatic extinguishing system, Carbon dioxide (CO_2), Industrial safety

Acknowledgments

To those who instilled in me the meaning of hope.

To those who have been my support in every moment.

To my dear parents, the symbol of sacrifice and giving.

To my brothers and sisters, you are the source of love and support.

To my friends who were my light in the darkness of the road.

To my distinguished professors, the beacon of knowledge and light, who did not skimp on their knowledge and guidance.

To everyone who believed in me even with a word.

I dedicate the fruit of this effort to you, out of gratitude and gratitude.

BEKHOTI ATMANE

Acknowledgments

In the name of Allah, the Merciful, the Compassionate

To those whom the mountains have bowed in humility to their greatness.

To my loving parents.

who made their toil a ladder for me to dream, and their love a light to guide me.

To them I dedicate my first words, for without them I would not have been, and without their patience I would not have learned.

To my teachers and professors.

who opened for me the doors of knowledge. and planted in my heart the seeds of inquiry. They were candles that illuminated the path of knowledge.

To them belongs the praise and credit after God.

And to Palestine.

the land that bleeds with patience and steadfastness. and teaches us that the truth does not die. To her I dedicate these words.

And on its pure soil, I raise the hope of a future that shines with pride and freedom.

SOFI ABDERRAHMANE

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Introduction

Introduction

The risk of fire is one of the most significant dangers in the industry, with a direct impact on health, safety of people and property, as well as on the environment and the continuity of essential services. The responsibility of protecting people and property from the effects of fires lies with the industrial sector, and indeed with everyone in general.

Most fires are of human origin (negligence, malice, thermal causes...). The most common natural causes include lightning and fermentation. Some causes can also be energetic, such as sparks, chemical reactions, or short circuits. According to experts, electrical fires are often caused by accidental localized overheating, particularly at electrical connections.

In a fire protection system, it is not enough to detect the fire and secure the area. It is often necessary to protect people and property by intervening at the very start of the fire. This is where automatic fire suppression systems come into play, whether they use gas, water, water mist, foam, or powder. The extinguishing agent, managed by automation, aims to prevent the fire from spreading or to completely extinguish it. To control and manage any potential fire outbreak, it is imperative to install suppression equipment tailored to specific risks. These systems must ensure full control of the dangers associated with the onset of a fire. The role of an Automatic Fire Suppression System (AFSS) is to detect, alert, and extinguish or at least contain the early stages of a fire. To define the objective to be achieved, it is crucial to identify the type of fire risk present.

In this study, we will explore various fire protection systems and select a specific system to evaluate its performance in fire protection.

This work has been structured as follows:

- **Chapter 1:** State of the Art and Theoretical Context
- **Chapter 2:** Design of the Automatic Fire Extinguishing System
- **Chapter 3:** Evaluation and Optimization of CO_2 Automatic Fire Extinguishing Systems at Sonatrach

With technological advancements, the role of humans in fire prevention has been significantly reduced thanks to automatic systems that minimize response time. In this study, we aim to achieve the following objectives:

- Evaluate the effectiveness of automatic fire suppression systems;
- Highlight the associated advantages and disadvantages;
- Study and analyze their performance.

To achieve these objectives, we have selected the automatic CO2 gas fire suppression system installed in the control room to examine its efficiency under real working conditions, comparing its results with the APSAD standards (R3).

Chapter I: State of the Art and Theoretical Context

Chaptre 1: State of the Art and Theoretical Context

1.1 Introduction

Due to the hazardous nature of flammable liquids, their presence at gas stations increases the likelihood of accidents such as fires and explosions. Therefore, it is necessary to take strict precautionary measures to ensure a safe environment and minimize risks that may affect workers, customers, and property.

1.2 The importance of safety at service stations:

1.2.1 Protection of Employees

- Ensures a safe working environment for employees, reducing the risk of injuries and illnesses.
- Compliance with safety regulations helps prevent accidents related to hazardous materials and equipment.

1.2.2 Customer Safety

- A safe service station protects customers from potential hazards, such as slips, trips, and falls, as well as exposure to flammable materials.
- Clear signage and safety protocols enhance customer confidence and satisfaction.

1.2.3 Health and Well-being

- Promoting a culture of safety contributes to the overall health and well-being of employees, leading to higher morale and job satisfaction.
- Safe practices reduce stress and anxiety related to workplace hazards.

1.2.4 Emergency Preparedness

- Implementing safety protocols prepares employees to respond effectively to emergencies, such as fires or chemical spills.

- Regular drills and training ensure that staff are familiar with emergency procedures, minimizing panic and confusion during actual incidents.

1.3 Risks related to flammable liquids

The hazards associated with flammable liquids in fuel stations include several key aspects, such as [1]:

1.3.1 Fire and Explosion Risk

- Leakage of flammable liquids can lead to the formation of flammable vapors, which may ignite due to an electrical spark or another heat source.
- Sparks from electrical devices or even smoking near these liquids can cause ignition.

1.3.2 Environmental Pollution

- When flammable liquids leak into the soil or groundwater, they can cause severe pollution, requiring environmental protection measures such as installing leak detection systems.

1.3.3 Exposure to Toxic Vapors

- Vapors released from these liquids can lead to health issues when inhaled for long periods, such as poisoning or respiratory problems.

1.3.4 Thermal Effects and Secondary Explosions

- In the event of ignition or explosion, the resulting heat can worsen the situation by spreading the fire to other areas or causing secondary explosions.

1.4 International Standards and Regulations

1.4.1 Overview of applicable safety standards (NFPA, ISO, etc.)

When it comes to safety standards, several organizations provide guidelines and regulations to ensure safety across various industries. Here’s an overview of some of the most widely recognized safety standards:

a) National Fire Protection Association (NFPA)

NFPA is an American nonprofit organization founded in 1896 that develops and publishes more than 300 codes and standards to reduce the risk of fire and related hazards. NFPA standards are a key reference in the fields of fire, electrical, and life safety. [6]

Figure 1-1: National Fire Protection Association

b) NFPA1 Fire Code: Provides comprehensive fire safety requirements for buildings, processes, and facilities.[6]

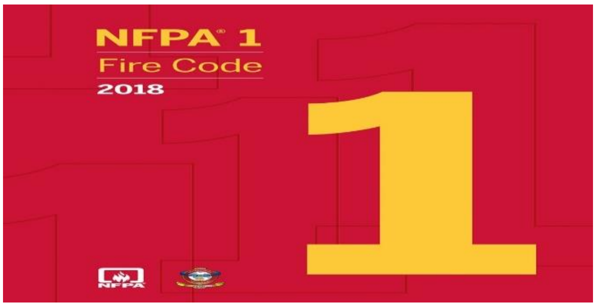

Figure 1-2: NFPA1 Fire code

c) NFPA 70 National Electrical Code (NEC): Sets the standard for safe electrical design, installation, and inspection to protect people and property from electrical hazards.[6]

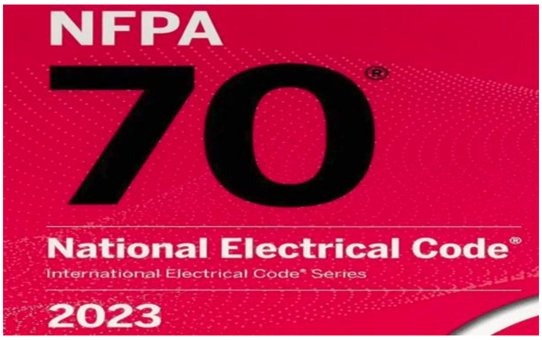

Figure 1-3: National electrical code NFPA70

d) **NFPA 101 Life Safety Code:** Provides requirements for the design, operation, and maintenance of buildings to protect occupants from fire and related hazards.[6]

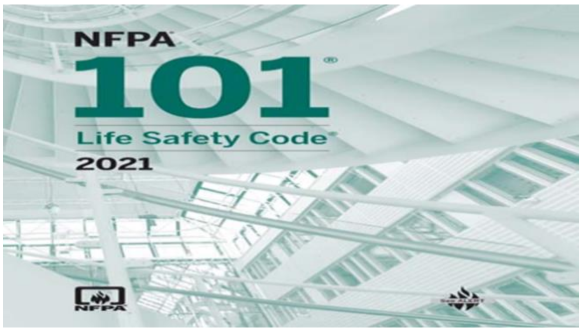

Figure 1-4: NFPA 101 Life Safety Code

e) **NFPA 1001 Standard for Fire Fighter Professional Qualifications**: Sets the criteria for firefighter training and certification. [6]


Figure 1-5: Fire Fighter Professional Qualifications NFPA1001

1.4.2 International Organization for Standardization (ISO)

The International Organization for Standardization (ISO) is an independent non-governmental organization that develops and publishes international standards to ensure quality, safety and efficiency in products, services and systems. ISO was founded in 1947 and is headquartered in Geneva, Switzerland. With more than 160 member countries, the organization facilitates international trade and promotes global cooperation through the development of common standards. [4]

Figure 1-6: International Organization for Standardization (ISO)

a) **ISO 9001- Quality Management System:**

- Specifies requirements for a quality management system to ensure organizations meet customer needs and continuously improve their satisfaction.[4]
- Used across all industries to enhance efficiency and quality.[4]

Figure 1-7: ISO 9001: Quality Management System

b) **ISO 14001-Environmental Management Systems:**

- Helps organizations improve their environmental performance by managing waste, resources, and compliance with environmental laws.[4]

Figure 1-8: ISO 14001 Environmental Management System

- Used to promote environmental sustainability.[4]

a) ISO 50001-Energy Management Systems:

- Provides a framework for improving energy efficiency and reducing energy consumption in organizations.[4]

Figure 1-9: ISO 50001-Energy Management Systems

- Aims to support global efforts to reduce carbon emissions.[4]

1.5 Specific requirements for automatic extinguishing systems

Automatic fire extinguishing systems are essential devices for fire protection in various environments, such as commercial buildings, industrial facilities, and data centers. To ensure their effectiveness, these systems must meet specific technical and regulatory requirements. Below is a detailed analysis of these requirements.[2]

– **Design and Installation**

- Automatic extinguishing units must be designed and installed by qualified and trained personnel.
- All instructions and limitations mentioned in the manual must be followed.

– **Components**

- Systems must include components such as FM-200 cylinders, detection tubing, and nozzles.
- All components must comply with recognized standards such as NFPA-2001 and UL.

– **Pressure and Temperature**

- Cylinders must operate under a specified operating pressure (150 psi at 70 degrees Fahrenheit).
- The operating temperature range must be between 0 to 130 degrees Fahrenheit.

– **Minimum Design Concentration**

- The minimum required concentration must be determined based on the type of hazard (such as Class A, B, and C fires).
- The required quantity of FM-200 must be calculated based on the hazard volume and temperature.

– **Closing Openings**

Means must be provided to close all openings in the hazard area and shut down ventilation at the time of discharge.

– **Maintenance Testing**

- Regular inspections of the system must be conducted, including pressure and weight checks.
- All inspections and procedures must be recorded in a maintenance log.

– **Training**

Personnel involved must be trained on how to properly use and maintain the system.

– **Compliance with Standards:**

Systems must comply with applicable local and international standards.

1.6 Existing technologies for automatic extinguishing

1.6.1 Comparison of the different solutions available (CO_2, foam, powder)

1) Automatic CO_2 Fire Suppression

- **Principle:** CO_2 works by reducing the oxygen concentration in the air, thereby suffocating the fire. It is particularly effective for electrical and flammable liquid fires, as it leaves no residue and does not damage electronic equipment.
- **Applications:** Computer rooms, server rooms, electrical installations, and areas where water cannot be used.
- **Advantages:**
  - No residue after suppression.
  - Effective on Class B (flammable liquids) and Class C (gases) fires.
- **Disadvantages:**
  - Risk of asphyxiation in occupied areas due to high CO_2 concentration.

Figure 1-10: Automatic CO_2 Fire Suppression

  - Less effective in very cold or poorly ventilated environments.

2) Automatic Foam Fire Suppression

- **Principle:** Foam works by smothering the fire, isolating the surrounding air from the vapors or gases emitted by the burning fuel, and by cooling. It is often used for flammable liquid fires and Class A (solid materials) fires.
- **Applications:** Industrial kitchens, flammable liquid storage areas, hydrocarbon storage zones.

- **Advantages:**
    - Effective for Class A and B fires.
    - Can be used in environments where water is ineffective or hazardous.
- **Disadvantages:**
    - Requires cleanup after use.

Figure 1-11: Automatic Foam Fire Suppression

    - May damage certain electronic equipment.

3) Automatic Powder Fire Suppression

- **Principle:** Chemical powder extinguishes the fire by isolating the oxygen. It is versatile and can be used for Class A, B, and C fires.
- Applications**:** Garages, workshops, industrial areas, and places where different types of fires may occur.
- **Advantages:**
    - Versatility: effective on multiple fire classes.
    - Easy to use and maintain.
- **Disadvantages:**
    - Leaves residues that are difficult to clean, especially on electronic equipment.

Figure 1-12: Automatic Powder Fire Suppression

- May damage sensitive equipment.

I.6.2 Comparison of Solutions

Table 1-1: Comparison of Solutions

Criterion	CO_2	Foam	Powder
Effectiveness	Electrical and liquid fires	Class A and B fires	Class A, B, and C fires
Residue	None	Requires cleanup	
Material Damage	None	May damage electronics	May damage electronics
Human Safety	Risk of asphyxiation	Safe	Safe
Applications	Computer rooms, electrical installations	Kitchens, flammable liquid storage	Garages, workshops, industrial areas

1.6.2 Strengths and limitations of current systems

I. CO_2 Systems

Strengths:

No residue: Leaves no traces after extinguishing, making it ideal for electronic equipment and sensitive areas.

- Rapid effectiveness: Acts quickly by reducing oxygen concentration, suffocating the fire.

- Suitable for electrical fires: Does not conduct electricity, making it safe for electrical installations.

Limitations:

- Health risk: Can cause asphyxiation in enclosed or poorly ventilated spaces.
- Less effective in large spaces: Requires a high concentration to be effective.
- Not suitable for Class A fires: Less effective on solid materials like wood or paper.

II. Foam Systems :

- **Strengths:**
  - Effective on flammable liquids: Ideal for Class B fires (hydrocarbons, gasoline, etc.).
  - Prevents reignition**:** Forms an insulating layer that prevents the fire from reigniting.
  - Cooling effect**:** Helps lower the temperature of the fire.
- **Limitations:**
  - Cleaning required**:** Foam leaves residues that need to be cleaned.
  - Potential damage**:** Can damage electronic equipment and sensitive surfaces.
  - Less effective on deep-seated fires**:** Requires prolonged application for solid material fires.

III. Powder Systems:

- Strengths**:**
  - Versatile: Effective on Class A, B, and C fires.
  - Rapid action**:** Acts quickly to suffocate the fire.
  - Easy to use**:** Simple to install and maintain.
- **Limitations:**
  - Difficult-to-clean residues: Powder can damage electronic equipment and sensitive surfaces.
  - Reduced visibility**:** Can cause temporary obscurity, hindering evacuation.
  - Less effective on metal fires: Unsuitable for Class D fires (combustible metals).

IV. Water (Sprinkler) Systems

- **Strengths:**

  - Eco-friendly and economical: Water is a natural, abundant, and low-cost extinguishing agent.
  - Effective against Class A and B fires: Limits fire spread and protects people and property.
  - Automatic and reliable: Operates without human intervention, with precise thermal detection.
- **Limitations:**
  - Damage to electrical equipment**:** Can cause short circuits or corrosion.
  - Risk of freezing or pipe rupture**:** May be ineffective in certain conditions.
  - Not suitable for Class C and D fires**:** Ineffective on combustible gases and metals.

V. Inert Gas Systems (CO_2 ,etc.):

- **Strengths:**
  - Clean and residue-free**:** Leaves no traces after extinguishing, ideal for sensitive equipment.
  - Effective on electrical and Class B/C fires**:** Reduces oxygen concentration without damaging installations.
  - Eco-friendly**:** No environmental impact (zero global warming potential).
- **Limitations:**
  - Asphyxiation risk: Requires strict safety measures, such as evacuating people.
  - High cost**:** Involves significant installation, maintenance, and refill expenses.
  - Requires perfect sealing**:** The gas must be confined in the protected area to be effective.

1.7 Conclusion

In this chapter, we explored the theoretical and practical foundations of safety in fuel stations, with a focus on the risks associated with flammable liquids. An overview of international standards and regulations, such as **NFPA** and **ISO**, was presented, serving as an essential reference framework for applying best safety practices. Additionally, current technologies for automatic fire suppression systems, such as **CO_2**, **foam**, and **powder**, were analyzed, highlighting their strengths and limitations.

Through this analysis, it is clear that the choice of the appropriate system depends on the nature of potential risks, the environment to be protected, and the available equipment. No single system fits all situations; therefore, fire suppression systems must be designed based on a thorough study of the specific needs and conditions of each site.

Chapter II: Design of the Automatic Fire Extinguishing System

Chaptre 2: Design of the Automatic Fire Extinguishing System

2.1 Introduction

Automatic extinguishing systems are one of the most important means of protection in various facilities, as they work to detect fires in their early stages and extinguish them without human intervention. These systems consist of fixed extension networks with openings distributed in the places to be protected, and are fed by a continuous source of the appropriate extinguishing material. They operate automatically when heat or smoke from a fire is detected, ensuring a quick and effective response. These systems vary to include water sprinklers, gases, foam, and chemical powder, and the appropriate type is chosen based on the nature of the risks and the surrounding environment. These systems contribute to minimizing material and human losses by extinguishing the fire immediately, giving enough time to evacuate buildings and limit the spread of the fire to neighboring areas.

Figure 2-1: Automatic extinguishing systems

2.2 Technical Specifications of the System

Designing an effective automatic fire suppression system requires a thorough understanding of the specific hazards associated with the environment in which it will operate. The system must be tailored to the risk classification, operational conditions, and occupancy of the protected area. The following technical parameters are essential for system specification:

1) Fire Classification and Risk Type

Fire behavior and suppression methods vary depending on the nature of the combustible material. The most recognized classification system includes [7]:

- Class A: Fires involving ordinary solid combustibles such as wood, paper, and cloth.
- Class B: Fires involving flammable liquids like gasoline, oil, and solvents.
- Class C: Fires originating from flammable gases such as propane, methane, or natural gas.
- Class D: Fires involving combustible metals like magnesium and titanium.
- Class K (or F): Fires involving cooking oils and fats, especially in commercial kitchens.

Example: In a data center environment, the primary threat is an electrical fire (Class C), for which water-based systems pose a risk of equipment damage and electrical hazards. Therefore, clean agent systems such as FM-200 or Novec 1230 are typically recommended (NFPA 75, NFPA 2001).

2) Suppression Area and Volume

System coverage must be designed according to the geometry of the protected space, including floor area, ceiling height, and obstruction layout. Calculations are typically carried out using standards such as NFPA 13 (Standard for the Installation of Sprinkler Systems) or ISO 6182. The number and placement of nozzles must ensure uniform agent distribution and meet the minimum density requirements.

3) Discharge Flow Rate and Pressure

The discharge characteristics—flow rate (measured in L/min or gpm) and operating pressure (bar or psi)—must be optimized to guarantee effective dispersion of the extinguishing agent. Factors such as pipe diameter, elevation changes, and agent type must be taken into account. High-pressure systems (e.g., CO_2 or water mist) may require reinforced piping and specialized pumps.[3]

4) Activation Time

Rapid activation is critical to limiting fire propagation and minimizing damage, especially in sensitive environments like laboratories, archives, and healthcare facilities. The typical response time ranges between 10 to 30 seconds from fire detection to agent discharge (NFPA 72, Clause 10.6).

5) Detection Logic and System Integration

Fire detection must be closely integrated with the suppression system's logic controllers, such as Programmable Logic Controllers (PLCs) or Fire Alarm Control Panels (FACP). These systems should support [13]:

- Automatic activation sequences.
- Manual override capabilities.
- Interfacing with HVAC shutdown systems and building management systems (BMS).
- Fail-safe mechanisms in the event of power loss (as per EN 54 and UL 864).

2.3 Environmental and Economic Constraints

a) Environmental Constraints

Designing for environmental compatibility ensures reliability and longevity of the suppression system. Several environmental conditions must be considered:

- Extreme Temperatures: In facilities such as cold storage warehouses, dry-pipe systems are preferred to avoid water freezing in pipes (NFPA 13).
- Corrosive Environments: In chemical processing or marine facilities, materials such as 316L stainless steel are required for corrosion resistance. Enclosures and components must comply with IP/NEMA ratings depending on humidity, chemical exposure, and ingress protection needs.
- Occupied Spaces: In human-occupied zones (e.g., hospitals, offices), it is critical to use agents that are non-toxic and breathable, such as Novec 1230 or Inergen, both of which meet safety standards under ISO 14520 and NFPA 2001.

b) Economic Considerations

Economic factors influence not only the selection of the system but also its operational sustainability:

- Initial Capital vs. Risk Tolerance: High-value or high-risk areas (e.g., data centers, refineries) justify greater investment in advanced suppression technologies. Cost-benefit analysis using risk matrix methodologies is often applied.
- Maintenance and Recharge Costs: Some agents, such as CO_2 or AFFF foam, require frequent maintenance and recharging after discharge, increasing operational expenditure. Regular testing per NFPA 25 or EN 12845 is mandatory.
- System Life Cycle and Upgradability: The suppression system should be modular and scalable, allowing for future expansion or compliance with upcoming codes. Components should be compatible with open protocols (e.g., Modbus, BACnet) to enable seamless integration with other safety systems.

2.4 Types of fire detectors (temperature, flame, gas)

Fire detectors are used to monitor fires in their early stages by sensing physical or chemical changes in the surrounding environment. They can be classified into three main categories,

Figure 2-2: fire detectors

including heat detectors, flame detectors, and gas detectors.

2.4.1 Heat detectors

Heat detectors are sensors used to detect fires based on changes in ambient temperature. These detectors are used as part of fire early warning systems, alerting people or triggering automatic extinguishing systems when the temperature rises to an abnormal level.[9]

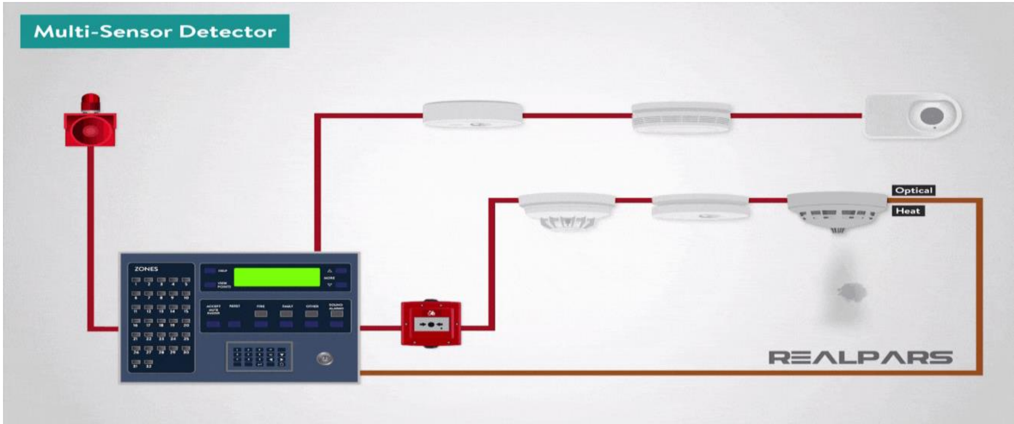

Figure 2-3:Heat detectors (Détecteurs de température)

Genres:

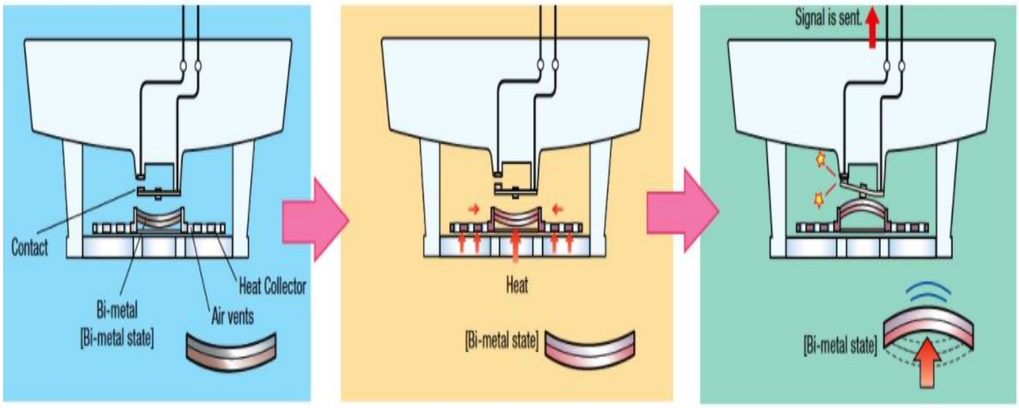

Figure 2-4: Rate-of-Rise Detectors

a) Fixed Temperature Detectors: They work when the temperature reaches a certain predetermined limit (such as 57°C or 70°C depending on the environment). They contain a sensitive element (such as a soluble metal or an electronic sensor) that activates the alarm when the set threshold is exceeded. Used in places where the temperature does not change rapidly, such as warehouses and mechanical rooms

b) Rate-of-Rise Detectors: Responds to rapid increase in temperature, even if it does not reach the maximum threshold.

It relies on sensors that sense the rapid change in temperature (such as 8-12 ° C per minute).

Used in environments where heat can rise rapidly, such as factories and kitchens.

Advantages and disadvantages

- It is characterized by high reliability, as it does not issue false alarms due to smoke or dust.
- Suitable for use in harsh environments such as kitchens and warehouses.
- Easy to maintain and have a long lifespan.

Defects:

- They respond slowly compared to smoke or flame detectors, as they need a significant rise in temperature.
- Ineffective in detecting fires in their early stages, which may lead to delays in response.

2.4.2 Flame detectors

Flame detectors are specialized sensors used to detect fires based on the light radiation emitted by the flame. Different from heat and smoke detectors, they can detect fire as soon as flame appears, making them the fastest means of detecting fires.

Genres [5]:

1) UV Flame Detectors:

It captures radiation in the range of 180-280 nm, the spectrum emitted by flames in its early stages. They are characterized by the speed of their response (within 3-4 milliseconds). Very sensitive, but they may be exposed to false alarms due to other radiation such as lightning or electric welding.

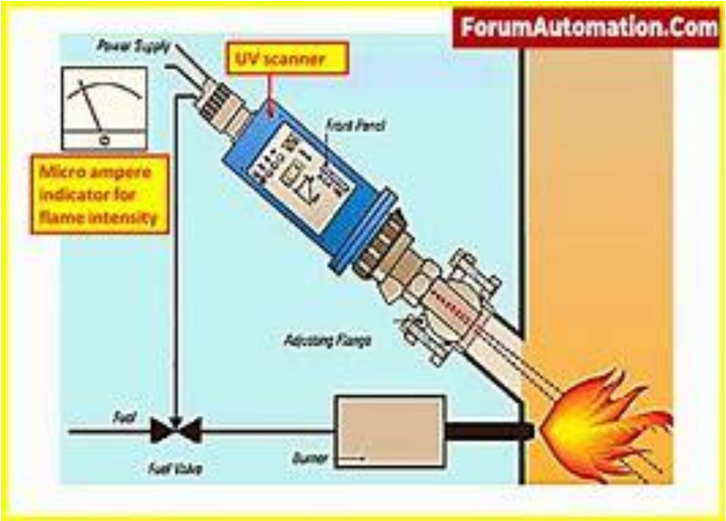

Figure 2-6: UV Flame Detectors

2) IR Infrared Detectors:

It captures thermal radiation emitted by the flame in the range of 4.3 microns. Suitable for detecting fires burning with hydrocarbons (such as gasoline and natural gas). They may be affected by thermal radiation from hot equipment, so they are used with special

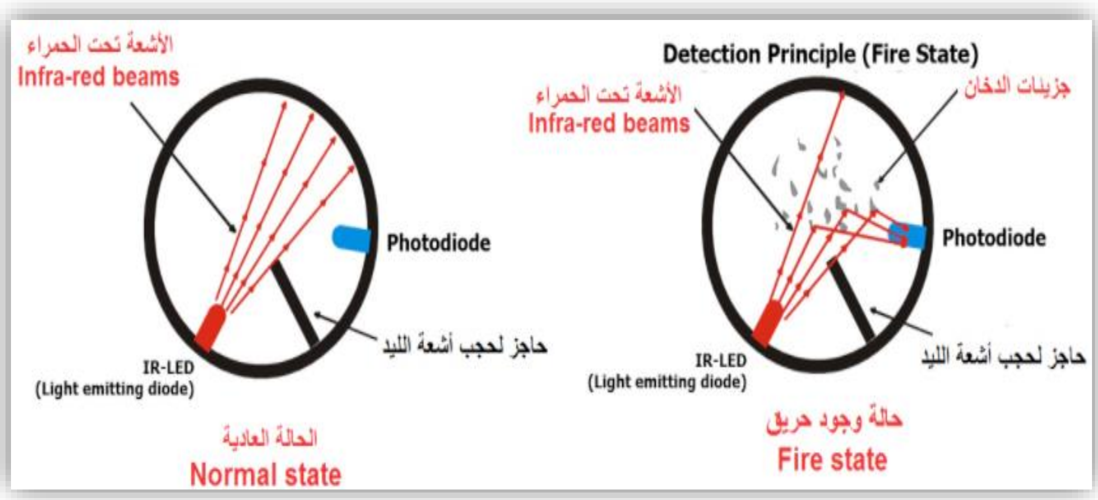

Figure 2-7: IR Infrared Detectors

filters.

Advantages and Disadvantages of Flame Detectors

Advantages:

- Superior responsiveness compared to smoke or heat detectors.
- Effective in detecting fires in open spaces.

- Not affected by dust, smoke, or fog like smoke detectors.
- Reduces the risk of false alarms when using dual or tri-spectral models.

Disadvantages:

- May be affected by external radiation such as sunlight or welding.
- Requires precise installation to achieve optimal coverage.
- Some types are expensive compared to heat or smoke detectors.

2.4.3 Gas detectors

Gas detectors are sensors used to detect the leakage of gases into the air, whether they are flammable, toxic, or invisible gases that pose a safety hazard. These detectors are used in industrial environments, homes, oil installations, and gas stations to protect people and equipment from potential hazards.[10]

Figure 2-8: Gas detectors

1) Combustible Gas Detectors:

Detects flammable gases such as methane (CH_4), propane (C_3H_8), and butane. It works by sensing the concentration of gas in the air and comparing it to the minimum ignition limit (LEL - Lower Explosive Limit). If the gas concentration exceeds a hazardous percentage (usually 10-25% of LEL), the alarm is triggered. Often rely on catalytic sensors or IR sensors.[10]

Figure 2-9: Toxic Gas Detectors

2) Toxic Gas Detectors:

Toxic gases such as carbon monoxide (CO), ammonia (NH_3), sulfur dioxide (SO_2) and hydrogen sulfide (H_2S) are detected. It works via chemical or electrochemical sensors that detect the interaction between the gas and the sensor, causing an electrical change that triggers the alarm. Used in chemical plants, mines, and waste treatment facilities.[10]

Advantages and Disadvantages of Gas Detectors

Advantages:

- Provide safety by preventing fires and explosions caused by the leakage of flammable gases.
- Reduce health risks by protecting people from exposure to toxic gases that may cause suffocation or poisoning.
- Offer a quick response, activating immediately upon detecting an abnormal concentration of gas in the atmosphere.
- Feature advanced communication systems that allow integration with remote monitoring systems.

Disadvantages:

- Sensitive to environmental factors such as humidity and dust, which may lead to inaccurate readings.
- Require regular maintenance to ensure sensor accuracy and prevent false alarms.
- Some advanced models are expensive, particularly those used in industrial plants.

2.5 Types of extinguishing agents (FM200 gas, sprinkler system, foam)

Extinguishing agents are substances that are used to put out fires by removing one of the essential elements in a fire triangle, which consists of heat, fuel, oxygen, or a chemical chain reaction. These factors vary depending on the nature of the fire, as each type of fire has a suitable extinguishing material that can deal with it effectively. The right choice of firefighter is crucial, not only to prevent the spread of flames, but also to minimize damage caused by fire and protect lives and property.

Figure 2-10: Extinguishing agents

2.5.1 Fire extinguishing with FM-200

FM-200 is the commercial name for Heptafluoropropane (HFC-227ea), which is an extinguishing gas. It primarily works through the physical mechanism of heat absorption and by inhibiting the chain reaction responsible for combustion, without significantly reducing the oxygen content in the air. FM-200 is effective when the energy released is necessary for sustaining combustion and can be used on gas fires, liquid fires, and solid fires that burn without the presence of embers.[14]

The advantages of using the FM-200:

This system is used to gradually replace ozone-depleting gases such as Halon 1301, which is now banned. When used at its nominal extinguishing concentration (maximum 9%), FM-200 does not lower the oxygen level to a point that would prevent occupants from remaining in the room. After a fire, the gas can be dispersed through natural ventilation due to the absence of toxic side effects. Since it contains neither bromine nor chlorine, its ozone depletion potential is zero. It is stored in cylinders as a liquid, pressurized with nitrogen, and therefore occupies little space. There is no risk of damage from thermal shock to sensitive electronic equipment, and FM-200 is non-conductive and non-corrosive. Moreover, it leaves no deposits or oily residues that could harm software, data files, or communication equipment,

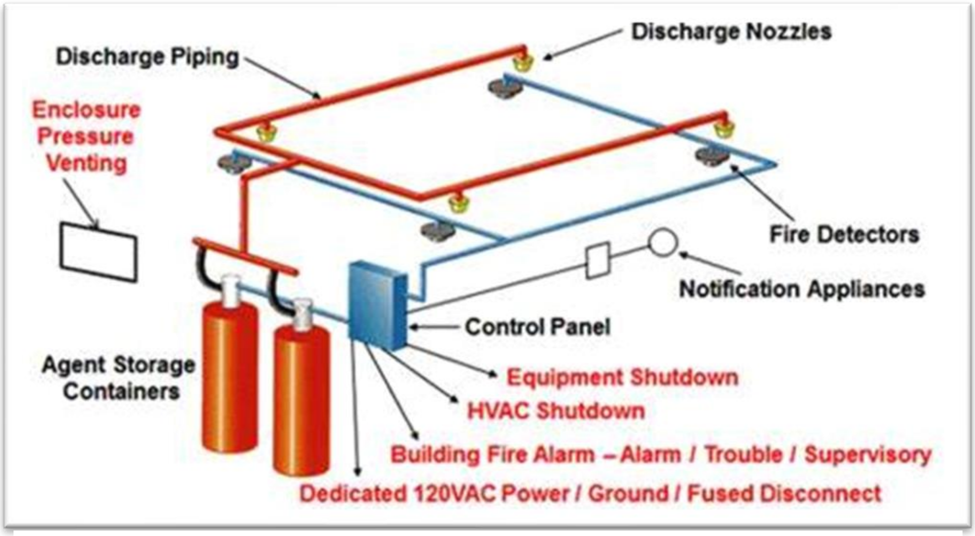

Figure 2-11: FM-200

which leads to reduced cleaning time and cost after discharge.

Field of application:

The FM-200 system is used in areas where the use of water could lead to equipment damage. These include:

- Data centers and electrical rooms
- Gas turbines
- Oil exploration and offshore production facilities
- Telecommunications centers

- Power generators
- Museums, archives, and data storage facilities

2.5.2 The sprinkler system

The sprinkler system is a fire protection method consisting of a water supply system, providing adequate pressure and flow rate to a piping system onto which fire sprinklers are connected. When a fire is detected, the system automatically discharges water to control or extinguish the flames, helping to protect lives and property.[14]

Operating principle

- When a fire breaks out, the heat generated rises and reaches one of the sprinkler heads installed in the ceiling. The temperature causes the bulb or fuse holding the head closed to break.
- The constant pressure in the pipe feeding the head is then released, allowing water to flow out and spray the area on fire. The pressure drop resulting from the head opening triggers the start-up of the pumps, ensuring that the pressure and water supply are maintained. This pressure drop also activates a hydraulic gong, triggering the alarm (with transmission to a fire control center). If the fire is not brought under control at

Figure 2-12:The sprinkler system

this stage, the increase in heat causes other sprinkler heads to open.

Sprinkler Heads & Pumping System

Sprinkler heads come in various types, including bulb-type and fusible-link models, which differ in deflector design, orifice diameter, and operating temperature—the most common being those activated at 68°C and 93°C. The pumping system, the standard technical solution to ensure required flow and pressure in the network, typically consists of: a jockey pump, two electric pumps, and two engine-driven pumps.

2.5.3 Extinguishing fires with foam

Figure 2-13: Extinguishing fires with foam

Foam is a non-toxic, lightweight, and material-friendly heterogeneous mixture of air and water, created using a foaming agent and a generator. Composed of tiny bubbles, it is less dense than liquids and effectively smothers fires by being applied directly onto the burning surface or into the fire volume to suppress flames.[8]

1) Foam Production Process:

Foam is generated by vigorously mixing three essential components: pressurized water, a foaming agent, and a gas source. The gas used depends on the foam type—chemical foams require CO_2, while physical foams utilize ambient air. This energetic blending process creates the stable bubble structure required for fire suppression.

Figure 2-14: Foam Production Process

Fire Suppression Mechanism of Foam

Foam acts as an effective fire suppressant by forming a protective blanket over the hazard area, isolating flames from oxygen and preventing the release of flammable vapors (isolation principle). Simultaneously, the water content in the foam provides rapid cooling. Due to its high efficiency and fast action, foam is ideal for high-risk scenarios involving rapid flame spread and intense fire development. Foam performance is characterized by its "expansion ratio"—the ratio of foam volume produced to the volume of foam solution used, determined by the amount of air incorporated during mixing.[8]

Advantages and Limitations of Firefighting Foam

Advantages:

- Rapid Fire Suppression: Quickly smothers flames by cutting off oxygen and cooling surfaces
- Versatile Application: Effective on liquid (Class B) and some solid (Class A) fires
- Vapor Suppression: Prevents flammable vapor release and re-ignition
- Material Compatibility: Generally non-corrosive to equipment when properly selected
- Thermal Protection: Creates a heat-resistant barrier for exposed structures

Limitations :

- Environmental Concerns: Some formulations contain PFAS (persistent pollutants)
- Cleanup Requirements: Leaves residue requiring post-fire remediation
- System Complexity: Requires proper proportioning equipment and regular maintenance
- Limited Effectiveness: Less efficient on pressurized gas fires or three-dimensional fires
- Expansion Sensitivity: Performance depends on correct air/water/foam concentration ratio

2.6 Conclusion

In this chapter, we have presented the main fire detection systems, the criteria for choosing detectors for prevention, and the various automatic extinguishing modes (such as FM200, sprinkler and foam). The following chapter will be devoted to an in-depth study of the CO_2 sprinkler system, analyzing its technical specifics and areas of application.

Chapter III: Evaluation and Optimization of CO_2 Automatic Fire Extinguishing Systems at Sonatrach

Chaptre 3: Evaluation and Optimization of CO_2 Automatic Fire Extinguishing Systems at SONATRACH

3.1 Introduction

This chapter focuses on evaluating the implementation, operation, and effectiveness of a CO_2 gas-based automatic extinguishing system in an industrial environment, addressing its efficiency and reliability to determine its suitability for practical applications.

3.2 Company Presentation

An oil refinery is a plant where petroleum is fractionated to produce a wide variety of gaseous (propane and butane, etc.), liquid (gasoline, diesel and fuel oil, etc.) and even solid (bitumen, etc.) products. The Adrar refinery is one of five in Algeria, and the only one with a catalytic cracking unit (FCC).[11]

3.2.1 Historical background and geographic distribution

The Adrar refinery is managed by a joint venture called SORALCHIN. This is an Algerian-Chinese company made up of the China National Petroleum Corporation (CNPC) and the Algerian petroleum company (SONATRACH). The Adrar refinery became operational at the end of March 2006.[11]

3.2.2 Geometrical situation

The Adrar refinery (RA1D) covers an area of 75 hectares and is built on a site located 02 km from the commune of SBAA and 44 km north of Adrar, in south-western Algeria. The refinery site is located in the middle of the Guebi desert, some 900 m from an agricultural zone attached to the village of Sbaa, to the west of the site. It is bounded [11]:

- To the north by the daira of TSABET;

- To the south by the commune of GOURARA;

- To the west by the commune of SBAA;

- To the east by undeveloped land.

3.2.3 Geographical coordinates

- Longitude 00° 11 West;
- Latitude 27° 49 North;
- Average altitude is 275 metres.

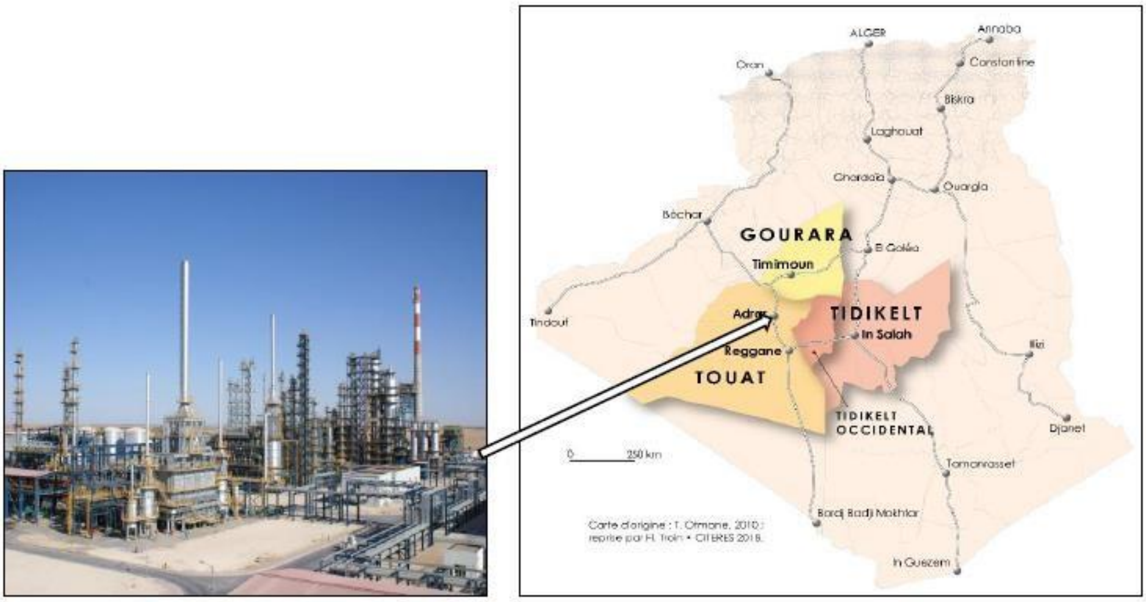

Figure 3-1: Geographical location of the Adrar refinery[11]

Figure 3-2: layout of the Adrar refinery[11]

3.2.4 Production capacity

The annual processing capacity of the SEBAA refinery is around 600,000 tonnes of crude oil, equivalent to 12,500 barrels per day.

The refinery's main commercial products are propane, butane, butane and propylene and diesel fuel, as well as certain gas and fuel oil by-products. The following table shows the refinery's annual production capacity.[11]

Table 3-1: shows the quantities and percentages of products obtained from the refinery[11]

Products	**Quantities (Tonnes/Year)**	**In percent (%)**
Propane	20 500	**3.41**
Butane	32 500	**5.41**
Premium gasoline	10 000	**1.66**
Regular gasoline	208 300	**34.66**
Kerosene (J and A1)	30 000	**5**
Gas oïl (diesel)	238 400	**39.73**
Fuel oïl (Mazout)	13 000	**2.16**

3.2.5 Liquefaction activities, Refining and Petrochemicals

The industrial energy facilities include four liquefied natural gas (LNG) complexes with a total capacity of 56 million cubic meters per year, along with two liquefied petroleum gas (LPG) complexes with a capacity of 11 million tons per year. Additionally, the infrastructure features six refineries for crude oil and condensates, providing a production capacity of 30.5 million tons per year, reinforcing its role in meeting both domestic and international market demands.[12]

In partnership, an advanced industrial complex comprises multiple production units: a Methanol Complex with a capacity of 120,000 tons per year, and a High-Density Polyethylene (HDPE) Complex producing 130,000 tons annually. Additionally, the facility includes two Helium Units, collectively yielding1,200 million **SCF/year**. Complementing these operations are two Ammonia/Urea Complexes, boasting an annual output of 2.8 million tons of ammonia and 3.4 million tons of urea, reinforcing the site's pivotal role in petrochemical and agricultural industries.[12]

3.3 Purpose of an Automatic Fire Extinguishing System in the Company

Automatic fire extinguishing systems play a vital role in protecting energy infrastructure from fire risks by: early detection and suppression of fires to prevent their spread, minimising physical damage to equipment and infrastructure, preventing downtime that leads to financial and logistical losses, and ensuring the safety of individuals by responding promptly to threats, enhancing resilience and supporting the sustainability of energy infrastructure.[14]

3.3.1 CO_2 Automatic Fire Extinguishing System

Carbon dioxide (CO_2) is one of the most effective fire suppression agents, characterized by a set of physical and chemical properties that make it the optimal choice for numerous industrial and commercial applications. This non-flammable gas is colorless, odorless, non-conductive to electricity, and leaves no residue after suppression, making it ideal for protecting sensitive equipment.[14]

The working mechanism of carbon dioxide in fire suppression relies on two main principles: First, it reduces the oxygen concentration in the fire area to below 15%, which is the critical threshold required for combustion to continue. Second, it contributes to heat absorption through the expansion process when released from the cylinder, thereby enhancing its effectiveness in controlling flames. The strength of this system lies in its ability to form a dense blanket that isolates the fire from surrounding oxygen.

The applications of CO_2 fire suppression systems vary to include electrical transformer rooms, data centers, and server rooms, where its importance in protecting sensitive electronic equipment stands out. It is also effectively used in cold storage units, flammable material storage areas, and chemical laboratories, due to its non-reactivity with most chemical substances.

Advantages:

- Leaves no residue after use, making it ideal for protecting electronic devices.
- Does not cause harm to the environment compared to Halon.
- Extinguishes fires quickly and can be integrated with automatic extinguishing systems.
- Versatile – Effective on Class B (flammable liquids) and Class C (electrical) fires

Figure 3-3: CO_2 Automatic Fire Extinguishing System

Limitations:

- Ineffective in open spaces due to the rapid dispersion of gas.
- Can cause suffocation when used indoors without proper ventilation.
- Not suitable for fires caused by solid materials such as wood or paper**.**
- Dangerous for humans at fire suppression concentrations (34-75% CO_2)

Safety Precautions [14]:

- **Pre-discharge Alarm** – Mandatory warning system to evacuate personnel
- **Proper Ventilation** – Required after discharge to prevent CO_2 build-up
- **Training** – Personnel must understand hazards and emergency procedures
- **Signage** – Clear labelling of CO_2-protected areas

3.3.2 Criteria for Choosing CO_2 as the Extinguishing Agent

CO_2 fire suppression systems offer exceptional compatibility for protecting electrical and industrial installations, including transformers, cable rooms, and heavy machinery, due to their non-conductive and non-damaging properties. The gaseous agent leaves no residue after discharge, significantly minimizing post-fire clean-up and maintenance requirements. These systems provide rapid flame suppression by efficiently reducing oxygen concentration to below combustion levels, enabling early-stage fire extinguishment. When designing CO_2 protection, engineers must consider both geographic coverage (entire buildings, specific rooms, or individual equipment) and performance objectives (complete extinction, suppression, or fire control). The system's effectiveness is maximized when integrated with early detection technologies, ensuring prompt activation for optimal fire response. This combination of features makes CO_2 systems particularly valuable for safeguarding critical infrastructure where quick, clean, and reliable fire protection is essential.[14]

3.3.3 CO_2 Quantity Calculation Method

The APSAD R3 standard specifies that the minimum required CO_2 quantity for both local application (spot protection) and total flooding (ambient protection) systems shall be calculated using a prescribed mathematical formula. This calculation methodology applies uniformly to:

$$Q = K_B (0.2\,A + 0.75\,V)$$

Volume Calculation :

$$V = V_V + 4\,V_Z - V_G$$

Area Calculation:

$$A = A_V + 30\,A_0$$

Variable Definitions:

- V_V**:** Enclosure volume to be protected (m^3)
- V_G**:** Volume of permanent non-combustible obstructions (m^3)
- V_Z**:** Net ventilation air exchange during CO_2 discharge (m^3)
- A_0**:** Effective opening area during fire conditions (m^2)
- A_V**:** Total boundary surface area including openings (m^2)
- K_B**:** Material coefficient (default value = 1 as per APSAD R3 requirements)

3.4 Application to the Electrical Substation

- **Calculation of volume and surface area for the "substation" enclosure:**
  - Dimensions of the enclosure:
    - Height: 3 m
    - Length: 30 m
    - Width: 5 m
  - Volume of the enclosure **(V_V):**

$$V_V = 3 \times 30 \times 5 = 450\ m^3$$

❖ The total surface area of the **A_V** enclosure:

$$A_V = 2\times ((3\times5) + (5\times30) + (30\times3)) = 510\ m^2$$

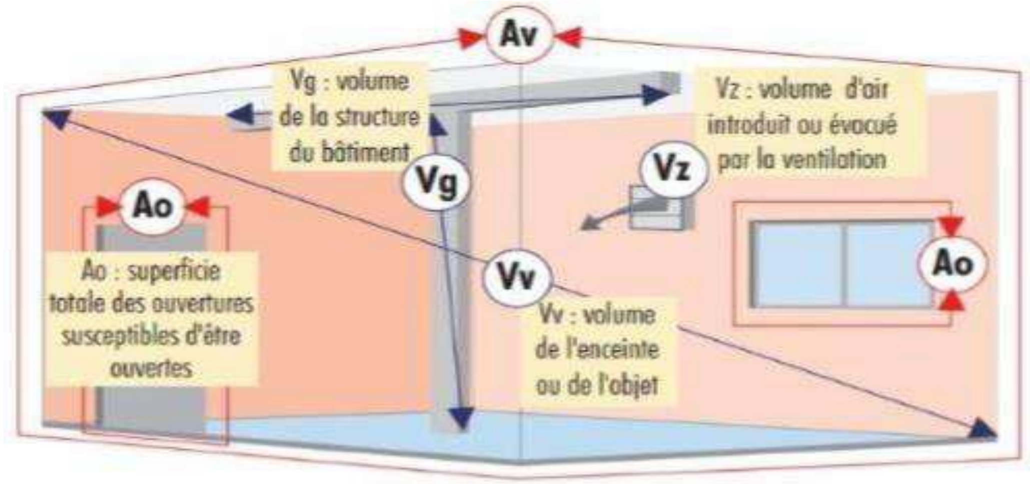

Figure 3-4: Parameters for calculating the amount of CO2

❖ **Calculate the volume of the building structure that can be deduced, in m³ (fixed non-combustible elements) V_G:**

There are 7 electrical cabinets :

V_{G1} = 12×2.25×1.8= **48.6 m^3**

V_{G2} = 1.05×1.65×2= **3.46 m^3**

V_{G3} = 1.1×2.3×10= **25.3 m^3**

V_{G4}= 1.1×2.3×9.4= **23.8 m^3**

V_{G5} = 2×0.63×0.35= **0.44 m^3**

V_{G6} = 0.3× 0.8× 1= **0.24 m^3**

V_{G7} =0.8×0.55×0.85 = **0.37 m^3**

Then the sum of VG**: $V_{G1}+V_{G2}+V_{G3}+V_{G4}+V_{G5}+V_{G6}+V_{G7}$**

$$V_G = 48.6+3.46+25.3+23.8+0.44+0.24+0.37= \mathbf{102.21 m^3}$$

With a V_Z ventilation system package:

V_{Z1}=2× (0.5× 0.7× 2) =1.4 **m^3**

V_{Z2}= 2× (0.5×0.7×3) =2.1 **m^3**

V_{Z3}=2× (0.5× 0.7× 14) =9.8 m^3

V_{Z4}= 0.5× 0.7×13=4.5 m^3

$V_Z = V_{Z1} + V_{Z2} + V_{Z3} + V_{Z4}$

V_Z= 1.4 +2.1+9.8+4.5= **17.79** m^3

- **Calculate the area of openings that can be assumed to be open AO:**

$$A_0 = (3\times2) + (2\times1.2) = 8.24 m^2$$

The variables V and A:

$V = V_V + 4 \times V_Z - V_G$

V= 450 + 4× (17.79) - 102.21 = 419 m^3

$A = A_V + 30 \times A_0$

A= 510 + 30× (8.24) = 757.2m^2

- **Determine the baseline CO2 quantity for this enclosure:**

Use the law:

$$Q = K_B \times (0.2 \times A + 0.75 \times V)$$

K_B = 1 for this type of installation

$$Q_{co2} = 1\times (0.2 \times 757.2 + 0.75 \times 419)$$

Result: Number of Bottles Required

Previously calculated

$$Q_{co2} = 465 Kg$$

If each bottle has a capacity of 45 kg, the required number of bottles is calculated as follows:

$$Np = 465 \div 45 = 10 \text{ bottles}$$

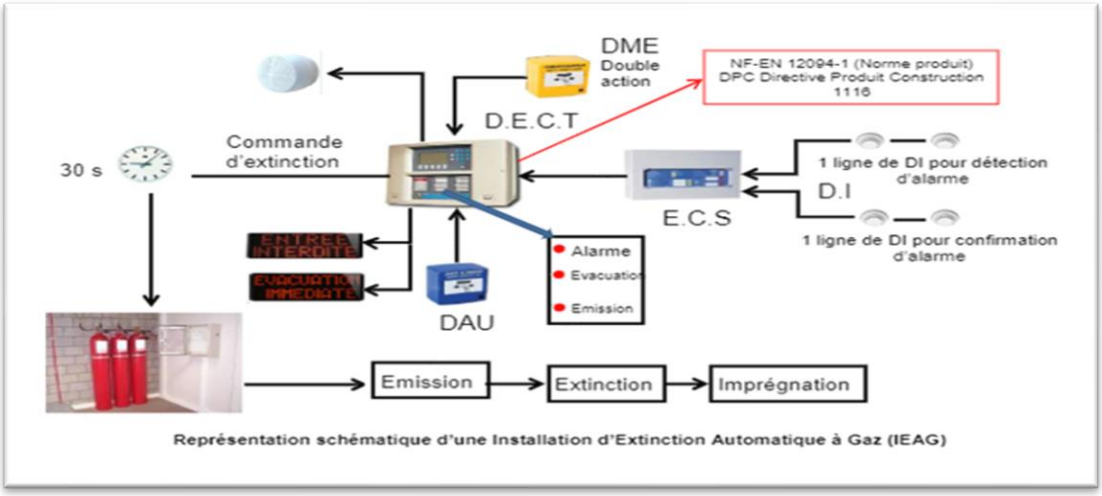

Figure 3-5:diagram of a CO2 extinguishing system

3.5 Synoptic of the CO_2 Extinguishing Installation

- **Detection (smoke sensors, control panels) :**

  The system ensures early fire detection via smoke detectors (optical and linear types). These detectors are widely used in electrical substations as they provide comprehensive coverage of the protected area using radiation beams (emitter and receiver). The first detection triggers the control panel (APS) into pre-alarm mode upon activation of a smoke detector in the first zone.

- **Actuation mechanism**:

  The system operates on a dual-detection principle. After the initial detection, a second smoke detector in another zone must activate to confirm the fire. Upon confirmation, an audible alarm and visual indicators (inside and outside the protected area) are triggered to ensure immediate evacuation.

- **Activation:**

  Once detection is confirmed, an alarm (siren and strobe light) sounds for 30 seconds to facilitate evacuation. The ventilation system shuts down, and doors are automatically sealed. An electrical signal is then sent to the sparklet connected to the pilot cylinder, releasing pressurized CO_2 at 60 bars. This activates the main cylinder bank, which includes a dual-function check valve (serving as both a reservoir connector and a safety component). A reserve cylinder bank acts as a backup if the primary system fails.

- **Discharge system and nozzles**:

CO_2 is rapidly discharged through pipelines connected to diffusers in the protected area, reducing oxygen concentration to **14%** to suffocate flames and extinguish the fire. If the system fails to activate automatically, manual override is possible via a break-glass unit

Figure 3-6: Discharge system and nozzles

near the protected area or from the control room.

3.6 System Performance Evaluation

The CO_2 fire suppression system's performance is evaluated through three key aspects: detection and activation processes, testing and maintenance protocols, and quantifiable performance metrics.

3.6.1 Detection and Activation Process

The system employs a dual-stage smoke detection methodology where initial detection by optical or linear smoke detectors triggers a pre-alarm state. A secondary detection in a separate zone is required to confirm the fire event, ensuring reliable activation. Upon confirmation, the system initiates audible and visual alarms with a 30-second delay to allow for safe evacuation while automatically shutting down ventilation systems and sealing doors. The triggering logic incorporates this evacuation window before CO_2 discharge commences, with provisions for manual override through break-glass units or from the control room in case of automatic system failure.

3.6.2 Testing and Maintenance

Routine maintenance involves monthly visual inspections to verify detector cleanliness, check cylinder pressure gauges, ensure diffusers remain obstruction-free, and confirm alarm panel and backup power functionality. Annual comprehensive testing requires certified technicians and safety officers to conduct functional tests using smoke testers, pressure gauges, and timing devices. The testing protocol follows a strict sequence: (1) simulating smoke detection in Zone 1 to validate pre-alarm activation, (2) triggering Zone 2 detectors to confirm full alarm response, and (3) verifying proper ventilation shutdown, door sealing, and CO_2 release timing. All test results, including any anomalies and corrective actions, must be meticulously documented in the maintenance register.

3.6.3 Performance Metrics

System effectiveness is measured through several key indicators: The CO_2 inventory is regularly compared against design specifications for both main and reserve cylinder banks. Response time accuracy is critical, with a target of ≤60 seconds from initial detection to CO_2 discharge. Post-discharge evaluations verify the system's ability to maintain oxygen levels at ≤14% for the required duration (typically 10+ minutes) through proper room sealing. Alarm effectiveness assessments have identified gaps in external alarm coverage that may impact evacuation compliance, noting this as an area for potential improvement in the overall system performance.

3.7 Conclusion and Recommendations

This chapter has involved calculating the required CO_2 quantity for the protected facility along with its necessary reserve supply, followed by a comprehensive performance evaluation of the studied system covering reactivity, activation mechanisms, response time, and testing/maintenance protocols. Based on our analysis of this automatic CO_2 fire suppression system, we recommend the following critical improvements:

- enhancing door sealing and enclosure integrity during discharge to ensure effective gas retention and proper impregnation time;
- installing external alarm systems to improve incident communication and evacuation procedures;
- implementing rigorous equipment monitoring and reliability programs to maintain optimal system response during emergencies;

- incorporating a smoke extraction system to facilitate safer evacuation and control temperature rise within protected areas;
- equipping the facility with insulating flooring to mitigate electrostatic risks.

These measures collectively address current system limitations while significantly improving operational safety and effectiveness, with potential future research directions including smart detection technologies and IoT-based monitoring systems for enhanced fire protection performance

General conclusion

General conclusion

At the conclusion of this end-of-study field exercise, we evaluated the effectiveness of the automatic CO_2 extinguishing system and were able to adapt the automatic extinguishing system to comply with the required standards and recommendations.

All the tasks associated with this project were completed in a period of 30 days, during which we were able to:

- Gain the necessary knowledge and insight into how the fire protection system works;
- Conduct a thorough field inspection of the equipment dedicated to the system;
- Submit a technical proposal that enhances the effectiveness of the CO_2 automatic extinguishing system.

This internship is of great importance both in terms of enhancing technical skills and building professional relationships. It gave us the opportunity to apply the theoretical knowledge gained during our academic career and confirmed our future desire to work in the field of Health, Safety and Environment (HSE), although we realize that we are still at the beginning of the road and need more learning and development.

Bibliography

1. European Solvents Industry Group (ESIG). (2013). Flammability: A safety guide for users (Version 3). Brussels: ESIG. https://www.esig.org
2. Firetrace USA LLC. (2003). Design, installation, operation and maintenance manual for pre-engineered automatic indirect FM-200 clean agent extinguisher unit (Models ILP-300, ILP-600, & ILP-1200) (Rev. 6, April 23, 2004). Firetrace USA. https://www.firetrace.com
3. FM Global. FM Global Data Sheet 4-12: Fire Protection Systems. FM Global, 2020.
4. International Organization for Standardization (ISO). (n.d.). About us. https://www.iso.org/about-us.html
5. International Organization for Standardization (ISO). ISO 7240-20: Fire detection and alarm systems – Part 20: Requirements for flame detectors. ISO, 2020.
6. National Fire Protection Association (NFPA). (n.d.). Codes and standards. https://www.nfpa.org/codes-and-standards
7. National Fire Protection Association (NFPA). NFPA 10: Standard for Portable Fire Extinguishers. NFPA, 2021.
8. National Fire Protection Association (NFPA). NFPA 11: Standard for Low-, Medium-, and High-Expansion Foam. NFPA, 2021.
9. National Fire Protection Association (NFPA). NFPA 72: National Fire Alarm and Signaling Code. NFPA, 2022.
10. National Fire Protection Association (NFPA). NFPA 72: National Fire Alarm and Signaling Code. NFPA, 2022.
11. Rapport de stage Raffinerie SBAA d'Adrar 2023\2024
12. Sonatrach. (2022). Présentation Sonatrach [PDF]. https://sonatrach.com/wp-content/uploads/2022/12/Presentation-SH-Fr.pdf
13. Underwriters Laboratories (UL). UL 864: Control Units and Accessories for Fire Alarm Systems. UL, 2021.
14. Ziden , ahmed & bensalah,imed eddine Evaluation des performances de système extinction automatique à gaz CO2 2017- 2018

الجمهورية الجزائرية الديمقراطية الشعبية
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Université de Ghardaïa
Faculté des Sciences et de la Technologie

قسم :الآلية والكهروميكانيك

شعبة : طاقات متجددة
تخصص: طاقات متجددة وبيئة - مهني

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شهادة ترخيص بالتصحيح والايداع:

انا الاستاذ(ة) بكار بلقاسم
بصفتي المشرف المسؤول عن تصحيح مذكرة تخرج (ليسانس/ماستر/دكتورا) المعنونة بـ:

Design and Technical Analysis of an Automatic Fire Extinguishing System

من انجاز الطالب (الطلبة):

صوفي عبد الرحمان
بخوتي عثمان
التي نوقشت بتاريخ : 21 ماي 2025

اشهد ان الطالب/الطلبة قد قام /قاموا بالتعديلات والتصحيحات المطلوبة من طرف لجنة المناقشة وقد تم التحقق من ذلك من طرفنا وقد استوفت جميع الشروط المطلوبة.

امضاء المسؤول عن التصحيح

مصادقة رئيس القسم

جامعة غرداية
قسم الآلية والكهروميكانيك
كلية العلوم و التكنولوجيا
رئيس قسم الآلية والكهروميكانيك
عـزاوي محـمـد