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Performance evaluation of safety barriers for storage station (HBK case)

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All praise be to God who supported me during my educational path first and foremost.

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To all my brothers and sisters; my relatives, my female relatives, and the entire family.

To all my friends, close to my heart, and everyone who had a good touch in my life.

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DEDICATE

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Aya …

Somary

Somary

Abstract

Abstract

الترجمة

تعتبر السلامة المهنية أمر ضروري في كل مؤسسة، ومن أجل تحقيق ذلك يتم وضع حواجز أمان فعالة. لتحديد هذه الحواجز، من الضروري تطوير نهج كمية، كيفية أو شبه كمية.

هدف عملنا الأساسي هو تقييم أداء حواجز السلامة لوحدة تخزين البترول باستخدام تقنيات مختلفة. طبقنا طريقة HAZOP لتحديد سيناريوهات الحوادث المحتملة.بعد ذلك تم تحققنا من قبول هذه السيناريوهات باستخدام طريقة LOPA. تمثل هذه التقنية حلا عمليا وبسيطا للغاية لتحديد الاحتياجات من حيث حواجز الأمان.

الكلمات المفتاحية: حاجز أمان ; تخزين ; SIS;LOPA;أداء.

RESUME

La sécurité au travail est essentielle dans toute organisation, et pour y parvenir, des barrières de sécurité efficaces sont mises en place.

Pour identifier ces barrières, il est nécessaire de développer des approches quantitatives, qualitatives ou semi-quantitatives.

Notre principal objectif de notre travail est d'évaluer la performance des barrières de sécurité des unités de stockage de pétrole à l'aide de différentes techniques.

Nous avons appliqué la méthode HAZOP pour déterminer les scénarios d'accidents possibles, puis nous avons vérifié l'acceptabilité de ces scénarios à l'aide de la méthode LOPA. Cette technologie représente une solution très pratique et simple pour identifier les besoins en terme de barrière de sécurité.

Mots-clés : performance ; SIS ; LOPA ; stockage ; barrière de sécurité.

ABSTRACT

Occupational safety is essential in every organization, and in order to achieve this, effective safety barriers are put in place.

To identify these barriers, it is necessary to develop quantitative, qualitative or semi-quantitative approaches.

Our primary work objective is to evaluate the performance of petroleum storage unit safety barriers using different techniques.

We applied the HAZOP method to determine the possible accident scenarios. Then, we checked the acceptance of these scenarios using the LOPA method. This technology represents a very practical and simple solution to identify needs in terms of security barrier.

Keywords: performance; SIS; LOPA; storage; safety barrier.

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Abbreviation

Abbreviation

ALARP	As low as reasonably practicable
ANSI	American National Standards Institute
ARAMIS	American Rheumatism Association
BF	Barrier Functions
BKH	Benkahla
CCF	Common Cause Failure
CCPS	Center of Chemical Process Safety
DRT	Derection du relations du travail
E/E/EP	Electrical/Electronic/Electronic programable
ETA	Event tree anlysis
FAA	Federal Aviation Administration
FP	Failure probability
GLA	Guellale
HAZOP	Hazard and Operability
HBK	HAOUD BERKAOUI
ICI	Imperial Chemical Industries
IE	Initiating event
IEC	International Electrotechnical Commission
IFRC	International Federation of Red Cross
IPL	independent protection layers
ISA	International Society of Automation
ISO	International safety organization
L.P.G.	liquefied petroleum gas
LOPA	Layer Of Protection Analysis
MIL-STD	Military standard
MOC	management of change
MORT	Management Oversight & Risk Tree
OHSAS	Occupational Health and Safety Assessment Series
OSB	Organizational safety barrier
OSHA	Occupational Safety and Health administration

Abbreviation

PFD	probability of failure on demand
PHA	International Federation of Red Cross
PSA	Public service announcement
RGA	Récupération du gaz associé
RNNS	Recurrent neural networks
RRF	Risk reduction factor
SIL	Safety Integrity Level
SIS	Safety Instrumented Systems
TRC	Transport par canalisation(Pipeline transport)
TSB	Technical safety barrier
UTG	Usine de traitement de gaz(gas processing plant)
PFD	Process functional diagram
TVR	tension of vapor red

General introduction

Millions of industrial accidents occur every year and both cause loss of time, effort, money and sometimes loss of some families whether the work injuries are disabling or miraculous, total or partial disability.

In addition to the human suffering and the decline witnessed by the institution in the technical, economic, financial and even political aspects Which proves the importance of industrial security in the industrial production system Which obliges organizations to respect security standards and laws to ensure the optimum level of security and risk control that depends on the effectiveness of designed safety barriers Which in turn requires an evaluation of their performance.

So a question is asked:

Are the designed barriers with a performance that allows ensuring an adequate level of safety and acceptable risks?

To answer this question, the following questions are asked:

What are the safety barriers?

What is the used approach to assess these barriers?

This work aims to answer the above questions using operational safety tools (Hazard Analysis Methods) Using the HAZOP (Risk Operability) method, which is a qualitative; It is concerned with design review to capture design issues which can lead to risks and then accidents and the LOPA (Layer Of Protection Analysis) method, a semi-quantitative analysis method used to assess the security barriers put in place and/or to be considered in order to achieve the security objective (level of acceptable risk or tolerable risk).

In our study, we chose the storage unit of the regional directorate of the HAOUD BERKAOUI to evaluate the performance of the safety barriers placed by using analysis methods that allow knowing the level of risk through which the safety barrier is evaluated, whether it is sufficient to justify the level of risk.

The SIS organization:

To accomplish this thesis, we propose a work consisting of two parts, theoretical and practical.

Theoretical section includes:

The first chapter: deals with general concepts about safety and related standards.

The second chapter: presents a theoretical study of safety barriers in terms of concept and performance, and discusses the methods that will help us in that.

General introduction

The applied part includes:

The third chapter: presents a general introduction to the regional directorate of the HAOUD BERKAOUI, as well as a presentation of the system that we will study.

The fourth chapter: we will apply the HAZOP, LOPA, and ETA methods in order to know the level of performance of the security barriers of the storage.

I. *General concepts*

ChapterI
General
Concepts

I. General concepts

I.1 Introduction

Industrial establishments use modern technologies in order to raise productivity in a short period of time, including industrial machinery and equipment whose use requires energy sources, which increased the hazard rate.

Exposure to these hazards increases the possibility of risks that must be continuously monitored and controlled through safety techniques and systems such as Safety Instrumented Systems (SIS) in order to avoid accidents based on legal standards and references.

Safety Instrumented Systems (SIS) are one of the most commonly used methods of reducing the risks associated with major accident hazards in the process and other sectors[1]..... So, in this chapter, we will look at clarifying some concept: hazard, risk, risk management, risk reduction, safety instrumented system, safety, standards and regulations.

I.2 Definitions

I.2.1 Hazard

The term hazard is defined in the **OHSAS18001**as: “source or situation with a potential to cause harm in terms of injury or ill health, damage to property, damage to the workplace environment or a combination of these”[2].

A hazard is defined in Federal Aviation Administration **(FAA)** as a “condition, event, or circumstance that could lead to or contribute to an unplanned or undesirable event”[3].

There are several sources of definition of risk in different formats, but the content remains the same, where the importance lies in the effective management, identification of hazards and how to control them.

Based on unexpected release theory and hazards with different effects on accident developments, hazards resources can be categorized into two types: inherent hazards and controllable hazards[4].

Inherent hazards: are hazards that are an inherent part of a job or process and cannot be eliminated. These hazards can include physical, chemical, biological, and radiological hazards. Examples of inherent hazards include working at heights, working with hazardous chemicals, and operating heavy machinery. Inherent hazards can be managed through the use of control measures, such as engineering controls, administrative controls, and personal protective equipment[4].

Controllable Hazards: Controllable hazards are hazards that can be eliminated or controlled through effective management practices. These hazards can include ergonomic hazards, psychosocial hazards, and hazards related to workplace culture and behavior. Examples of controllable hazards include inadequate lighting, lack of training, and workplace bullying. Controllable hazards can be managed through effective risk management practices, such as hazard identification, risk assessment, and control measures[4].

I.2.2 Risk :

I.2.2.1 Risk defenition

Risk is the probability that an event will occur. The probability of damage occurring as a result of a target (employee, company, environment including population...) being exposed to hazard[5].

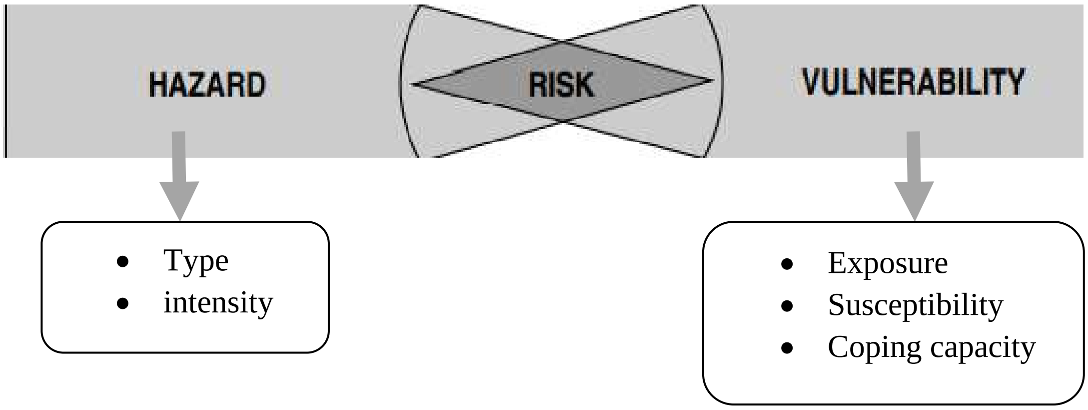

Figure 1 Risk as result of the interaction of the hazard and the vulnerability

Risk is characterized by the combination of the probability of occurrence of an accident and the severity of its consequences (figure 1 [6]).

I.2.3 Risk management

Risk Management is a process that identifies and evaluates any emerging threats or risks, whether internal or external.

According to ISO 31000:2018, there are essential steps of risk management Risk identification, risk analysis, risk evaluation, risk treatment, risk monitoring, communication and consultation and establishing the context[7].

I.2.3.1 Establishing the context:

In context establishment, several necessary risk assessment arrangements are needed, which consist of a risk management approach, risk evaluation criteria, impact criteria, and risk acceptance criteria.

I.2.3.2 Risk Communication:

Effective communication is crucial in risk management. It involves sharing information about risks, their potential impacts, and the actions being taken to address them with relevant stakeholders. Clear and timely communication helps in creating awareness, obtaining necessary support, and fostering a risk-aware culture within the organization[7].

I.2.3.3 Risk Identification:

Risk Identification: a). Threat Source Identification; b). Threat Event Identification; c). Vulnerability Identification[8].

I. General concepts

Identify situations, potential risks that could affect the organization (this risks can be internal (e.g., operational failures…) or external (e.g., natural disasters…)) and events (hazards/threats/opportunities/ vulnerabilities/) that can affect the activity considered and objectives defined. Many methods have been developed for this task, including checklists, HAZOP[9]…. .

I.2.3.4 Risk Analysis:

Risk analysis is an important stage in risk management. Risk analysis involves examining the causes and potential outcomes of each identified risk. In determining the risk level, it is necessary to have a matrix which then will be used to help in understanding the underlying factors contributing to the risk and the potential areas of vulnerability within the organization[8].

Risk Analysis depends on: a) Determining the likelihood in the risk scenario; b) Determining the impact on the risk scenario[8].

I.2.3.5 Risk Evaluation:

In this step, risks are evaluated based on their significance and prioritized accordingly. Risks that pose a high level of impact or likelihood are typically given more attention and resources. Examples as follows: 4risk scenarios high (priority), 20 moderate (second priority), 15 low (last priority), and 3 very low (no priority)[8].

Risk evaluation depends on: a). Determining the level of information security risk; b). Determining risk priority[8].

I.2.3.6 Risk Treatment:

Risk treatment involves developing and implementing strategies to manage or mitigate identified risks. Risk treatment options may include risk avoidance (eliminating the risk altogether), risk reduction (implementing controls to minimize the risk), risk transfer (such as purchasing insurance), or risk acceptance (where the organization consciously accepts the risk)[7].

I.2.3.7 Risk Monitoring:

Risk management is an ongoing process, and risks need to be continuously monitored to ensure the effectiveness of risk treatment strategies. Regular reviews help in identifying new risks, evaluating the performance of existing controls, and making necessary adjustments to the risk management plan[10].

I.2.3.8 Risk Reporting:

Regular reporting on risk management activities provides stakeholders with an overview of the organization's risk profile, ongoing efforts to mitigate risks, and progress in achieving risk management objectives. Reporting also helps in meeting regulatory requirements and demonstrating compliance with industry standards[7].

I.2.4 Risk reduction

A series of controls are put in place to continuously monitor and regulate the severity of the impact, probability, and potential for risks in order to mitigate and reduce the risks, including:

I.2.4.1 Preventive Controls

These measures aim to prevent risks from occurring in the first place. They involve implementing safeguards, policies, and procedures to minimize the likelihood of risks and their potential impact[10].

I.2.4.2 Detective Controls:

These controls focus on detecting risks or incidents after they have occurred. They involve monitoring and surveillance systems, audits, and inspections to identify and address risks in a timely manner[10].

I.2.4.3 Corrective Controls:

These controls are designed to correct or mitigate risks once they have been identified. They involve taking actions to eliminate or reduce the impact of risks, such as implementing remedial measures, conducting investigations, and making necessary adjustments to prevent future occurrences[10].

I.2.4.4 Administrative Controls:

These controls focus on organizational policies, procedures, and practices to manage risks. They include measures such as training and education, effective communication channels, clear responsibilities and accountabilities, and the establishment of risk management frameworks[10].

I.2.4.5 Technical Controls:

These controls involve the use of technology, systems, and tools to manage risks. Examples include access controls, encryption, firewalls, intrusion detection systems, and other security measures that help protect information, systems, and physical assets[10].

I.2.5 ALARP as low as reasonably practicable or as low as reasonably attainable/achievable:

The ALARP approach developed formally in the UK. It was a major innovation in the management of risks for potentially hazardous industries. The ALARP approach requires that risks between the upper limit of risk that can be tolerated in any circumstances and a lower limit below which risk is of no practical interest must be reduced to a level `as low as reasonably practicable[11].

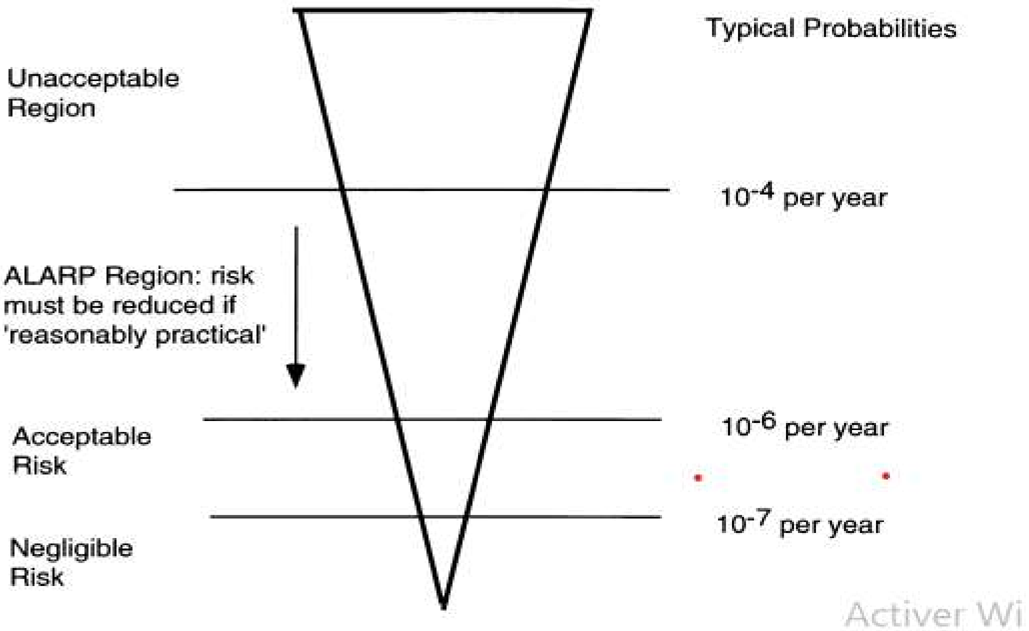

Figure 2 tolerable risk and ALARP

I.2.6 SAFETY INSTRUMENTED SYSTEM (SIS):

Safety Instrumented Systems instrumented system used to implement one or more safety instrumented functions[12]. (SIS) are one of the most commonly used methods of reducing the risks associated with major accident hazards in the process and other sectors[13].

An SIS is composed of any combination of sensor, logic solver, and final elements[12].

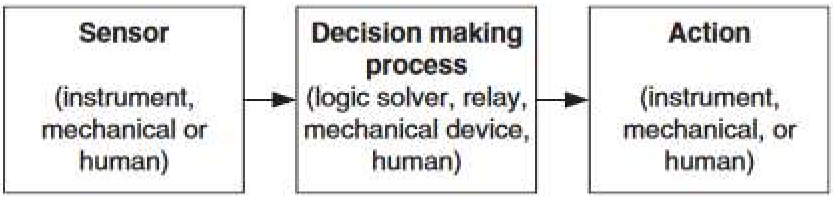

Figure 3 Basic elements of SIS

I.2.7 SAFETY

Is defined as the condition of being protected against physical harm or loss[14]. Safety as defined in MIL-STD is "freedom from those conditions that can cause death, injury, occupational illness, damage to or loss of equipment or property, or damageto the environment"[14].

I.2.8 STANDARDS AND REGULATIONS

The security of people and equipment is a very significant aspect in economic and industrial facilities in particular. As it became very concerned with the safety of people, equipment and the environment.Occupational Health and Safety is regulated by OHSA while until now the technical aspects were governed by ANSI/ISA S84 - 1996.

ANSI/ISA S84 – 1996 : “Application of Safety Instrumented Systems for the Process Industries”[15].

IEC 61508 : is a global system developed containing directives and principles leading to improve the functional safety of Electrical, Electronic and Programmable Safety (E/E/PE) systems[16].

IEC:61511. (2002): Focuses on Functional Safety - Safety systems equipped to the process industry[15].

IEC 62340: “Nuclear Power Plants - Instrumentation and Control Systems Important to Safety - Requirements for Coping with Common Cause Failure (CCF)”[17].

ISO 13702. (1999) :“Petroleum and natural gas industries—Control and mitigation of fires and explosions on offshore production installations Requirements and guidelines”[18].

ISO17776. (2000):“Petroleum and natural gas industries—Offshore production installations—Guidelines on tools and techniques for hazard identification and risk assessment”[18].

ISO 19353 (2019): “Machine Safety - Preventive Fire Protection and Protection”[17].

EN 62682 (2015): “Management of alarms systems for the process industries”[17].

ISO 13577-4 (2014):” Industrial furnace and associated processing equipment - Safety - Part 4: Protective systems”[17].

ISO 12100(2012):“Safety of Machinery - General Principles for Design - Risk Assessment and Risk Reduction”[17].

I.3 CONCLUSION

This chapter includes a set of important basic concepts related to occupational safety that help to achieve it. It also includes the process of risk analysis, standards and important regulations that help achieve occupational safety and security in order to protect workers, equipment and the environment. These standards and regulations guarantee the effectiveness of safety barriers by ensuring the proper functioning of their evaluation process and the methods used for that in accordance with international standards, and this will be mentioned in the next chapter

ChapterII
Performance evaluation of safety barriers

II. Performance evaluation of safety barriers

II.1 Introduction

Safety barriers have been used to protect humans and property from enemies and natural hazards. When man-made hazards were created by the industry, safety barriers were implemented to prevent accidents caused by these hazards[18].Energy theory was introduced by Gibson and developed by Haddon with ten accident prevention strategies. There are three elements in the Energy Theory: energy source, barrier and vulnerable target Safety barriers also play an important role in the Management Oversight & Risk Tree (MORT) concept[18].

II.2 Definition of safety barriers

The safety barrier and similar terms like defense, layer of protection, safety function, safety critical element, and safety system are impediments between the sensitive element to be protected and the hazard to prevent, control, or mitigate undesired events or accidents.

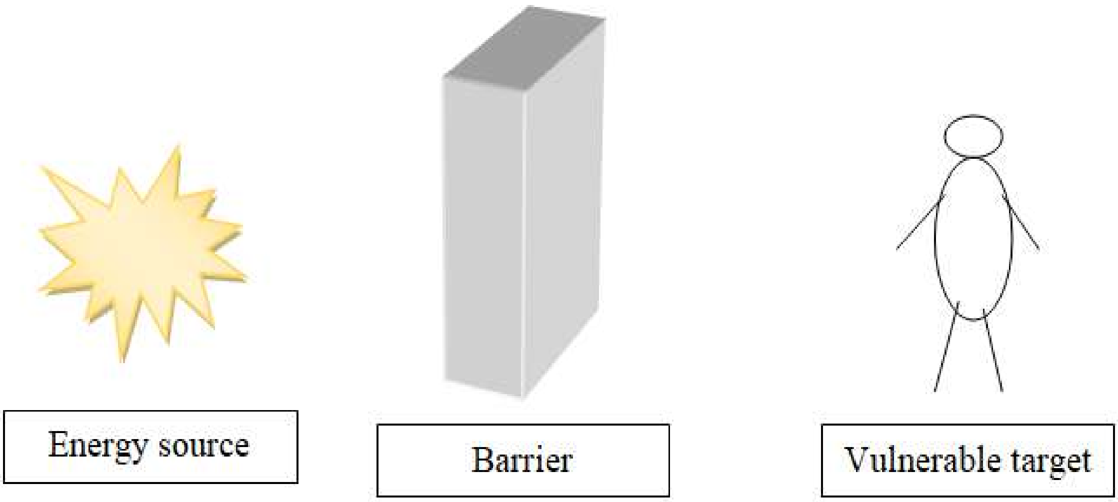

Figure 4 Safety barrier function

II.2.1 Classification of safety barriers

II.2.1.1 Classification of barrier functions (BF)

There are several divisions of the functions of safety barriers, but Commonly, barrier functions are classified as **preventing**, **controlling**, and **mitigating**(IEC:61508, IEC:61511, ISO:13702).Barriers intended to work before a specific initiating event takes place serve as a means of **prevention**.

They are supposed to ensure that the accident does not happen, or at least to slow down the developments that may result in an accident[18].

II. *Performance evaluation of safety barriers*

Barriers intended to work after a specific initiating event has taken place, serve as means of **protection**, and are supposed to shield the environment and the people in it, as well as the system itself, from the consequences of the accident[18].

The **control** function aims at limiting the deviation from a normal situation to an unacceptable one[18].

ARAMIS also proposes another classification of barrier functions: **avoid**, **prevent**, **control**, and **protect. Avoid** function aims at suppressing all the potential causes of an event by changing the design of the equipment or the type of product used. [18]

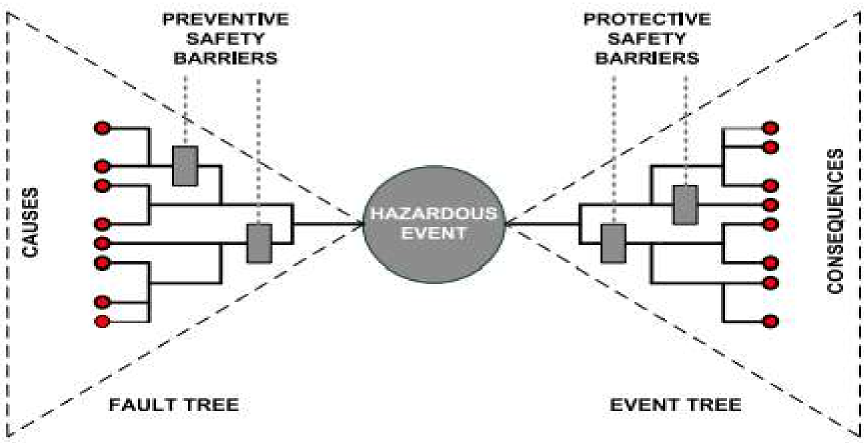

Figure 5 safety barriers function

The accident sequence				
Normal condition	Initial phase	Concluding phase	Injury phase	
Lack of control	Loss of control	Energy exposure		
Prevent		Protect		(Hollnagel, 2004)
Prevent	Control		Mitigate	(IEC 61508/11 ISO 13702
Avoid / Prevent	Control		Protect	(Duijm et al., 2004)

Figure 6 Generic safety functions related to a process model

II.2.1.2 Classification of barrier systems

II.2.1.2.1 Technical barriers (TSB):

Technical barriers depend on technological measures to prevent accidents and mitigate their consequences. [19]

Technical barriers are subdivided into:

Passive barriers: These have the capability of preventing risks during an entire system life cycle, with no need of human interactions or energy and information sources. Passive barriers may constitute physical barriers (such as a retention wall) or permanent barriers (such as corrosion prevention systems) or intrinsic safety design.[19]

Active barriers (Positive): These barriers must be automated or manually activated to operate or are mechanical and need to be activated by hardware/software to function. These included emergency shutoff valves, automatic interlocking devices ...ext.[13]

Detection barriers (SIS): The barriers detect and monitor potential risk events and send information to trigger other barriers. Detection barriers cannot prevent and protect against accidents. An example would be a flammable gas detector[19].

II.2.1.2.2 Organizational barriers(OSB):

Organizational barriers can be installed through a sound management program.[19]. Examples include compliance with on-site prevention codes, periodic inspections, preventative maintenance, and permit-to-work[19].

II.2.1.2.3 Human barriers:

The purpose of personnel barriers is to apply human knowledge and control to prevent improper behaviors in a safety system to reduce accidents[19].

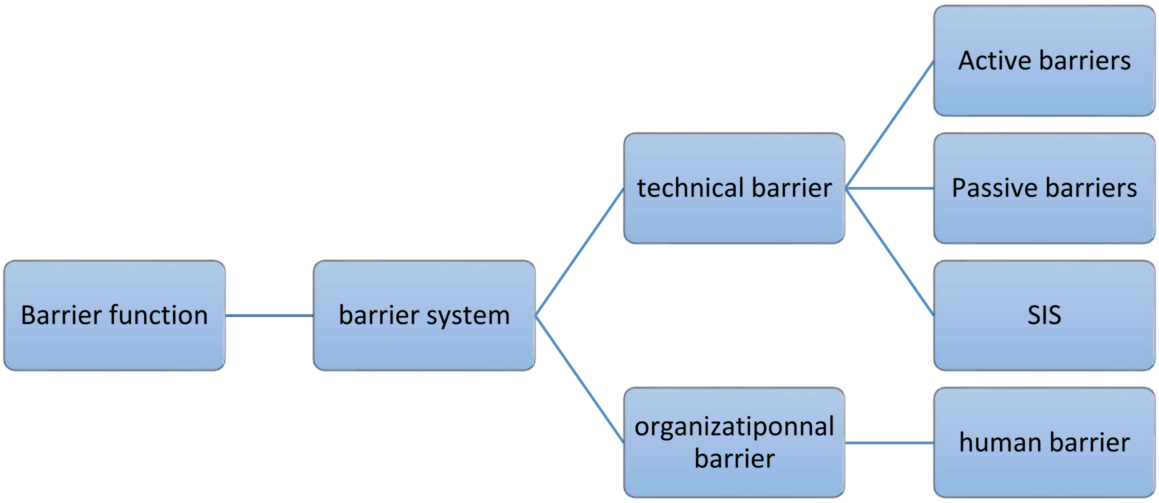

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Figure 8 Safety barriers classification

II. *Performance evaluation of safety barriers*

II.2.2 Operating modes of safety barriers

II.2.2.1 Operating mode on solicitation

The barrier alters its state to secure the system. In this instance, the failure rate on demand and the probability of failure on demand (PFD) of interest. One example would be the closure of a valve upon the discovery of a gas leak[20].

II.2.2.2 Continuous operating mode

In this case, we are interested in the failure rate and the probability of failure of the barrier related to a unit of time (failure rate/h or probability/year)[20].

II.2.3 Performance of safety barriers

A set of issues related to the analysis of barriers are addressed in the investigation of any accident caused by the initiating event, where the identification of failed, missing or functioning barriers is an important part of this process, as follows:

- Barriers that were in place and how they performed.
- Barriers that were in place but not used.
- Barriers that were not in place but were required[18].

The assessment of barrier performance is manageable in accident investigations where a specific event sequence already has occurred. The analyses of expected barrier performance are a vital part of the risk analyses. There are several divisions of the functions of safety barriers[18]. According to ARAMIS:

Effectiveness: Effectiveness of a safety barrier is the ability of a safety barrier to perform a safety function for a duration, Effectiveness of a safety barrier is the ability of a safety barrier to perform a safety function for a duration, in a specified conditions ,it is either a **percentage**(it may vary during the operating time of the safety barrier, for example, a valve that close completely on a safety demand will have an effectiveness of 100%), or a probability of the performance of safety function[18].

Response time: Response time is the duration between the straining of the safety barrier and the complete achievement (which is equal to the effectiveness) of the safety function performed by the safety barrier[18].

Level of confidence: Level of confidence of safety barriers the probability of failure on demand to perform properly required safety function according to a given effectiveness and response time under all the stated conditions within a stated period of time. This notion is similar to the notion of Safety Integrity Level (SIL)[19].

II. *Performance evaluation of safety barriers*

Table 1 safety barriers performance[18]

PSA (2002)	• Capacity, • Reliability, • Availability, • Efficiency, • Ability • Integrity • Robustness
(PSA/ RNNS)	• Functionality /efficiency • Availability/ reliability
Hollnagel (1995)	• Efficiency or adequacy • Resources required • Robustness (reliability) • Delay in implementation • Applicability to safety critical tasks • Availability • Evaluation
Snorre Sklet Recommendations	• Functionality/effectiveness • Reliability/availability • Response time • Robustness • Triggering event or condition

II.2.4 Performance evaluation of safety barriers

Whatever the security, technical, instrumental or human barrier, its performance is subject to degrading over time when no verification or monitoring is in place[20].

Maintaining the performance of these barriers over time must be ensured by the implementation of appropriate maintenance and inspection, and by carrying out periodic operating tests[20].

As for the barriers requiring human intervention, their performance is maintained by acting on the human factor through awareness-raising and training in industrial safety, in particular the use of extinguishing means and simulation exercises[20].

The motivation and the physical and moral state must be taken into consideration. Performance of safety barriers, an indicator of good control of the risks of an industrial process[20].

II.2.5 Methods used for the performance evaluation of safety barriers

In order to evaluate the performance of safety barriers, qualitative, semi-quantitative and quantitative analysis methods are used, the application of these methods depends on the objectives of the study and the data available.

II. ***Performance evaluation of safety barriers***

II.2.5.1 Presentation of the HAZOP (Hazard and Operability method:

II.2.5.1.1 HAZOP terms and definitions

Table 2 HAZOP terms

Guide words	Word or phrase that expresses and defines a specific type of deviation from a design intent of a property[21].
Parameter	Specific variable or characteristic of a system, process, or equipment that is being analyzed. Parameters can include various physical, chemical, operational factors that influence the behavior and performance of the system[21].
Deviation	Situations where a parameter or a combination of parameters deviates from its intended or expected value, condition, or behavior. These deviations are examined to identify potential hazards or operational issues[21].
Node	A section into which the system or process is divided for detailed review (a pipe section, vessel, step of a procedure for batch processes, etc.). The intended function and operation of each node can be adequately defined[21].

II.2.5.1.2 History and field of application

HAZOP is a risk study technique, which explores the effects of any deviations from the design and detects possible hazards that may occur in systems that manage highly hazardous materials[21].

It has its origins in the **1970s**, developed by the Imperial Chemical Industries **(ICI)** by engineers in the UK, but it really **became a standard** after an **explosion** in a chemical plant producing nylon intermediate in the United Kingdom that killed 28 people and injured dozens of others[21].

This is due to the need to properly handle the ongoing management of change (MOC) within the system to implement modifications and improvements. It continued to be applied in various sectors such as the chemical and **petroleum industries[21]**.

The identification of hazards is fundamental to ensure the safe design and operation of a system to eliminate any cause leading to major accidents such as explosion[21].

HAZOP is the focus of much of the research to improve the safety of chemical plants that encompass increasingly more complex and sophisticated processes[21].

II.2.5.1.3 Principal of HAZOP

The goal in a **HAZOP** study is to identify all aspects of design intent for which deviations may result in scenarios within the scope and objectives of the study**. HAZOP** studies focus on investigating **deviations[22].**Deviations are **potential problems**, for example, lack of flow in a transfer line or over pressuring a storage tank. Deviations are generated by applying **guide words**(More, Less, No….) to process **parameters**(Pressure, Temperature, Flow…)[22]**.**

Guide words + parameter = deviation[22].

for example High +Pressure =High Pressure[22].

The **HAZOP** study team chooses appropriate parameters for each **node**. The use of guide words with parameters provides the opportunity to explore deviations, thus helping to ensure completeness of scenario identification. A qualitative estimate is made of the severity and probability of the consequences of the scenario so that an estimate of the risks can be produced to help reduce them[22].

Table 3 HAZOP table

Node	Deviation		Causes	consequences	Evaluation			Safe guards	Evaluation			protection	Recommendations
	Guide-word	parameter			P	S	RR		P	S	RR		

II.2.5.1.4 **Procedure of the HAZOP method**:

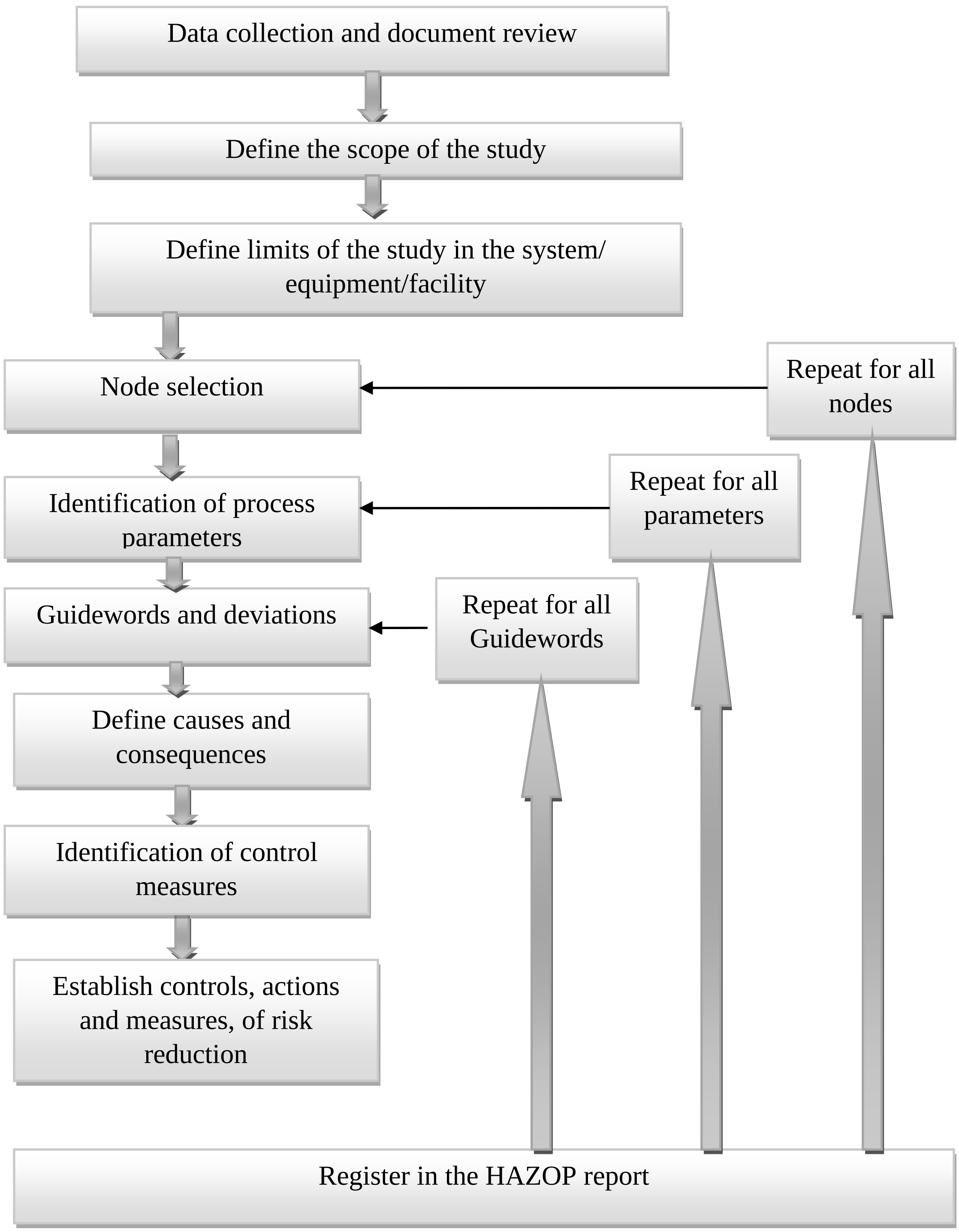

Figure 9 procedure of the HAZOP method[23]

II.2.5.1.5 Limitations and Benefits of the HAZOP method:

HAZOP is the most widely used PHA method in the world today due to its advantages[21]:.

II.2.5.1.5.1 Advantages of HAZOP

- Systematic and rigorous.
- Involves interaction of views from.
- Multidisciplinary experts.
- Can be applied to a wide range of types of system.
- Creates a detailed and auditable record of the hazards identification process[24].

However, it is not without its weaknesses[21]:

II.2.5.1.5.2 Limitations of HAZOP

- Requires a considerable amount of preparation.
- Time consuming[24].
- Novices may confuse the differences between guide-word, parameter, and deviation, leading to erroneous conclusions and reduced quality of HAZOP studies[21].

II.2.5.2 Presentation of the LOPA method:

II.2.5.2.1 LOPA terms and definitions

Table 4 LOPA terms

Initiating Event	The event or condition that initiates a hazardous scenario or sequence of events[25].
Risk Reduction Factor (RRF)	The factor by which the risk is reduced due to the combined effectiveness of all the independent protection layers.
Consequence.	The potential outcome or impact of a hazardous event, such as injuries, environmental damage, or financial losses[25].
Risk Tolerance Criteria	The predefined criteria or limits that indicate the acceptable level of risk for an organization or process.
Risk Acceptance	Risk Acceptance: The decision to accept a certain level of risk based on an organization's risk tolerance criteria and after considering the effectiveness of existing safeguards.
Frequency	The rate or probability of occurrence of an event, such as an initiating event or failure of a protection layer[25].
Layers of Protection	The various safety measures and safeguards implemented to prevent or mitigate the consequences of a hazard, typically including physical barriers, safety systems, alarms, emergency response plans, etc[25].
Safety Integrity Level (SIL)	A quantitative measure of the reliability and performance of a safety instrumented system (SIS) in reducing risk[18].

II.2.5.2.2 History and field of application

Adaptation of Layer of Protection Analysis (LOPA) began in the chemical process industry in the late 1990s[25].

Arthur Dowel land William Bridges, among others, began implementing the technique in their companies and consultancies as a method that captures the main concepts of independent protective safety systems, without requiring a high degree of quantitative analysis[25].

As the method became more widely used in the United States and Europe, guidelines began to be issued by the AICHE Center of Chemical Process Safety (CCPS)[25].

Other international agencies and codes such as the International Electro technical Commission (IEC) and International Society of Automation (ISA) began to reference LOPA as a semi-quantitative method for determining the required safety integrity level (SIL) for Safety Instrumented Systems (SIS)[25].

II.2.5.2.3 Principal of LOPA method

LOPA is typically applied **after qualitative** hazards analysis has been completed, which provides the LOPA team with a listing of hazard **scenarios** with associated consequence description and potential safeguards for consideration[26].

A LOPA program is most successful when a procedure is developed that sets the criteria for when LOPA is used and who is qualified to use it. A well-written procedure will also incorporate criteria for evaluation of initiating cause frequency and IPL probability to fail on demand (PFD)[26].

II.2.5.2.4 Procedure of the LOPA method:

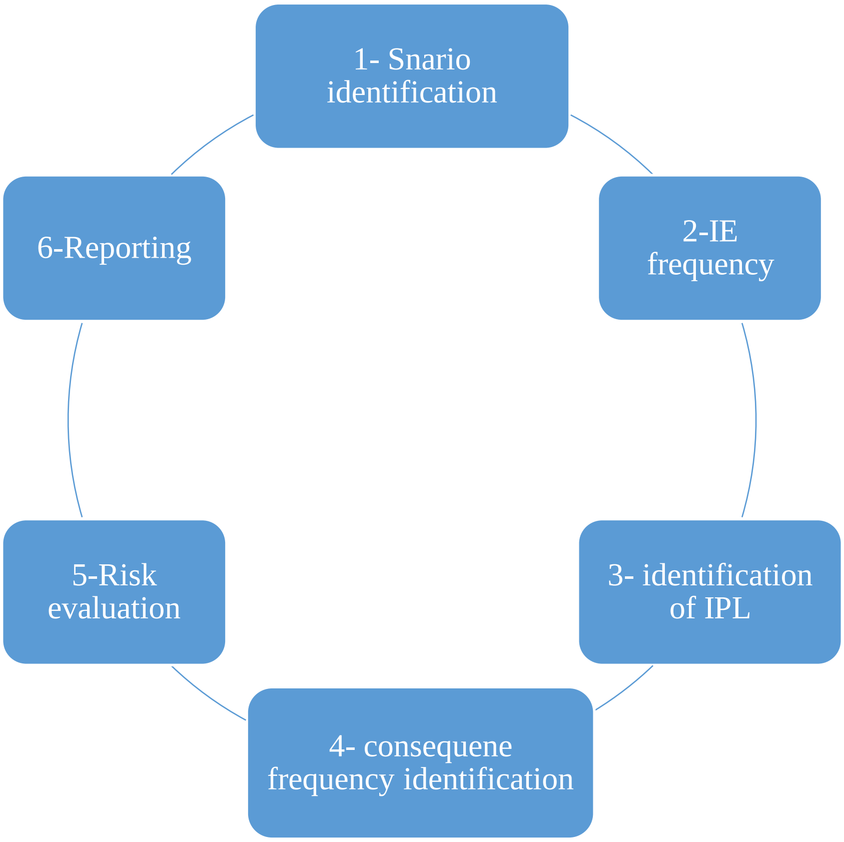

Figure 10 LOPA steps[25]

1. **Step1**: Determine the specific process scenario or hazard that will be analyzed using LOPA. This could be a specific event or deviation from normal operating conditions that may lead to undesirable consequences. Identify the initiating event or cause that could lead to the hazardous scenario. This could be a process upset, equipment failure, human error, or external event[25].
2. **Step2**: Estimate the frequency of the initiating event for the scenario[25].
3. **Step3**: Identify and list the independent protection layers that are already in place or are planned to mitigate the consequences of the initiating event. These can be engineering controls, safety instrumented systems (SIS), alarms, relief systems, safety procedures, or physical barriers. Estimate the probability of failure on demand for each independent protection layer. PFD represents the likelihood of a layer failing to perform its intended function when required. This estimation is based on historical data, industry standards, reliability analysis, or expert judgment[25].

4. **Step4**: Calculate the mitigated frequency of consequence occurrence by combining the initiating event frequency and the IPL probabilities. Calculate the Risk Reduction Factor for each independent protection layer by using the PFD values. The RRF is the inverse of the PFD and represents the level of risk reduction provided by each layer. It indicates how effectively the layer can reduce the risk of the hazardous scenario[25].

IPLs are extrinsic safety systems; they can be active or passive systems, as long as the following criteria are met:

- **Specificity:** The IPL is capable of detecting and preventing or mitigating the consequences of specified, potentially hazardous event(s), such as a runaway reaction, loss of containment, or an explosion[26].
- **Independence**: An IPL is independent of all the other protection layers associated with the identified potentially hazardous event. Independence requires that the performance is not affected by the failure of another protection layer or by the conditions that caused another protection layer to fail. Most importantly, the protection layer is independent of the initiating cause[26].
- **Dependability**: The protection provided by the IPL reduces the identified risk by a known and specified amount[26].
- **Audit ability:** The IPL is designed to permit regular periodic validation of the protective function[26].

5. **Step5:** Evaluate the risk of the scenario based on tolerable risk criteria. If needed to lower the scenario frequency and risk to a tolerable level[25].

Frequency	Consequence: Minor C1	Moderate C2	Serious C3	Catastrophic C4
F4. High	B	B	A	A
F3. Medium	C	B	B	A
F2. Low	D	C	B	A
F1. Remote	D	D	C	B

Figure 11 Risk matrix[27]

6. **Step6:**Continue to analyze all credible and significant scenarios or cause-consequence pairs[25].

II.2.5.3 Benefits of LOPA method

- LOPA is a simple approach, which needs less time and resources and is more rigorous than HAZOP.
- It improves the identification of scenarios by using the cause-consequence pairing from PHA studies.
- It helps to set the needed SIS (Safety Instrumented Systems), and SIL rating.

- It can be used as a Cost Benefit Analysis tool during choosing the process safety instrumentation.
- It is useful in decision-making based on risks during different stages like design, management of change, etc.
- It provides due credit to all protective layers and gives the accurate rate of the specific risk level of the unit/ equipment.
- LOPA supports compliance with process safety regulations - including OSHA PSM 1910.119, SEVESO II regulations, ANSI/ISA S84.01, IEC 61,508 and IEC 61511[28].

II.2.5.3.1 Limitations of LOPA

- Risk tolerance criteria must be determined for LOPA activity before the beginning of the process.
- It does not decide specific IPLs to be used and the decision is left to the user depending on his experience[28].

II.2.5.4 Presentation of the ETA (Event Tree Analysis) method:

II.2.5.4.1 History and field of application:

Event Tree Analysis was developed in the early 1970s for risk assessment of nuclear power plants.It is a technique for identifying and analyzing the frequency of hazards using inductive reasoning to convert different initiating events into possible consequences relating to the operation or failure of technical/human/organizational safety devices[29].

II.2.5.4.2 Principle of ETA method

ETA determines the probability of all the possible outcomes resulting from the occurrence of an IE.ETA determines the probability of all possible outcomes resulting from the occurrence of IE. By analyzing all possible outcomes and determining their percentage. To calculate the probability of consequences, the FP of each barrier should be quantified[30].

II.2.5.4.3 Procedure of the ETA method:

The Event Tree analysis takes place in several preliminary steps:

- **Defining the Initiating Event:** Identifying and clearly defining the event or condition that triggers the analysis. This event should be specific and well-defined[29].
- **Identification of the security functions planned to control its development:** The safety functions must be ensured by barriers aimed at preventing the materialization process of an accident caused by an initiating event[29].
- **Event Tree construction:** Creating a graphical representation of the event and its potential consequences using a tree-like structure. The initiating event is represented as the root node, and the subsequent consequences are represented as branches or nodes[29].
- **Description and exploitation of the sequences of events identified:** to examine the development of each branch by systematically considering the operation or failure of the safety function until a potential accident is reached. The propagation of the probabilities of occurrence of the initiating events makes it possible to calculate the probability of the feared event[29].

- **Analyze result reporting:** Review the event tree analysis results, assumptions, and calculations. Recommendations and feedback from experts and stakeholders to refine the analysis and ensure its accuracy and reliability[31].

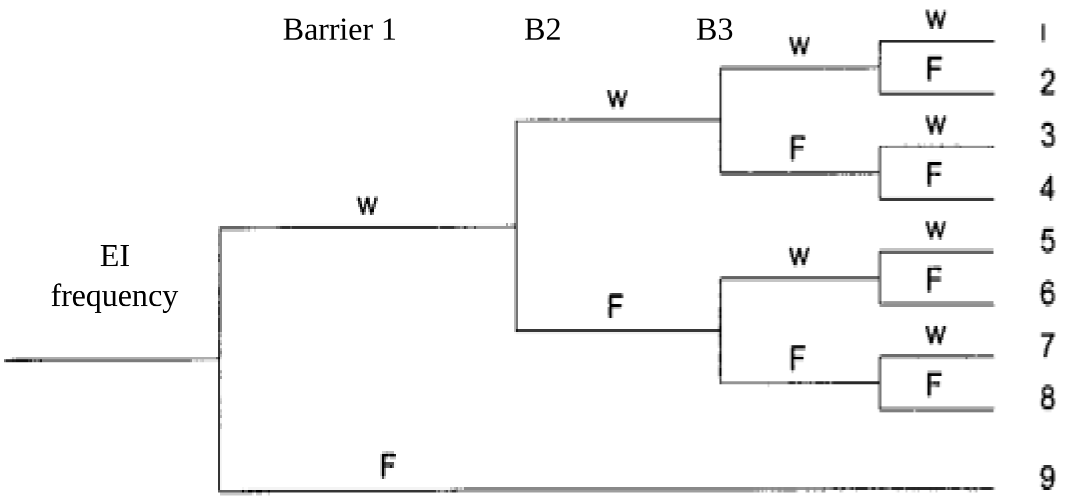

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Figure 12 Event tree[32]

II.2.5.4.4 Advantages of ETA method

- Provides a systematic coverage of the time sequence of event propagation to its potential outcomes or consequences[33].
- used as a design tool to demonstrate the effectiveness of protective systems[33].
- used for human reliability assessment(human error-rate prediction)[33].
- The ETA may be qualitative, quantitative, or both, depending on the objectives of the analysis. In quantitative risk assessment application, event trees may be developed independently or follow on from Fault Tree Analysis[33].

II.2.5.4.5 Limitations of ETA method

ETA relies on accurate and reliable data regarding the probabilities of events and their consequences. However, obtaining precise data can be challenging, especially for rare or complex events. Limited or inaccurate data can affect the reliability and accuracy of the analysis results[30].

II.3 Conclusion

In order to control the risks and avoid its negative consequences for the organization, the concept of the safety barrier was dealt with, its classification, and knowledge of its performance, which made us deal with the evaluation of the latter in order to know the extent of its effectiveness and the extent of the readiness of the safety barrier to carry out its function. This assessment, which is carried out through analysis methods, made us address the most important ones, which will help us in our next study (case HBK).

III. Presentation of the HBK region and the system studied

Chapter III

Presentation of the HBK region and the system studied

III. Presentation of the HBK region and the system studied

III.1 Introduction

The Haoud Berkaoui Regional Directorate is part of the Production Division of Sonatrach's exploration and production activity. The first oil treatment center was commissioned in 1967; today there are 5 oil treatment units and one gas treatment unit. The number of producing wells is 95, including 49 by gas lift for secondary recovery.

To improve recovery capacity, there are 28 water injection wells. The overall structure of the Regional Management revolves around administrative and technical functions under the direction and authority of the regional director.

III.2 Presentation of HBK direction

The HAOUD BERKAOUI Regional Management is part of the Production Division of SONATRACH's upstream activity.

The first oil treatment center was commissioned in 1967; today there are 5 oil treatment units and one gas treatment unit.

Each production center receives crude from various wells, stabilizes it, stores it in tanks before shipping it (to the TRC lines).The gas recovered from the stabilization is compressed and routed to the Guellala gas processing plant (UTG/GLA) which extracts LPG, sales gas and gas-lift from it.

The number of producing wells is 95, including 49 by gas lift for secondary recovery. To improve recovery capacity, there are 28 water injection wells.

The overall structure of the Regional Management revolves around administrative and technical functions under the direction and authority of the regional director.

HBK essentially consists of three main fields: HaoudBerkaoui, Guellala, Benkahla and several peripheral fields: Benkahla East, Guellala North East, DraaEtamra, Haniet El Mokta, Bab El Hattabat, Sahane, N'goussa and Mokh El Kebch.

III.2.1 Field layout

On the RN49 road, linking Ghardaia to HassiMessaoud, 35 km from Ouargla, a crossroads indicates the presence of an oil field. This is the HaoudBerkaoui Regional Directorate, located 772 km south of Algiers, 35 km northwest of Ouargla and 100 km west of HassiMessaoud.

III. *Presentation of the HBK region and the system studied*

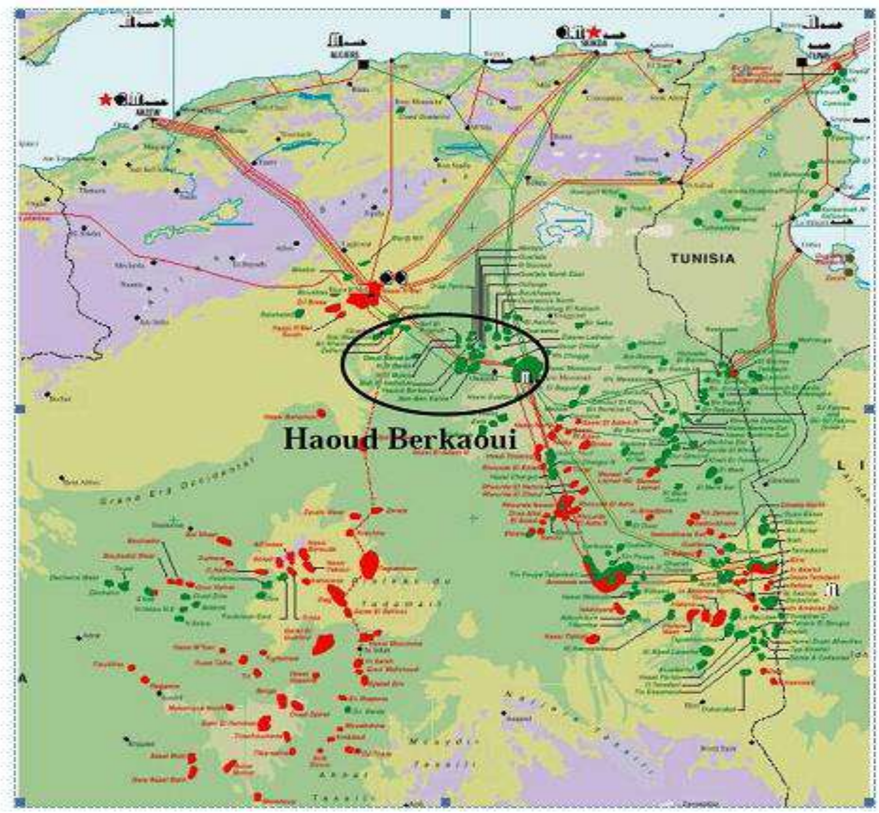

Figure 13 Field layout

III.2.2 History of the region

The region was managed by Hassi-Messaoud until 1977, the year in which it became autonomous.The geophysical studies carried out in the region of Ouargla made it possible to know the existence of two (2) structures called: Haoud-Berkaoui and Benkahla.

The first hole in the region was OA01 at Ouargla in 1963. It was in March 1965 that the first OK101 hole was drilled at the top of the Haoud-Berkaoui structure which located an accumulation of light oil with a density of 43° API (d=0.8) in the lower series (SI) of the clayey-sandstone Triassic (TAG) by the French Algerian oil company (CFPA). This drilling reached the Gothlandian at 3327.8m.

The production test carried out by the CFPA gave a flow rate of 11 m3/hour with a reservoir pressure of 520 kg/cm2 and a GOR of 101 m3/m3. This successful test was a promoter, it persuaded the producers to set up other wells around the structure, which made it possible to highlight other peripheral deposits.

The stages characterizing the development of the Regional Direction are:

- **1967**: Commissioning of the HBK oil treatment center (Discovered in March 1965, well OK 101).

III. *Presentation of the HBK region and the system studied*

- **1971**: Commissioning of the BKH oil treatment center (Discovered in November 66, OKP 24 well).
- **1976**: Commissioning of the GLA oil treatment center (Discovered in October 1969, GLA 02 well).
- **1977**: Creation of the HBK Regional Directorate.
- **1978**: Commissioning of the GLA/NE oil treatment center.
- **1979**: Commissioning of the DRT oil treatment center.
- **1987**: Attachment of the ONR sector to Hassi R'MEL.
- **1992**: Commissioning of the three flared gas compression stations of the CP/HBK, BKH and GLA (boosting) and of the UTG/GLA as well as the start-up of the gas-lift oil wells.
- **1993**: Commissioning of the new water injection stations HBK, BKH and GLA.
- **2000**: Commissioning of the three oil removal stations at HBK, BKH, and GLA and wastewater treatment plant.
- **2008**: Start of the associated gas recovery and re-instrumentation project (RGA Project).

III.2.3 Production of HBK

The HAOUD BERKAOUI region produces oil by natural depletion: it is the internal energy of the deposit which pushes the crude oil towards the surface under the effect of pressure. For pressure maintenance there is an injection of water in the three sectors HBK, BKH and GLA. For weak wells, production is ensured by gas-lift.

Types of wells:

- Producers without gas-lift.
- Producers with gas-lift.
- Water producers.
- Water injectors.

The connection of these wells is therefore carried out by group. The crude producing wells with or without gas-lift are connected and grouped together by set of wells called collector or manifold. These manifolds are collected, in addition to the wells that arrive individually, at the processing center.

In this center the crude passes through separators where it will get rid of water and gas. The water, in small quantities and of poor quality, is thrown away. The gas is collected. Freed from its liquids, the gas is compressed and then sent to the GUELLALA gas treatment unit. In this plant, the gas will be separated from light hydrocarbon particles by thermodynamic processes to obtain L.P.G. (liquefied petroleum gas on the one hand and dry gas on the other. The latter will be distributed over the three fields HBK, BKH and GLA .Where it will be served for gas-lift.

Similarly, water from wells, which produce water, is collected for each field in the centres. This water will be chemically treated against corrosion before being sent to the injection wells for pressure maintenance.

III. Presentation of the HBK region and the system studied

III.2.4 Administrative Presentation

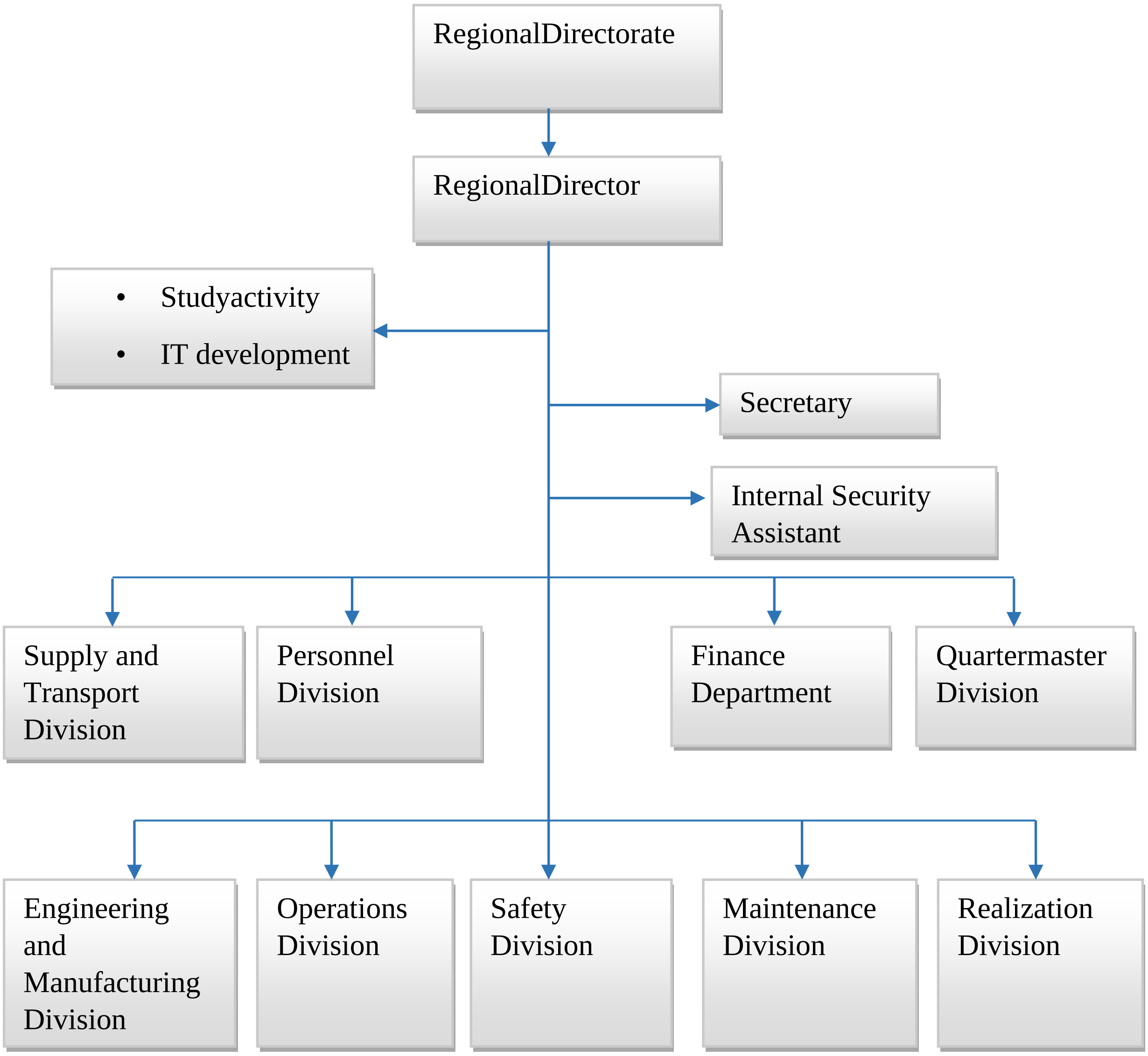

Figure 14 Organization chart of the Haoud Berkaoui Regional Directoration

III.2.5 Presentation of the security division

III.2.5.1 Main mission

Preserving the health of employees, safeguarding production facilities and protecting the environment.

Composed of:

- Prevention Service;
- Service Intervention;
- Environment service;
- Service Guellala;

III. *Presentation of the HBK region and the system studied*

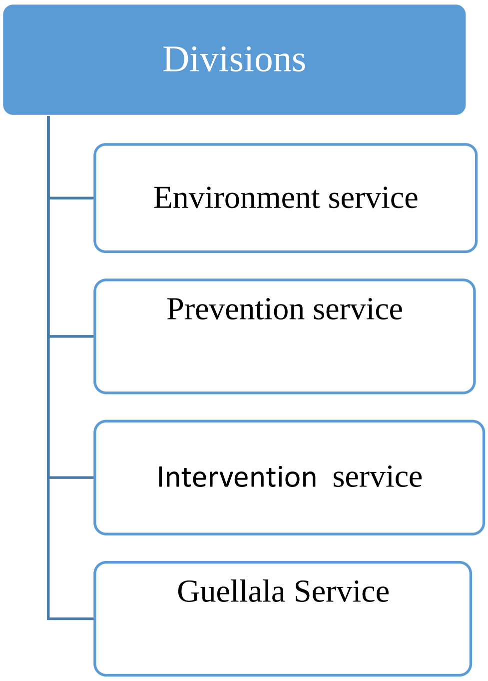

Figure 15 Division organisation chart

III.2.5.1.1 The role of the Prevention Service

- Work in collaboration with the other structures, with regard to new projects, modification work on the installations to give its opinion on the safety aspect in accordance with the standards and regulations in force.
- Recommend the various safety instructions during work (welding, handling, etc.)
- Attend the various tests of safety equipment on snubbing and drilling rigs.
- Organize staff awareness campaigns.
- Train staff in the use of first aid equipment.
- Establish monthly and annual reports relating to these activities and analyze the causes of accidents or incidents.
- Performs daily checks of equipment at production centers, construction sites and the various workshops of the Regional Department.
- Ensure the follow-up of the works in optimal safety conditions.
- Conduct facility security audits.
- Writing general and specific safety instructions.
- Work in collaboration with the occupational physician.
- Ensure the application of the various regulatory controls and inspections of equipment.

III.2.5.1.2 The role of the intervention Service

Its purpose is to intervene in the event of an alert, at the level of the Regional Management and to ensure the monitoring of the installations at the production center.

To accomplish his mission well, he is called to:

- Maintain and periodically check the equipment (motor pumps, rolling motor pump vehicles, fire protection network, etc.).
- Ensure preventive maintenance of protection systems.
- Hazardous work coverage.
- Establish information sheets for each person passing through and issue badges.
- Establish, update and apply intervention plans.
- Carry out periodic exercises on real or simulated fire in collaboration with the technical services or Civil Protection.
- Enforce general and specific safety instructions.

III.2.5.1.3 The role of the environment Service

The Regional Directorate of HBK is one of the first Regions that has made a lot of effort in terms of the construction of environmental protection infrastructures.

To this end, it should be noted that the HBK Regional Directorate has:

- Three (03) de-oiling stations intended to treat industrial liquid effluents generated by the three Production Centers: HBK, GLA and BKH.
- One (01) domestic wastewater treatment plant.
- One (01) Technical Landfill Center for the storage of household waste.
- One (01) storage area for ferrous and non-ferrous waste.
- One (01) inert waste storage area.

With regard to atmospheric emissions, once commissioned, the RGA project facilities will improve the recovery of associated gases.

The main tasks and missions assigned to the Environment Unit are:

- Identification of environmental aspects and sources of pollution.
- Evaluation of the intensity of the different types of pollution.
- Presentation of mitigation measures.
- Updating of regulatory monitoring in terms of environmental protection.
- Information and awareness dedicated to staff on topics related to environmental protection.

III.2.6 The HBK Production Center

The Haoud Berkaoui center is intended to produce oil from neighboring fields as well as gas harvesting, it consists mainly of six units:

- Separation unit;
- Unit of storage and shipping;
- Boosting unit;
- Oil removal unit;
- Water injection unit;
- Utility unit;

III. Presentation of the HBK region and the system studied

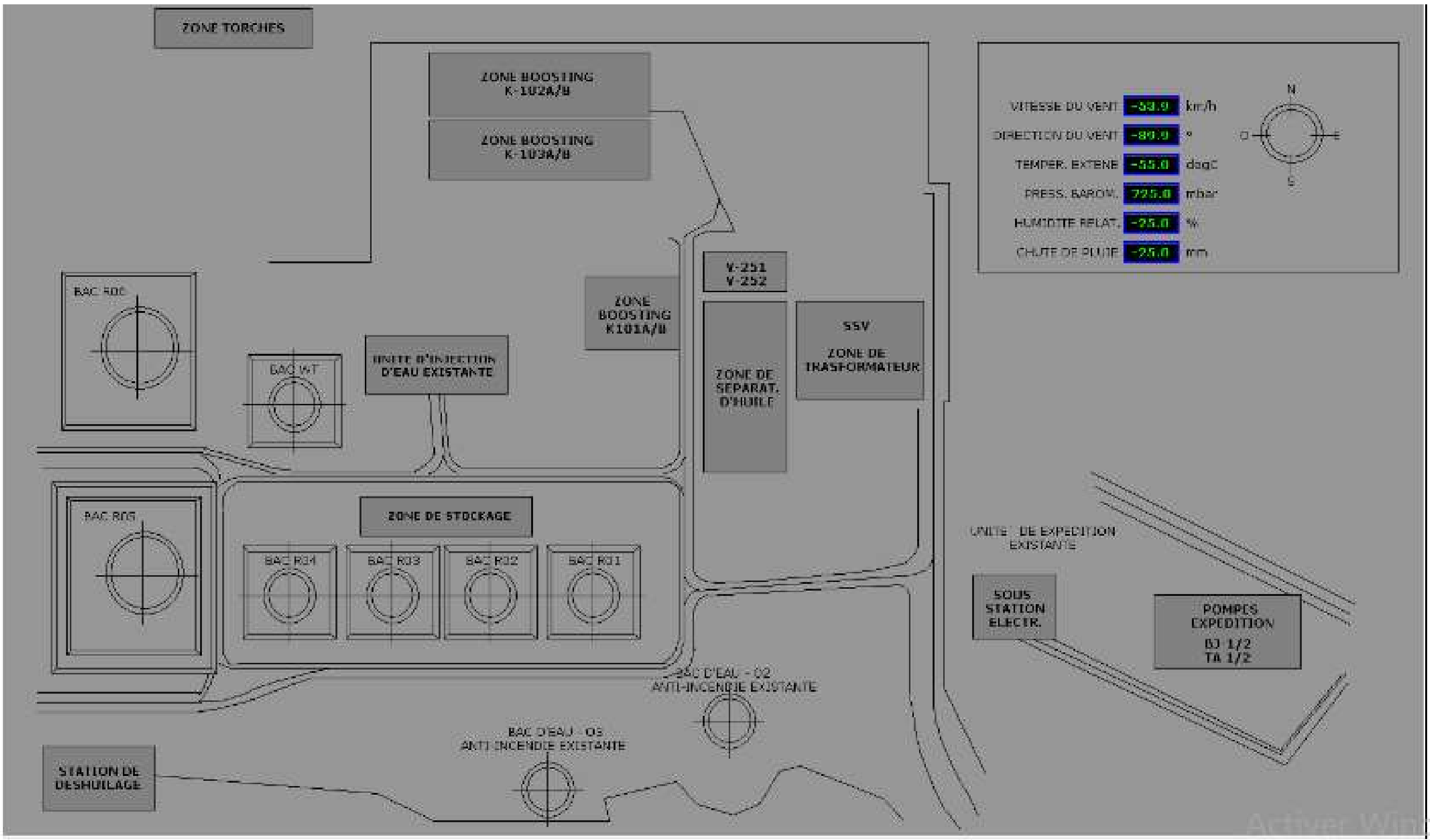

Figure 16 HBK zones

Among the HBK production center units we chose the storage unit to do our study.

III.3 Definition and general information on the storage of hydrocarbons:

The storage of hydrocarbons is a recurring management factor for many local authorities and public establishments.

The purpose of the most important storages is to ensure the operation of the heating devices of the premises of the community or the establishment.

In addition, many activities carried out by agents require the transport, use and storage of small quantities of petroleum products, in particular to ensure the operation of thermal engine work equipment: generator, brush cutter, hedge trimmer, chainsaw,

The main risks associated with fuel storage are the risk of fire, explosion or the risk of environmental pollution in the event of spillage of petroleum products in nature.

III.3.1 The purpose of Storage:

- putting the product to rest followed by a decanting operation before shipment
- Allows the collection of different oil fields in order to transport large quantities of product

- Allows continuity of production and operation while ensuring permanent storage
- Control the quality of the product shipped; allows natural degassing for the elimination of unwanted gases

III.4 The different atmospheric storage tanks:

There are 3 types of liquid hydrocarbon storage tanks:

- Fixed roof tanks;
- Floating roof tanks;
- Fixed roof tanks and floating screen;

III.5 Different types of accidents:

In a storage park you can face several types of accidents, such as:

- Flash fire;
- Pool fire;
- VCE (Vapor Cloud Explosion);
- BLEVE (Boiling Liquid Expanding Vapor Explosion);

III.6 Conclusion:

In this chapter, we dealt with a general introduction to the company in which we conducted our study, and then we talked about the warehousing process (its description, purpose, and storage units). This is as a prelude to applying HAZOP and LOPA to see if storage is done in safe storage units or not

Chapter IV
Application of HAZOP-LOPA-ADE methods

This chapter is devoted to the application of the LOPA method at the level of the HBK industrial zone (particularly on the "storage" system).
We will apply the LOPA method starting with a qualitative application of the HAZOP method to collect information on the system (R-06), ETA to present all the scenarios of the dangerous phenomena that can occur within the storage tank, then an application proper of the LOPA method.

IV.1 Structural and function description of the tank R06

IV.1.1 Description of the system studied "Petroleum storage tank R06 / CP.HBK"

The R06 tank, of the fixed roof type, is a cylindrical piece of equipment with a capacity of approximately 5000 m3. It was carried out to increase the oil storage capacity (at atmospheric pressure) at the Haoud Berkaoui production center. This equipment was installed by the MES Company in 2009 according to the “API 650” standard.

Table 5 technical information of R-06

Year of construction	2009
Made by	ALSIM Cosider
Mounted by	MES Spa
Calculated density	0,815
Nominal diameter	24m
Nominal height	10,81m
Nominal capacity	4880m^3
Material of construction	A.283.C
Operating temperature	80/-5 °C
Calculated Pressure	Atm
Partial annealing	No
Revision No.	/
Code used	API 650

Table 6 Tank R-06 main equipments

filling line (has two valves)	• MOV146: automatic valve • manual valve (guard valve)
A shipping line (has two valves)	• MOV156 : automatic valve • manual valve (guard valve).
Two purge systems	• Pipe 4" (inch). • Two manual valves (one of the valves is a guard valve). • a purging gaze

- An access ladder .
- Three manholes.

- A remote metering system.
- Four vents with flame arrestors.
- Four grounding connections.
- A cooling crown (For fire safety of the tank).
- Three foam chambers (For fire safety of the tank).
- Four foam overflow outlets (For fire safety of the tank).

Figure 17 Oil storage tank R-06

IV.1.2 . Operation of the R06 oil storage tank

IV.1.2.1 Filling phase

Oil is supplied to Tank R06 by opening the automatic valve E11, which is remotely controlled from the control room, the oil arrives from the LP (Low Pressure) separators via the 10" filling line.

After opening the automatic valve, the SS5 remote gauging system follows the variation in the level of Tank R06 and transmits the measurement instantly to the control room.

The system is set to transmit to the operators of the control room a first high level "High Level" at 8.50m, then a second very high level "High-High Level" at 9.50m, but without automatically stopping the filling operation which can only be done after operator intervention.

IV.1.2.2 Settling phase and elimination of water

After filling the R06 tank, a phase of physical decantation of the water is necessary before starting the shipping operation. This decantation takes place thanks to the difference in density between water and oil. The heaviest water accumulates in the bottom of the tank and the oil comes on top, without forgetting a certain quantity of gas. which emerges through the vents in the roof of the tank.

Once settling is complete, the water removal operation (purge) begins by manually opening the SS3 purge valve which discharges into a manhole connected to the purge network and then to the de-oiling station.

Generally the settling is done in about four (04) hours and the purge in two (02) hours. The objective of decanting and purging is to optimize the elimination of water and reduce the salinity of the oil even after the separation batteries, in order to comply with the standards for marketing the product.

IV.1.2.3 Expedition phase

After decantation and elimination of the water, the shipping phase begins by opening the automatic valve E41, thus ensuring the supply, via the 14" line, of the BJ-1 and BJ shipping electric pumps -2 or TA-1 and TA-2 turbo pumps which in turn deliver the oil via the 12" shipping line to the Haoud El Hamra /TRC pipe.

In this phase also the variation of the tank level is monitored by the same remote gauging system preceding SS3. Like the filling phase, the system is set to give two alarms. The first low level alarm “Low at 3.50m” and the second very low level alarm “Low-Low at 3.00m”.

Once shipping is complete, shipping valve E41 is closed voluntarily by the operator.

Table Functional and Technical Analysis of R06 tank 7

<table>
<tr><th colspan="3">Operating stage</th></tr>
<tr><th>Subsystem [Main function]</th><th>Equipment [Intermediate function]</th><th>Component [Elementary function]</th></tr>
<tr><td rowspan="5"><u>SS1: Power Subsystem [Ensuring Tray R06 is Full]</u></td><td rowspan="2">E11: Automatic valve "MOV146" [Ensure the filling of Tray R06 by closing and opening it remotely]</td><td>C111 : Valve 10"</td></tr>
<tr><td>C112: electric motor [To provide the mechanical energy that opens and closes the valve].</td></tr>
<tr><td rowspan="3">E12 : Manual valve 10" [The normal state is 100% open in the event of a faulty MOV146 valve, Ensure closing and opening manually]</td><td>C121 : 10" Check Valve [Prevents Backflow of Oil from Pan]</td></tr>
<tr><td>C122 : two gaskets 10" connecting metal flanges [Prevents valve leaks]</td></tr>
<tr><td>C123 : 10" line [Ensure oil delivery]</td></tr>
<tr><td rowspan="6"><u>SS2: Subsystem The Capacity of the R06 tank [Ensuring oil storage]</u></td><td rowspan="3">E21 : The tank Ceremony Robe</td><td>C211 : two oil inlet and outlet holes[Ensure access and oil outlet to and via the Tank]</td></tr>
<tr><td>C212 : Four groundings [Ensuring discharge of electricity]</td></tr>
<tr><td>C213 : Six metal ferrules [Ensure the consolidation of the Tank]</td></tr>
<tr><td rowspan="2">E22 : The roof of the tank</td><td>C221 : Four vents with flame arresters[Ensure the degassing and smothering of the flame]</td></tr>
<tr><td>C222 : manual dip hole [Oil level indication manually]</td></tr>
<tr><td>E23 : tank Bottom Sheets</td><td>C231 : metal sheets [constitute the tank platform]</td></tr>
</table>

		C232 : Bin fixing bolts [Ensure the stability of the Bin]
SS3: Purge Subsystem [Ensure Oily Water Drainage]	E31 : Purge line "1" [Ensure the evacuation of water]	C311 : 4" pipe line [Make sure the tray is routed to the drain hole]
		C312 : two manual valves [Ensure the closing and opening of the purge line]
		C313 : Purge hole and pipe to the de-oiling station [Ensure the routing of oily water to the de-oiling station]
	E32 : Purge line "2" [Ensure the evacuation of water]	C321 : Pipe line 4" [Ensure the routing of the Tray to the bowl of the purge]
		C322 : two manual valves [ensure the closing and opening of the purge line]
		C323 : Purge hole and pipe to the de-oiling station [Ensure the routing of oily water to the de-oiling station]
SS4: Tank Shipping Subsystem R06 [Provide power to shipping pumps]	E41 : Automatic valve "MOV156" [Ensure the shipment of oil from tank R06 to the pumps by remote control]	C411 : 14" valve
		C412 : electric motor [To provide the mechanical energy that opens and closes the valve]
	E42 : Manual valve [The normal state is 100% open in the event of the MOV156 valve failing, ensure closing and opening manually]	C421 : 14" line [Ensure oil delivery]
		C422 : two gaskets 14" connecting metal flanges [Prevents valve leaks]
SS5 : SS5: Level Control Subsystem [Ensure filling monitoring to avoid overflow]	E51 : three electronic cards.	C511 : Electronic temperature map[Capturing temperature variation]
		C512 : Level electronic map [Capturing the level variation]
		C513 : Transmission electronic board[Ensure signal transmission]
	E52 : Wiring [Ensure 24v power supply and transmission of captured parameters]	C521 : Electrical wiring [Ensure 24v power supply]
		C522 : instrumentation wiring [Ensuring the transmission of captured measurements]
Security and Surveillance Phase		
SS6 : Monitoring Subsystem	E61 : surveillance cameras [Ensure the capture of the	C611 : Camera[Ensure Capture]

[Provide Monitoring of the production center]	production center such as the entourage of Bac R06]	C612 : Câblage[Assurer l'alimentation électrique et la transmission des signaux]
	E62 : Guardhouse [the continuous monitoring of the production center]	C621 : the control of the camera [Ensure scanning of the zone]
		C622 : the display screens [Ensuring the appearance of the circumstances that occurred at the area level]
<u>SS7 :</u> Safety subsystem [Ensuring extinction and limiting the severity in the event of a disaster]	E71 : Foam extinguishing system [Provide cooling and smothering in the event of a fire]	C711 : Three foam boxes [Ensuring the formation of foam inside the tank]
		C712 : Four Foam Weirs [Ensure the formation of foam at the level of the retention basin]
		C713 : Foam concentrate tank [Store foam concentrate]
	E72 : Retention Bowl	C721 : merlon [retain the overflowing oil from the tank]
		C722 : two purge holes [Ensure the draining of oily water for oil removal and oil sanitation in the event of an overflow]
	E73 : the fire-fighting network [ensure the extinction of the fire]	C731 : Three fire-fighting posts [Ensure the supply of the pipes]
		C732 : Two crowns of cooling [Cool from tray]
		C733 : A mixed cannon [Attacks foam or water fire]
	E74 : mobile intervention resources [Ensuring intervention in areas without a fire protection network]	C741 : Four Fire Fighting Trucks [To ensure the extinction of the fire]
		C742 : Six 4x4 cars [Ensuring rapid movement of the intervention team]
		C743 : An ambulance [Ensuring the evacuation of the wounded]

IV.2 Analysis by the HAZOP method

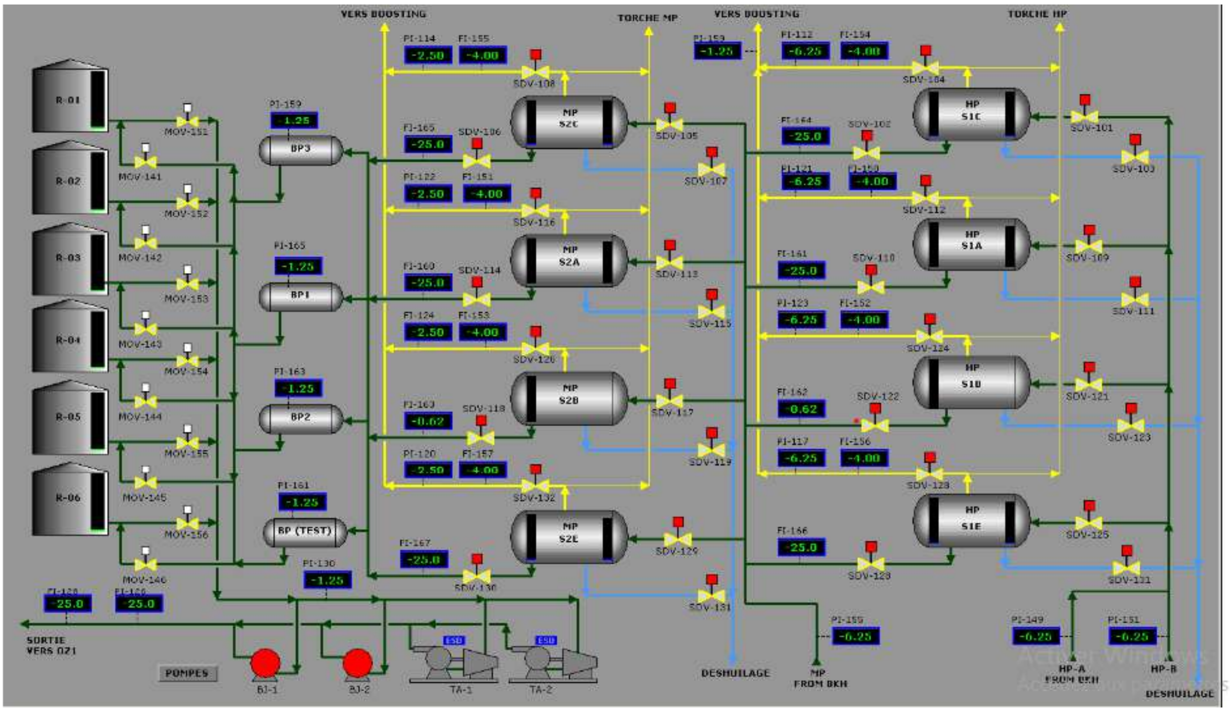

Figure 18 PFD of HBK center

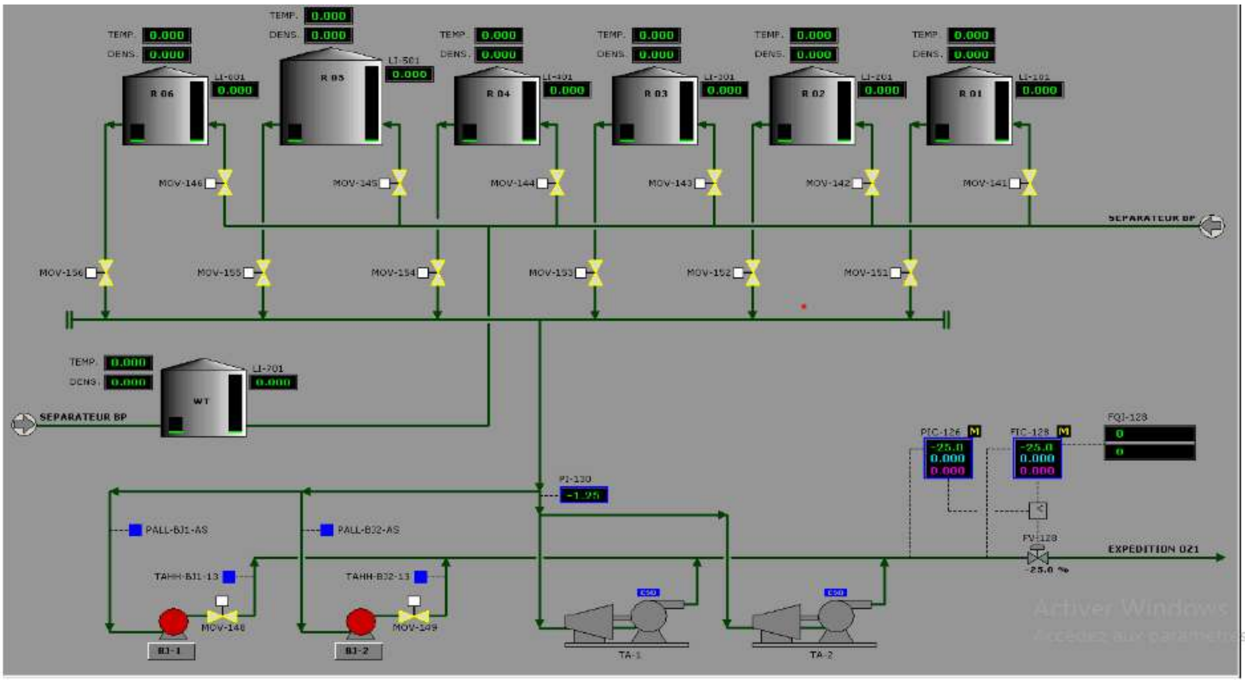

Figure 19 Storage zone of HBK

Table 8 Risk Matrix adopted from SH DP HBK

Severity

S1				
S2				
S3				
S4				
	P1	**P2**	**P3**	**P4**

Probability

Table 9 Risk level

Risk classification	Description
	Acceptable
	Tolerable
	Unacceptable

Table 10 Table IV 6 Frequency and probabilities

Probability	Description	Frequency
P4	Very probable Occurred frequently within SH	1/year
P3	Likely Occurred (or could occur) within SH, could occur during lifetime of the facility	10-2 à 10-1/year
P2	Unlikely Already (or could be) met in an organization similar to SH	10-4 à 10-2/ year
P1	Definitely Unlikely Never met or heard of but physically possible (or extremely rare)	< 10-4 / year

Table 11 Severity of hazard

Severity	Production/goods
S1	significant damage and total stoppage of production
S2	Localized damage and partial unit shutdown
S3	Minor damage and brief stop production
S4	ace of damage, no stoppage of production

PROJECT: Oil storage
HAZOP Study
Node boundary: From MOV-146 to MOV-156

Meeting date : 05/06/2023

System/ Node title : storage tank R-06

HAZOP leader: HSE supervisor/engineer

Project N:

Parameter: pressure

Node	Deviation		Causes	consequences				Safe guards				protection	Recommendations
	Guide-word				P	S	CR		P	S	CR		
From MOV-146 to MOV-156	High	pressure (pressure in tank high than 0.204 Bar)	Upstream - Bad separation. - Blockage of pipeline by foreign body-barium sulfate. - MOV-146 valve stuck open. --Human errors. Downstream - Blockage of pipeline by sticking of impurities around the pipelines. - MOV-156 valve stuck closed. -Human errors.	-Temperature increasing. -TVR increasing (TVR high than 850 mbar) -roof burst. -Oil spilling -Effect the product quality -atmospheric and environment Pollution. -injuries. -Explosion	2	4		-Alarm system. -Surveillance cameras. -DCS. -Foam extinguishing system. - Merlon -purge system. -Intervention tools (fixed and mobile). -Pressure detector. -TVR measuring.	2	3		- Emergencie plan. -Intervention	-Using automatic system -Using the artificial intelligence in the advance detection of any event. -Ensure the maintenance of existing barriers. -Pressure alarm system

	Low-Low	Pressure (low than 0.204 Bar)	-MOV-146 valves stuck closed and MOV-156 stuck open and the pump is active	- Tank collapsing. -Bad product quality -wasting time.	2	1		-Alarm system. -Surveillance cameras. -DCS. -Intervention				- Emergencie plan. -Intervention	-Using automatic system -Using the artificial intelligence in the advance detection of any event. -Ensure the maintenance of existing barriers. -Pressure alarm system

PROJECT: Oil storage
HAZOP Study
Node boundary: From MOV-146 to MOV-156

Meeting date : 05/06/2023

System/ Node title : storage tank R-06

HAZOP leader: HSE supervisor/engineer

Project N:

Parameter: Temperature

Node	Deviation		Causes	consequences				Safe guards				protection	Recommendations
					P	S	RR		P	S	RR		
From MOV-146 to MOV-156	High	Temperature	-Pressure increasing -Extern fire - Ambient temperature is higher.	-degassing -loss of energy -TVR increasing (TVR higher than 850 mbar). - Disasters (boil over-fire-explosion…). -decreasing product quality. -injuries. -Material losses. -Roof burst. - Formation of ATEX zone. -Air and environment pollution.	3	4		-Alarm system. -Surveillance cameras. -DCS. -Foam extinguishing system. - Merlon -purge system. -Intervention tools (fixed and mobile). -TVR measuring.	3	2		-Emergencie plan (IIP). -Intervention	-using automatic system -using the artificial intelligence in the advance detection of any event. -ensure the maintenance of existing barriers. -using fire/flam detectors. -ATEX zones classification. -Using equipments according to the ATEX zone. - Deluge system automatic.

PROJECT: Oil storage
HAZOP Study
Node boundary: From MOV-146 to MOV-156

Meeting date : 05/06/2023

System/ Node title : storage tank R-06

HAZOP leader: HSE supervisor/engineer

Project N:

Parameter: Level

Node	Deviation		Causes	consequences				Safe guards				protection	Recommendations
	Guide-word	parameter			P	S	RR		P	S	RR		
From MOV-146 to MOV-156	High	Level (hgh tahan 9.50 m)	-MOV-146 stuck open and MOV-156 stuck close. -poor handling on valves. .	-overflow. -Roof burst. -dangerous phenomena.	2	4		-Alarm system. -Surveillance cameras. -DCS. -Merlon. -purge system. - manual dip hole -intervention tools (fixed and mobile).	2	3		-Emergencie plan (IIP). -Intervention	-using automatic system -using the artificial intelligence in the advance detection of any event. -ensure the maintenance of existing barriers.
	Low	Level (low than 3m)	-MOV-146 stuck close and MOV-156 stuck open. - Oil return	-pump cavitations -work stopping	2	3		-Vibration probe -Surveillance cameras. -DCS. -intervention tools (fixed and mobile). - Check valve	2	2		Emergencie plan (IIP). -Intervention	-using automatic system -using the artificial intelligence in the advance detection of any event. -ensure the maintenance of existing barriers.

PROJECT: Oil storage
HAZOP Study
Node boundary: From MOV-146 to MOV-156

Meeting date : 05/06/2023

System/ Node title : storage tank R-06

HAZOP leader: HSE supervisor/engineer

Project N:

Parameter: Flow

Node	Deviation		Causes	consequences				Safe guards				protection	Recommendations
			Upstream		P	S	RR		P	S	RR		
From MOV-146 to MOV-156	No/low	Flow	- Blockage of pipeline by foreign body-barium sulfate. - Leak of oil in the pipeline before the tank. -MOV-146 stuck close. - Untimely closing. -Human errors.	- Pump cavitations - stopping production. -In case of leakage: -environment pollution. -Air pollution. - Loss of energy (oil).	2	3		- Surveillance cameras. -DCS. - Intervention tools (fixed and mobile).	2	2		-Emergency plan (IIP). -Intervention	-Using automatic system -Using the artificial intelligence in the advance detection of any event. -Ensure the maintenance of existing barriers. -Using bypass pipeline. - Flow alarm system. -Regulation loop which changes the principal line by bypass automatically
			Downstream										
			- MOV-156 stuck close. - Blockage of pipeline by sticking of impurities around the pipelines.										

IV.3 Analysis of safety barriers using the LOPA method

After the identification of the acceptability criteria, the risk matrix, HAZOP method and the evaluation of its consequences and the existing barriers. We move on to the steps of the LOPA method:

Step1: Scenario identification

According to the HAZOP method, there are several scenarios and initiating events in level parameter, we do the LOPA method for each scenario.

Table 12 Scenarios/ consequences/ severity

Scenarios	Initiating event	consequences	severity
1	Failure of MOV-146 valve (Remote control valve) (stuck open)	-roof burst -overflow (may cause a fire) - Unit shutdown.	**4**
2	Failure of MOV-156 valve (Remote control valve) (stuck close)	-roof burst -overflow (may cause a fire) - Unit shutdown.	**4**
3	Poor handling on valves.	-roof burst -overflow (may cause a fire) - Unit shutdown.	**4**

Step 2: Initiating event frequency

Table 13 initiating events frequencies

Initiating event	frequency	references
Failure of MOV-156 / MOV-146 valves	10-1/ year	CCPS, 2001
Poor handling on manual valves.	0.032 /year	CCPS, 2001

Step 3: Identification of IPL and PFD

Table 14 IPLs and PFDs

IPL	PFD	references
DCS control loop/DCS operator	10-1	CCPS, 2001
Alarm/ manual valve operator.	10-1	CCPS, 2001

Step 4: consequence frequency determination

We choose the scenarios: 2 and 3

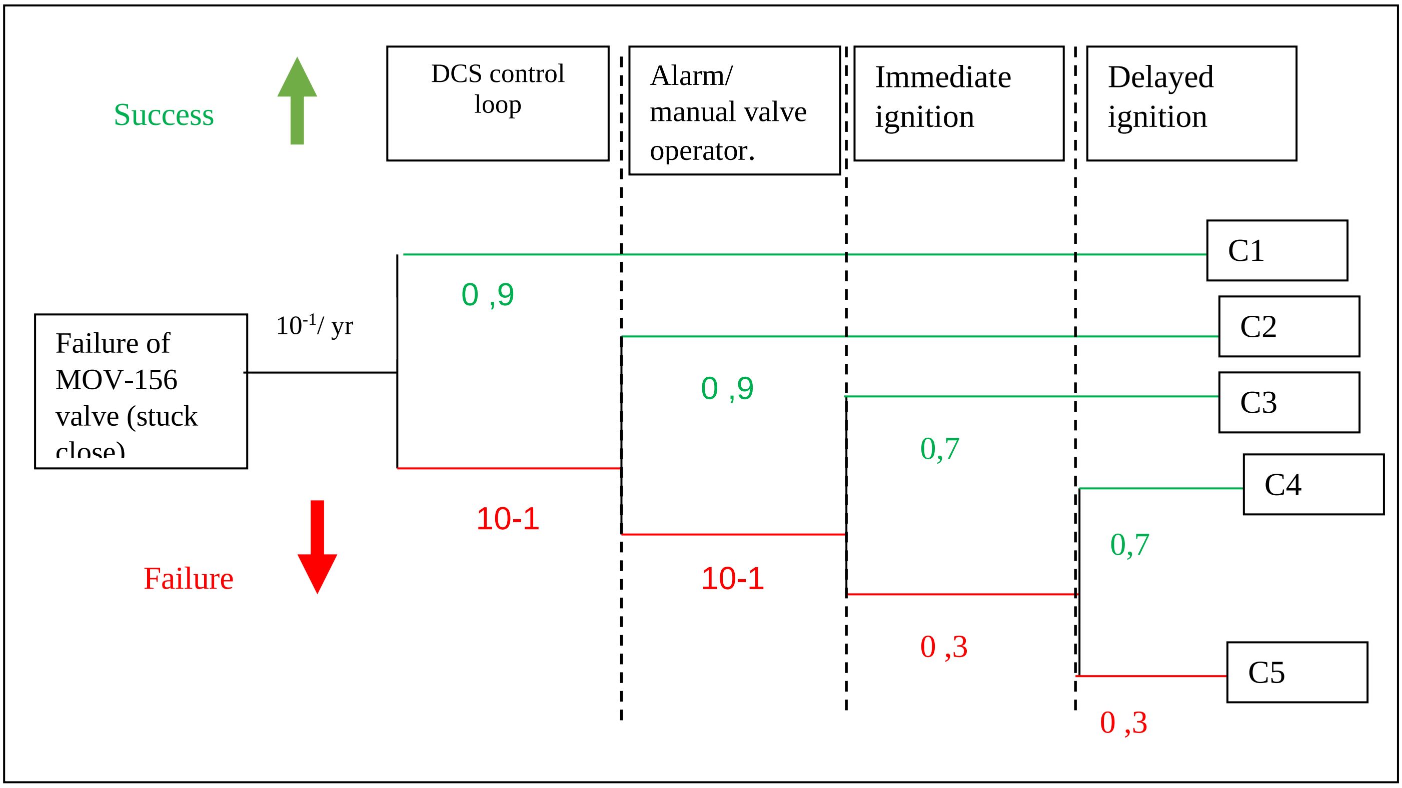

Table 15 Consequences frequencies 2nd scenario

	Consequences	Frequency
C1	Metrized setuation.	9×10^{-2}/ yr
C2	Metrized setuation.	9×10^{-3}/ yr
C3	Pool fire	7×10^{-4}/ yr
C4	UVCE	2.1×10^{-4}/ yr
C5	Pollution - loss of energy - unit shutdown	9×10^{-5}/ yr

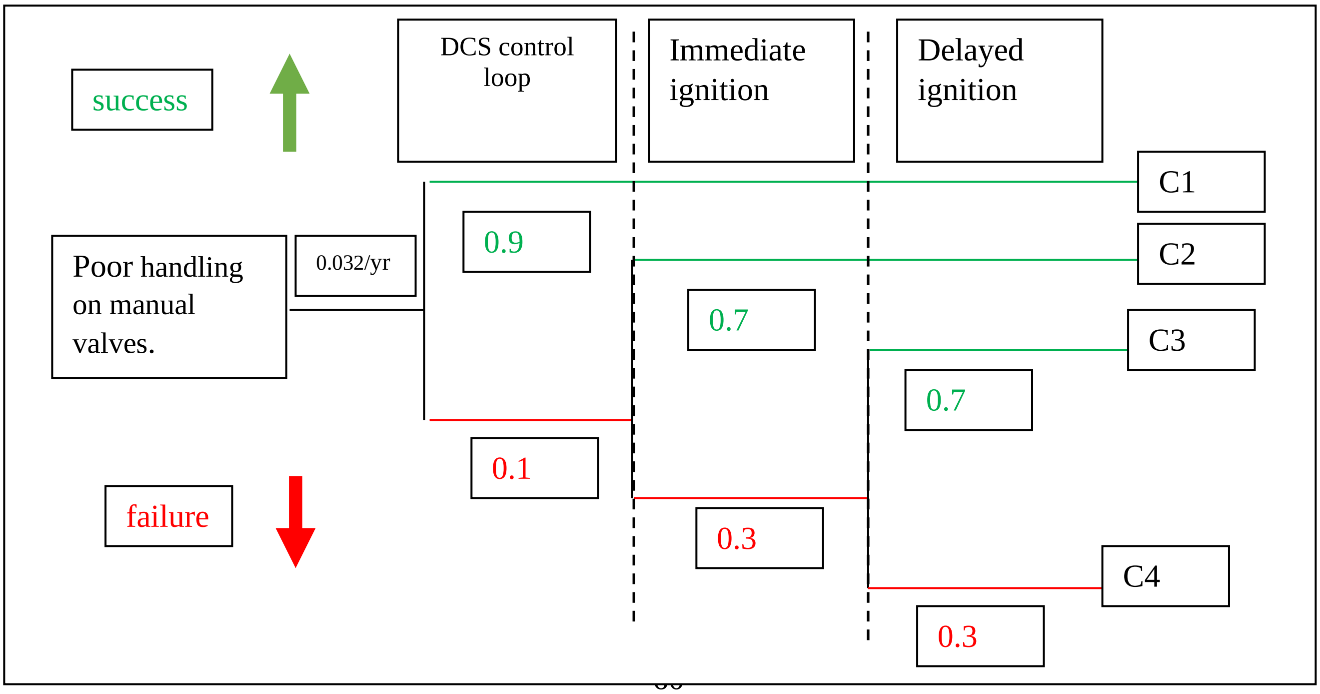

Table 16 Consequences frequencies 3rd scenario

	Consequences	Frequency
C1	Metrized setuation.	2.88×10^{-2}/ yr
C2	Pool fire	2.24×10^{-3}/ yr
C3	UVCE	6.72×10^{-4}/ yr
C4	Pollution - loss of energy - unit shutdown	2.88×10^{-4}/ yr

Step 5: Risk evaluation

Table 17 Consequences risk evaluation

	Consequences	**Probability**	**Severity**
1	Tablecloth fire	**P2**	**S4**
2	UVCE	**P2**	**S4**
3	Unit shutdown	**P2**	**S3**

Table 18 Risk reduction

	P1	**P2**	**P3**	**P4**
S1				
S2				
S3	**3**			
S4	**1,2**			

IV.4 Conclusion

Applying qualitative method (HAZOP) to helping for identifying initiating events and scenarios to analyzing the existence of barriers and their performance and evaluation by quantitative method (LOPA or ETA). After selecting two scenarios from multiple incident scenarios and estimating their frequency, we ended up examining these two scenarios, assessing the risks of both scenarios before and after the application of the protective layers. According to the different results It has been noted that the scenarios are judged ALARP because security is enhanced.

Recommendations

The main recommendations for this scenario are:

- Ensure training and information of operators to know and master any disruptions that may occur.
- Respect for the periodicity of instrumented loop tests and the frequency of taring by Vanes.
- Establishment of an ATEX procedure (zones, periodic adequacy audit) Electrical and Non-Electrical Equipment Installation Management of ATEX.
- Using SIS more effective and adapt to IPL criteria by the adapt SIL.
- Perform appropriate analysis methods for the tank.
- Safety meeting and inspection plan.

General conclusion

Oil and gas plants are most likely to be major risks that can go to disasters with catastrophic effects in the human, financial or environmental impact that negatively affects the reputation of the company and its brand image.

Therefore, measures must be taken to control at an acceptable level, the risks threatening the safety of the workplace.

The safety of our facility depends on its proper operation barriers and measures: preventive, protective or mitigating the best practices and selection criteria.

These barriers may deteriorate over time or be inadequate with evolution and technological.

So, in this modest memory and in the practical part we did first a separator description studied through functional and technical analysis followed by a dysfunctional analysis by the HAZOP method to facilitate the application the LOPA method. This method is used to analyze and to assess the performance of the safety barriers to prevent the occurrence of the accident or limit the consequences.

The implementation of this method is difficult, there are many difficulties Lack of information on the state of operation of the system return to Experience.

Major difficulties were encountered during the application of the LOPA method there is a lack of information on the state of operation of the system. We are Therefore; we suggest that further data studies will be the subject of future work.

Finally, and in the context of continuous improvement and enhancement of security we have made recommendations to ensure a safe working environment for them operators, goods and the environment.

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