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Application of the Fire and Explosion Risk Assessment study on drilling rig.

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DEDICATIONS

I dedicate this work to my family especially

my father and my mother

hey sacrificed a lot and did all they can in order to make me the person that I have been and reach where I am now I want to thank them from all of my heart , and I thank God for making me their son.

I would like to dedicate this work to my teachers and schoolmates since the beginning of my school life until now

Akram Djedri

DEDICATIONS

I dedicate this work to my family especially

my father and my mother

They sacrificed a lot and did all they can in order to make me the person that I have been and reach where I am now I want to thank them from all of my heart, and I thank God for making me their son.

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Ladouani Housseyn

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Abstract:

The objective of our research fire and explosion risk assessment is to understand the principles, methodologies, and tools used to assess and manage the risks associated with fires and explosions. This includes learning how to identify potential hazards, evaluate their likelihood and consequences, and develop strategies to mitigate these risks effectively. Such studies help us in various industries to create safer environments and prevent accidents. First, in the first chapter, we talked about fires and explosions, their definition, Classification of Fires and Extinguishing methods for each class and types of explosion and its effects and its conditions and prevention and protection measures.

In the second chapter, we talked about the FERA method, its definition, objectives, methodology, and some methods similar to it, QRA and Hazop. In the third chapter, we talked about the ENAFOR Company. We applied the FERA method on an oil drilling rig and performed fire simulations using software Aloha.

الملخص:

الهدف من بحثنا لتقييم مخاطر الحرائق والانفجارات هو فهم المبادئ والمنهجيات والأدوات المستخدمة لتقييم وإدارة المخاطر المرتبطة بالحرائق والانفجارات .يتضمن ذلك تعلم كيفية تحديد المخاطر المحتملة، وتقييم احتمالاتها وعواقبها، ووضع استراتيجيات للتخفيف من هذه المخاطر بشكل فعال .تساعدنا مثل هذه الدراسات في مختلف الصناعات على خلق بيئات أكثر أمانًا ومنع وقوع الحوادث .أولا تحدثنا في الفصل الأول عن الحرائق والانفجارات وتعريفها وتصنيف الحرائق وطرق الإطفاء لكل صنف وأنواع الانفجارات وآثارها وشروطها وإجراءات الوقاية والحماية، وفي الفصل الثاني تحدثنا عن طريقة FERA تعريفها وأهدافها ومنهجيتها وبعض الطرق المشابهة لها QRA و .Hazop وفي الفصل الثالث تحدثنا عن شركة .ENAFOR قمنا بتطبيق طريقة FERAعلى منصة حفر النفط وقمنا بإجراء عمليات محاكاة للحريق باستخدام برنامجAloha .

Résumé:

L'objectif de nos recherches sur l'évaluation des risques d'incendie et d'explosion est de comprendre les principes, les méthodologies et les outils utilisés pour évaluer et gérer les risques associés aux incendies et aux explosions. Cela implique d'apprendre à identifier les dangers potentiels, à évaluer leur probabilité et leurs conséquences, et à élaborer des stratégies pour atténuer efficacement ces risques. De telles études nous aident dans diverses industries à créer des environnements plus sûrs et à prévenir les accidents. Tout d'abord, dans le premier chapitre, nous avons parlé des incendies et des explosions, de leur définition, de la classification des incendies et des méthodes d'extinction pour chaque classe et des types d'explosion et de ses effets et de ses conditions et des mesures de prévention et de protection. Dans le deuxième chapitre, nous avons parlé de la FERA méthode, sa définition, ses objectifs, sa méthodologie et quelques méthodes similaires, QRA et Hazop. Dans le troisième chapitre, nous avons parlé de la société ENAFOR. Nous avons appliqué la méthode FERA sur une plate-forme de forage pétrolier et réalisé des simulations d'incendie à l'aide du logiciel Aloha,

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LIST OF ABBREVIATIONS & ACRONYMS

AFP. Active Fire Protection
ATEX. Atmospheres Explosibles
BLEVE. Boiling liquid expanding vapor explosion
BOP. Blow Out Preventer
CIA. Chemical Industries Association
EN. European Standard
ENAFOR. Entreprise nationale algérienne du forage
ESD. Emergency shutdown valves
FERA. Fire and Explosion Risk Assessment
FMEA. Failure Mode and Effects Analysis
FMECA. failure mode, effects and criticality analysis
HACCP. Hazard Analysis Critical Control Point
HAZOP. Hazards and Operability Study
ICI. Imperial Chemical Industries
L.I.E. lower flammability limit
L.S.E. upper flammability limit
MAH. Major Accident Hazard
NFPA. National Fire Protection Association.
P&IDs. Piping and Instrument Diagram
PFD. Process Flow Diagram
PFE. Projet de Fin d'Études
PFP. II. Passive fire protection
PRA. Probabilistic Risk Analysis
QRA. Quantitative Risk Assessment
UVCE. Unconfined Vapor Cloud Explosion
VCE. Vapor Cloud Explosion

GENERAL INTRODUCTION

The oil and gas industry is inherently associated with fire and explosion hazards. Drilling rigs, in particular, concentrate a multitude of risk factors due to the presence of flammable hydrocarbons, high-pressure equipment, and electrical systems. These potential hazards necessitate a proactive approach to ensure the safety of personnel, minimize environmental damage, and protect valuable assets.

Fire and explosion incidents on drilling rigs can have catastrophic consequences. These events can result in:

-Loss of life and serious injuries

-Environmental pollution from spilled oil and toxic fumes

-Significant financial losses due to rig damage, production downtime, and liability claims

Therefore, there is a critical need to effectively assess and mitigate fire and explosion risks on drilling rigs. This PFE (Projet de Fin d'Études) focuses on the application of a Fire and Explosion Risk Assessment (FERA) study specifically tailored to drilling rig operations.

Where is the problem in how to conduct a Fire and Explosion Risk Assessment (FERA) study and simulate the damage resulting from a possible combustion or explosion accident?

In order to solve the previous problematic we should answer the next sub-questions:

-What do fire and explosion mean and what are the conditions for their occurrence?

-What are the methods of analysing fire and explosion risk?

-Which software we use to applicate this simulation?

We have the following hypotheses that may be considered as answers:

-Software ALOHA can model various fire and explosion scenarios the threat zone estimates from ALOHA can be used for emergency planning purposes. Understanding potential reach of a fire or explosion helps determine evacuation zones, resource allocation, and response strategies.

Our thesis is divided into three chapters:

In the first chapter we started by Overview on Fire and Explosion Risk.

In the second chapter we present the methods of analysing fire and explosion risk.

In the third and final chapter, we present ENAFOR Company and the application of the Fire and Explosion Risk Assessment study and simulation on drilling rig.

CHAPTER I:

Fire and Explosion Risk

INTRODUCTION:

Fire risk refers to the likelihood that a fire will occur in a specific place. It's important to consider fire risk because fires can be devastating, causing loss of life, property damage, and environmental harm.

The professional service technician, should have a basic knowledge of fire chemistry, theory of extinguishment, classification of fires and properties of different fuels. So, we started by breve description on how the fire occur and spread. This base knowledge will allow the professional technician to better understand the fire hazards that they may encounter, how various fire extinguishing agents, in theory, suppress fire and therefore have a better understanding of the equipment.

SECTION I: Overview on Fire Safety

1. Fire definition:

Fire is the visible effect of combustion, a continuous chemical reaction involving rapid oxidation at high temperature followed by heated gaseous and visible plus invisible radiation.

According to NFPA: “An oxidation process, which is a chemical reaction resulting in the evolution of light, heat, and combustion products”. [1]

Fire Triangle:

Fires, even the biggest ones, always start from a simple chemical reaction, combustion. Live combustion compared to the slow combustion that is oxidation, can only arise in the presence of three elements.

These three elements are necessary for a fire to develop, this is called the fire triangle:

• The fuel: (wood, paper, cardboard, textile, plastic material, etc.).

• The oxidizer: (oxygen).

• The heat source: (candle or match flame, light bulb, iron, spark, etc.).

Putting out a fire means acting on one of the three elements (fuel, oxidizer, heat source). If the action is easy when you put out a wastepaper basket with a glass of water, a flaming gas leak by closing the tap, a fryer fire by covering the latter with a lid, the problem becomes more complicated. Whether it is a drilling rig, a warehouse, a fuel tank or a forest.

However, it is by applying these simple principles, but with powerful means and a rigorous strategy that the firefighters will control the fire. If one of these three elements is not present or disappears during combustion, fire does not exist.

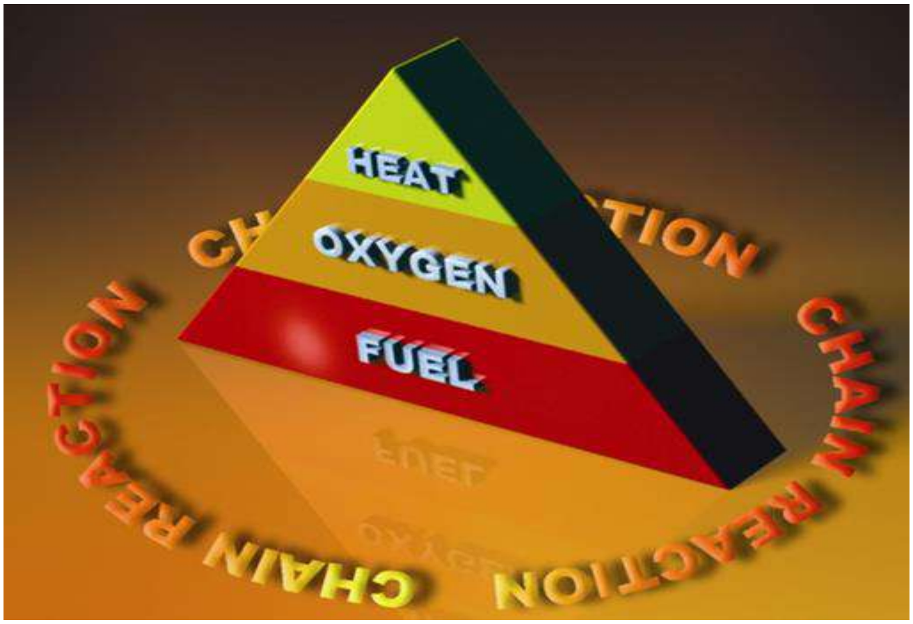


Figure 1: Fire Triangle *[2, p. 4]*

2. Classification of Fires:

- **Classe A:** solid-state fires in which the combustion is normally accompanied by the formation of embers and leaves an ash. Common examples of class "A" fires would be paper, wood. The preferred method for extinguishing class "A" fires is to remove the heat. Water is the most common agent, but others such as dry chemical, halon, halogenated agents and foam can be used effectively.
- **Classe B:** fire includes combustible liquid or gas (gasoline, oil, propane, and natural gas, etc.).These products can be found in ateliers.
- **Classe C:** fires involve live electrical equipment and require the use of an extinguishing agent and/or extinguisher that will not conduct electricity back to the fire fighter(s). Electricity is an energy source and an ignition source, but by itself will not burn. Instead, the live electrical equipment may serve as a source of ignition for a class "A "fire such as insulation or packing, or a class "B" fire.
- **Classe D:** metal fires (aluminum, titanium, magnesium, sodium, etc.). These very particular fires can occur in laboratories. These fires require special agents such as dry powders and special application techniques. Many common agents like water will actually react to burning metals and increase the intensity of the fire in a violent manner.

- **Classe k:** fires involve cooking media. These can be any animal or vegetable based fats or oils. These fires require special agents such as wet chemical extinguishers and systems that are alkaline in nature and have superior cooling capabilities. Prior to the 1998 edition of NFPA 10 these fires were considered to be Class "B" fires. After extensive testing it was decided that they are unique in nature and are totally different than Class "B" fires. [2, p. 6]

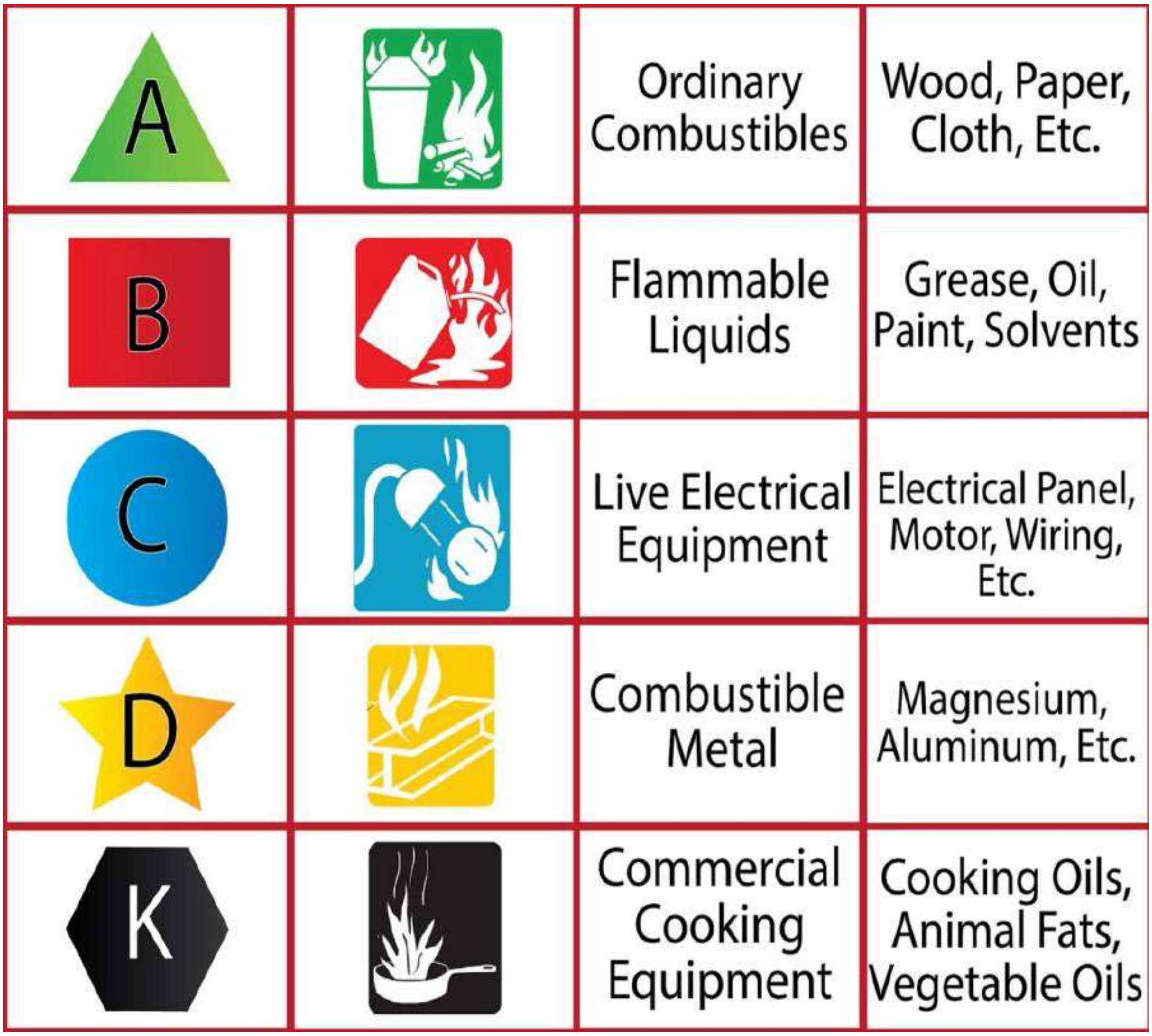


Figure 2: Fire classifications *[3]*

3. Extinguishing methods for each class: [4]

3. 1 Principles extinguishing agents:

- **Water fire extinguishers:**

The most common type, effective against ordinary combustibles (paper, wood, cloth) classified as Class A fires. They function by cooling the burning material and reducing its temperature below the point of ignition. However, they have limitations:

- **Freezing temperatures:** Pure water extinguishers freeze and become unusable in cold environments. Some types contain antifreeze for such conditions.
- **Electrical hazards:** Water conducts electricity, making them unsuitable for electrical fires (Class C). Using them on electrical fires can endanger the user.
- **Water damage:** While effective, water extinguishers can cause water damage to surroundings. Consider this potential consequence before using.

- **Dry powder fire extinguishers :**

Dry powder fire extinguishers are versatile and can be used on Class A, B, C, D, E fires. The powder smothers the fire by creating a barrier between the fuel and the oxygen.

- **Foam fire extinguishers:**

Foam fire extinguishers are used to put out Class B fires that involve flammable liquids such as (oil, gasoline, solvents). The foam creates a layer over the burning liquid, this foam layer suffocates the fire by:

- **Separating oxygen:** The foam physically blocks oxygen from reaching the burning liquid, interrupting the fire triangle.
- **Cooling effect:** The foam also has a cooling effect, helping to lower the fuel temperature below its ignition point.

- **CO2 fire extinguishers:**

Carbon Dioxide (CO_2) fire extinguishers have the distinct benefit of not leaving a residue after use. When it comes to protecting fragile and expensive electronic equipment, this might be a big concern. Food preparation spaces, labs, and printing or duplicating operations are all common examples. Extinguishers containing carbon dioxide are approved for use on Class B and Class C fires. Because the agent is released in the form of a gas/snow cloud, its range is limited to 1m to 2.4m. Because the agent can rapidly evaporate, this type of fire extinguisher is not suggested for outdoor use in windy situations or interior usage in regions prone to strong air currents .When used in restricted places, the concentration required for fire extinguishment limits the amount of oxygen in the area of the fire and should be handled with caution.

- **Wet chemical fire extinguishers:**

Wet chemical fire extinguishers are used to put out on only Class F fires that involve cooking oils and fats, such as in a commercial kitchen. The wet chemical creates a barrier over the burning oil, which prevents oxygen from reaching it and extinguishes the fire.

3. 2 Extinguishing methods:

Remember that each class of fire corresponds to one or more types of extinguishing agents and processes that can be found, for example, on the information labels of extinguishers or in the name of certain products.

To control a fire, it is necessary to break the association of the three elements of the fire triangle; this rupture can be carried out according to three modes:

- **Cooling:** Eliminating the heat is one of the best methods for putting out a fire. Water cooling is therefore one of the most often used techniques. The water absorbs the heat produced by the fire. As long as the water is still able to absorb heat, this works.
  It's crucial to remember, though, that water should never be utilized in flames caused by electrical currents, grease, cooking oils, or other flammable substances.
- **Smothering**: removes the oxygen content around the fire in order to make the atmosphere incombustible. An example of this is covering the candle with a cup. The fire burns out all the oxygen inside the glass creating a vacuum.
- **Starving:** Starving the fire from its fuel source is a different approach. When fire runs out of flammable materials, it will eventually burn out itself. For example, a bonfire in the open when it is not in contact with any other wood or dry grass will ultimately lose its blaze. In a gas fire, it will immediately extinguish if the gas supply is cut off. The same method is applied to your gas stove or drilling rig fire.

Good control of these processes makes it possible to determine the most appropriate extinguishing agent according to the risk to be protected, the environment and the means of implementation.

Apart from these three classic extinguishing modes, there is also a technique which consists in passing the fire from one class to another to allow its extinction. Thus, for certain type D fires (metal fires), the metal is immersed in a flammable liquid. The fire then becomes class B and is easier to extinguish.

- **CLASS "A":**

Water is the most used agent in class "A", it removes the heat. However, we could also use other agents such as foam, dry chemical (Powder ABC), and foam.

- **CLASS "B":**

The best agent for this class depends on the situation and circumstances because flammable liquids do not burn in their liquid phase; instead, the vapors created by these liquids inflame. Therefore, we can use a diversity of fire extinguishing agents; Powder ABC/BC, CO_2, and Foam.

- **CLASS "C":**

For class "C", we use most of the time the CO_2 agent because it includes electricity & electronics equipment, so we cannot use any wet substances like water or foam. We can also use Powder ABC/BC.

We consider electricity as an energy source, but it will not burn by itself.

- **CLASS "D":**

This type of fire needs special agents like dry chemical because it contains metals such as sodium, magnesium, zirconium and titanium.

The agents that we used before in other classes will not work in this class. For example, water will react to flammable metals and increase the intensity of the fire.

- **CLASS "K”:**

These fires necessitate wet chemical agent because they can be any fats or oils of an animal or vegetable.

Before, this type was considered as a fire in class "B". However, after a while, they decided on a different type of fire classified individually, considering the diversity of extinguishing type between them. [5]

Figure 3: Fire extinguisher types *[6]*

4. Definition of firefighting systems:

Fire-fighting systems placed in places where there is a high fire risk .For extinguishing, each fire class have a specific agent. The firefighting system is a mean of protection against fire and its consequences, and it aims to safeguard human lives and property (buildings, facilities industrial, machinery, equipment…).A Firefighting equipment is equipment designed to extinguish fires or protect the user from fire. It may be used by trained fire fighters, untrained users at the scene of a fire, or built into a building's infrastructure (such as a sprinkler system). [7]

4.1 Types of firefighting systems: there are two types:

I. **The automatic fire extinguishing system:** Is a fixed system that is installed in the sites to be protected according to it nature of on-site work and fire independent of the site and these systems are: Sprinkler systems, carbon dioxide systems, Simple systems, alternatives and foam, HALON Systems

II. **Manual extinguishing system:** Is the systems that are installed in the places to protect fire risks these systems are operated by a person or persons and through these systems .Rubber pipe systems or fire network, fire booths and manual fire extinguisher.

4.2 Types of fire protection: There are two different types of fire protection

I. **Active Fire Protection (AFP):** is a group of systems that require some amount of action or motion in order to work efficiently in the event of a fire. Actions may be manually operated, like a fire extinguisher or automatic, like a sprinkler, but either way they require some amount of action.

II. **Passive fire protection (PFP):** is an integral component of a fire safety strategy. It forms an essential element of the structural fire protection and fire safety in a building through, containing fires (known as “compartmentation, slowing the spread of fire with fire-resistant walls, floors and doors (protecting escape routes). [8]

5. Importance of fire safety:

Fire safety is important and necessary in the workplace in order to prevent and protect against the destruction caused by fire. Fire safety reduces the risk of injury and building damage that fires can cause. Fire safety is important in order to:

- Reduce the risk of injury to employees and customers.
- Reduce damage to facility/building.
- Protect against possible fines.
- Protect against losing customers trust.
- Protect employee jobs that would be lost due to extensive building damage.

SECTION II: Overview of Explosions

1. Definition of an explosion:

Concretely, and in everyday language, the word “explosion” represents a large number of phenomena. For our study, we present the definition given by Baker "In an open field, an explosion occurs if a sufficiently large quantity of energy is released, for a short enough time to generate a blast wave which propagates in the environment from of the emission source called the source of the explosion.

The definition given by the Groupement Français de Combustion is as follows: “An explosion is a sudden release of energy more or less confined, more or less controlled, with or without external consequences, the explosion can give rise to a pressure wave (blast wave), to a ball of fire. In the case of chemical explosion, the energy release process can be deflagration or detonation.

The explosion is therefore associated with a release of energy capable of generating violent, even destructive, mechanical and thermal effects. [9]

2. Types of explosions:

I. Physical explosion:

A physical explosion occurs when mechanical energy is suddenly released, such as the release of compressed gas. These types of physical explosions include rupture of a container and an explosion due to a rapid transition phase.

Container rupture occurs when a process vessel containing a material under pressure (such as air) suddenly fails. Tire explosion is a type of explosion due to the rupture of a container.

A rapid phase transition explosion occurs when a material is exposed to a heat source, causing the phase to change (from liquid to vapor, for example) and changing the volume of the material. .

II. Chemical explosion:

A chemical explosion requires a chemical reaction, which could be a combustion reaction (rapid exothermic reaction or rapid release of heat). A chemical explosion can occur in the vapor, liquid or solid phase.

The release of high volume propane gas is an example of an explosion due to a combustion reaction. The ignited gas can cause the vapors of a boiling liquid to explode explosively (BLEVE phenomenon).

A chemical reaction explosion can be an uncontrolled chemical process that results in rapid release of heat and chemicals.

III. Electric explosion:

An arc flash is an example of an electrical explosion. The Canadian Standards Association defines an arc flash hazard as a "dangerous situation characterized by the possibility of the release of energy caused by an electrical arc." It also specifies that there "may be a danger of arc flashes when conductors or other live circuit elements are exposed or are inside the equipment in a protected or enclosed state, if a person interacts with the equipment in a manner likely to cause an electric arc. Under normal service conditions, enclosed live equipment that has been installed and maintained correctly is not likely to present a danger of arc flashes. »

Fire, equipment damage, serious injury or death can occur near an arc flash.

Many factors can cause arcing, such as dust, dropped tools, accidental contact, condensation, equipment failure, corrosion and improper installation. [10]

3. Definition of ATEX:

On industrial sites and construction sites, the safety of personnel and equipment is a priority. Precise measures are put in place to prevent possible dangers. Among them, the ATEX indication.

ATEX is the abbreviation for "Explosive Atmosphere". An ATEX is an environment in which the risk of explosion is high due to the presence of combustibles, visible or not to the naked eye. According to standard EN 1127-1, an explosion is "a sudden reaction of oxidation or decomposition involving an increase in temperature or pressure or both simultaneously". The spread of combustion is almost immediate, accompanied by flames and heat waves. An ATEX can form under normal operating conditions or accidentally by the leak of one or more fuels.

In an ATEX, the air mixes with flammable materials. The explosion occurs when six simultaneous conditions are met:

- The presence of an oxidant (generally oxygen in the air)

- The presence of a fuel (propane, hydrogen, coal, wheat flour, etc.)

- The presence of an ignition source (spark, static electricity, heat, etc.)

- The particular state of the fuel (gas, dust, fog, etc.)

- obtaining an explosive range: the mixture is neither too lean nor too rich in fuel

- A confined space [11]

4. The effects of the explosion:

The explosion essentially produces overpressure and thermal effects as well as projection effects.

The overpressure effects generated by an explosion due to the production of combustion gases are relatively limited in a free field. Depending on the degree of confinement and congestion of the place where the explosion occurs, the effects of overpressure can become significant. In cases of strong confinement, it can reach around ten bars. Almost all gas or dust explosions have flame speeds of less than 100 meters per second and excess pressures of less than 10 bar: these are deflagrations. Under certain conditions (notably in product confinement conditions), transitions from deflagration to detonation are possible.

The effects of a tank burst are on the one hand effects of overpressure, due to the sudden expansion of the compressed gases and the instantaneous vaporization of part of the liquid phase, and on the other hand projections fragments of the tank.

The regulatory threshold values for evaluating the effects of overpressure on humans or structures are as follows:

- 20 mbar corresponding to the effects of broken windows
- 50 mbar corresponding to irreversible effects and slight damage to structures
- 140 mbar corresponding to the first lethal effects and serious damage to structures
- 200 mbar corresponding to significant lethal effects and serious damage to structures
- 300 mbar corresponding to very serious damage to structures

The thermal effects of an explosion are due to the radiation of the flame and hot combustion gases. Their range and severity vary depending on the extent of the explosion's propagation and its speed. The more an explosion is confined or in a crowded environment, the greater the flame speed and overpressure will be; the thermal effects will then be less marked, the flame "passing too quickly", and the overpressure effects will be clearly preponderant. Furthermore, the more the explosive conditions of the mixture are met over a large area, the more distant targets will be affected by the cumulative effects of radiation. [12]

5. Explosion conditions:

- Presence of fuel.
- Particular state of the fuel, which must be in the form of gas, mist or dust suspended in the air.
- Presence of an oxidant (generally oxygen in the air)
- Presence of an ignition source.
- Obtaining an explosive range (range of fuel concentrations in the air within which explosions are possible)
- Sufficient confinement (in the absence of confinement, a rapid combustion phenomenon is obtained with significant flames but, generally, without significant pressure effect).

Containment is not an essential condition but represents an aggravating factor in the explosion phenomenon and the associated risks. [13]

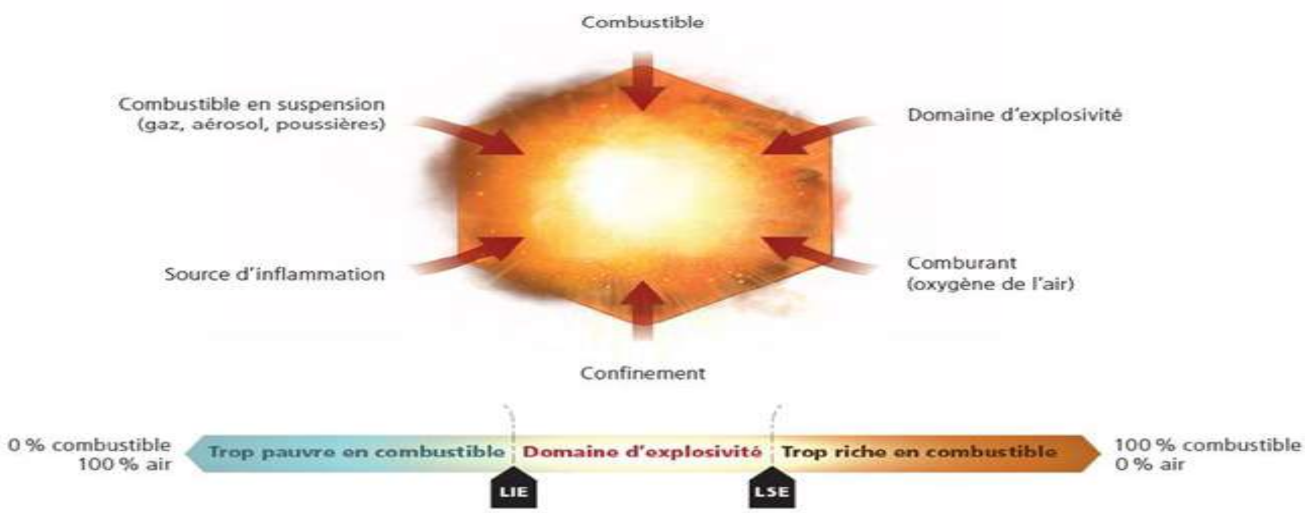


Figure 4: Explosion conditions *[13, p. 4]*

6. Dangerous phenomena:

BLEVE: "Boiling Liquid Expanding Vapor Explosion", the explosion of expanding gas coming from a boiling liquid (case of the Feyzin accident in 1966, 18 deaths).

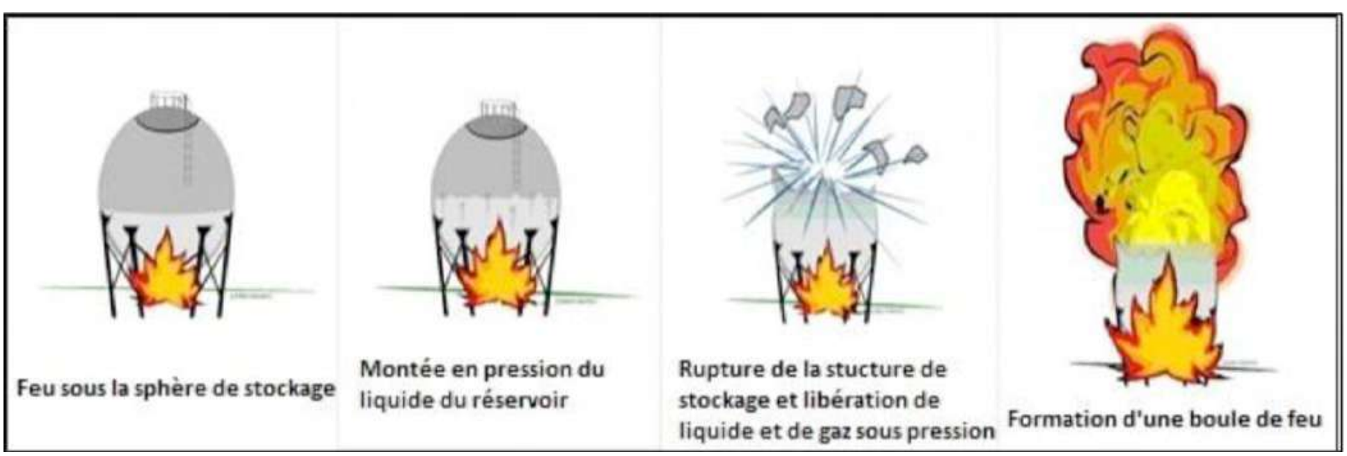


Figure 5: The different development phases of BLEVE *[14]*

Pressurized liquefied gas storages are likely to be the site of a BLEVE. This is a violent vaporization of an explosive nature following the rupture of a tank containing a liquid at a temperature much higher than its boiling point at atmospheric pressure. One of the causes may be the heating of a storage sphere caught in a fire. This can burst under the effect of internal pressure: fragments are then projected and liquefied gas is released, instantly vaporized. If the gas in question is flammable, a fireball is formed with intense thermal radiation.

UVCE: "Unconfined Vapor Cloud Explosion", explosion of a gas cloud in an unconfined environment (case of the Flixborough accident in 1974, 28 deaths).

Following a flammable gas leak, the mixture of gas and air forms a cloud which, upon encountering an ignition source, can explode. The effects are essentially pressure effects and thermal effects.

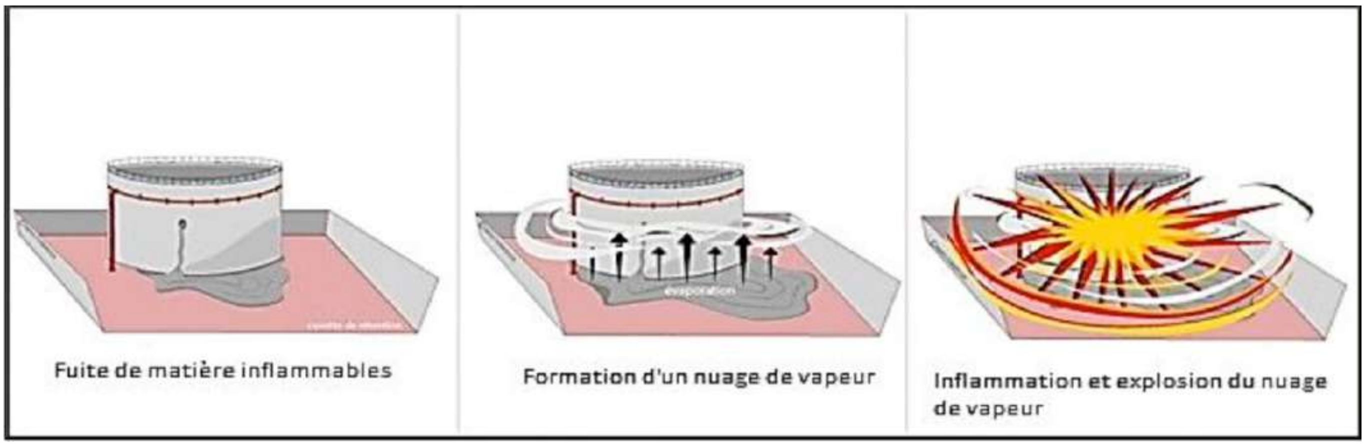


Figure 6: The different phases of development of a UVCE *[14]*

The fire of a stock of products: in warehouses for example: to the thermal effects of the fire itself can be added, depending on the nature of the products stored, risks of explosion and toxic risks.

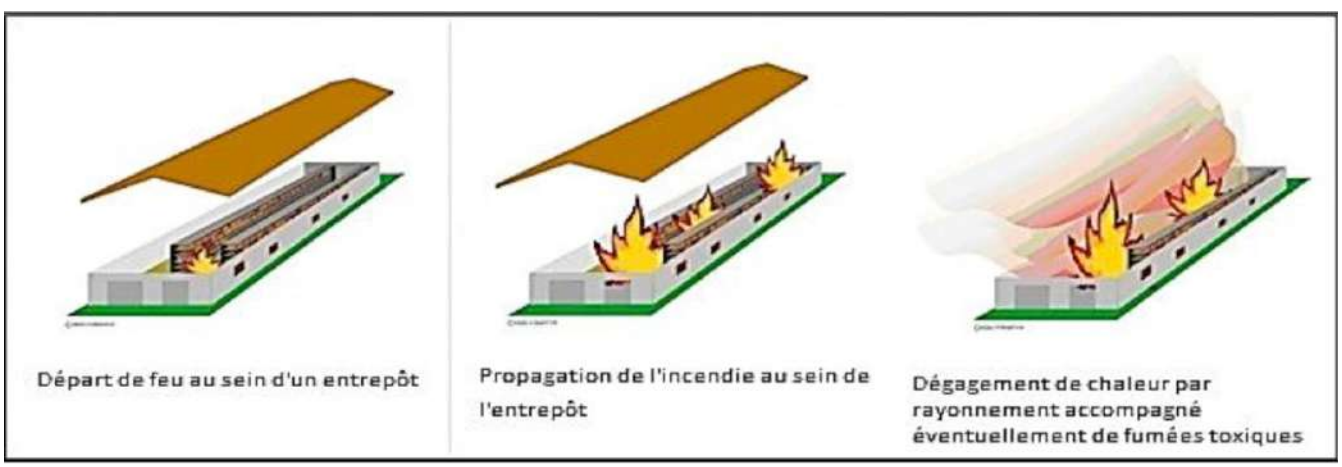


Figure 7: The different phases of fire development in a product stock *[14]*

The emission and dispersion of toxic products: during a major accident, following an explosion, fire or major leak, leading to pollution of the air, water and soil, leading to fatal consequences. (Bhopal accident in 1984) or lasting soil contamination and possible health consequences (Seveso accident in 1976).

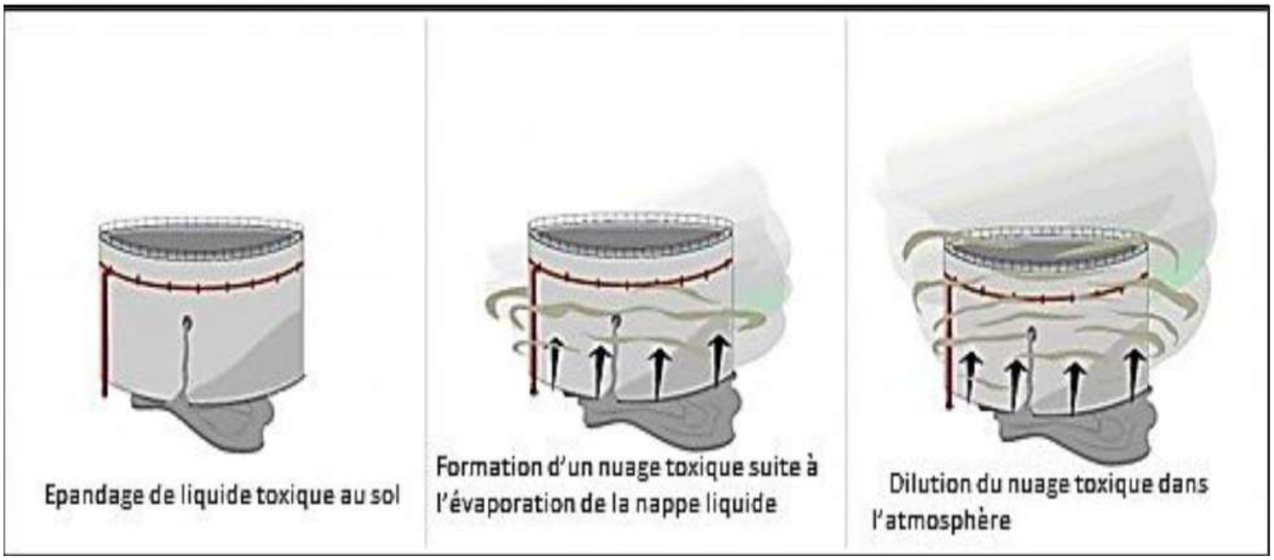


Figure 8: The different phases of development of the emission and dispersion of chemical products *[14]*

A pool fire: when a pool of flammable liquid, produced following the loss of containment of a tank, catches fire. This can generate significant thermal effects.

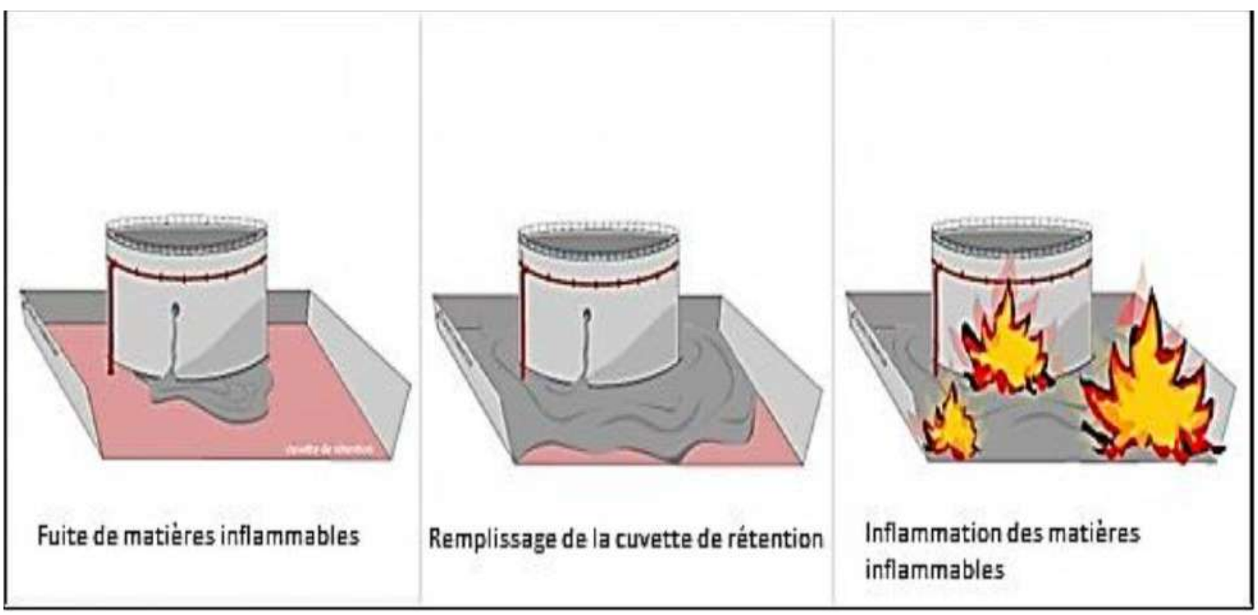


Figure 9: The different phases of development of a pool fire *[14]*

Boil-over : classic or in a thin layer, a phenomenon that can be encountered in the event of a fire in tanks of relatively viscous hydrocarbons (heavy fuel oil, diesel, domestic fuel oil) when water is present at the bottom of the tank.

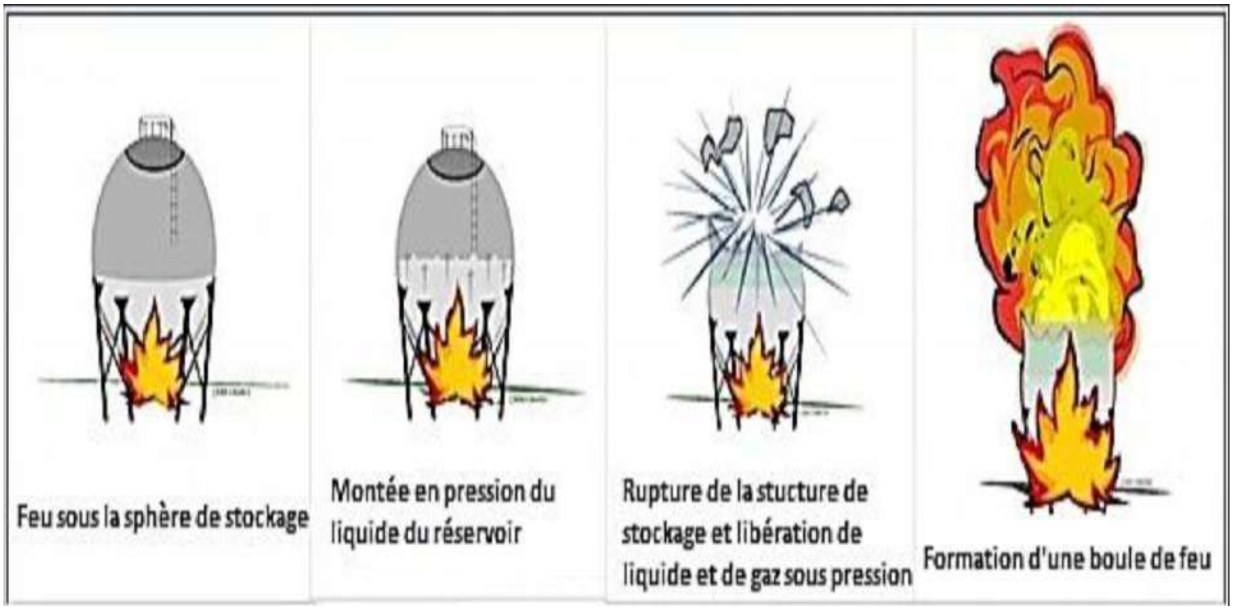


Figure 10: The different phases of development of a BOIL-OVER *[14]*

7. Explosion prevention and protection measures:

Explosion prevention is crucial for ensuring the safety of people and property in many environments, including industrial workplaces, refineries, grain silos, and chemical storage facilities.

Hierarchy of protective measures In accordance with the ATEX Directive 1999/92/EC, explosion prevention should follow a hierarchy aimed at eliminating hazards at the source:

- Prevent the formation of explosive atmospheres: This is the most effective and preferred measure. This involves:
  - Substituting non-flammable or less flammable products for hazardous substances.
  - Designing processes and equipment that prevent the release of flammable substances.
  - Implementing effective ventilation and aspiration systems to remove flammable gases and dusts.
- Eliminate ignition sources: If the formation of an explosive atmosphere cannot be completely prevented, it is crucial to eliminate potential ignition sources, such as:
  - Open flames, sparks, and hot surfaces.
  - Static electricity.
  - Tools and equipment not suitable for explosive atmospheres.
- Implement explosion protection measures: When it is impossible to completely prevent the formation of explosive atmospheres and ignition sources, protection measures must be put in place to limit the consequences of a potential explosion. This may include:

  - Explosion containment: This involves constructing strong enclosures or barriers to contain the explosion and minimize damage to the surroundings.
  - Explosion venting: Explosion venting systems can be installed to quickly evacuate flammable gases and dusts in the event of an explosion, thus reducing the pressure and impact of the explosion.
  - Explosion mitigation: Mitigation systems, such as explosion suppressors or blast panels, can be used to absorb the energy of the explosion and reduce its destructive effects.
- Organizational measures and training In addition to the technical measures mentioned above, it is essential to implement appropriate organizational and training measures to ensure explosion prevention:
  - Develop and implement an explosion risk assessment procedure to identify and analyze the specific risks for each worksite.
  - Implement training and awareness programs to inform employees about explosion hazards, safety procedures, and protective measures to be taken.
  - Establish clear emergency response procedures in the event of an explosion, including evacuation, alerting emergency services, and firefighting.
  - Carry out regular inspections and maintenance of installations and equipment to ensure their proper functioning and prevent failures that could lead to explosions.

Conclusion:

In this chapter, we discussed the fire and explosion safety in general covering all the basics sides.

Fire and explosion safety is paramount for preventing devastating consequences. By implementing the strategies discussed, we can significantly reduce the risk of these events.

CHAPTER II:

Overview of Risk Assessment Methods

Introduction:

Risk assessment is an essential component of risk management, which aims to identify, analyze and prioritize potential risks that a business, project or system may face. The goal is to make informed decisions to mitigate these risks and minimize their negative impact.

In this chapter, we presented certain risk assessment methods: Fire and explosion risk assessment, HAZOP, QRA.

SECTION I: Overview of Fire and Explosion Risk Assessment (FERA).

1. Definition of Fire and Explosion Risk Assessment (FERA):

A Fire and Explosion Risk Assessment (FERA) is a systematic process used to identify and evaluate the potential for fires and explosions within a facility or during an activity. It's a crucial component of ensuring safety and preventing catastrophic events.

2. Key Objectives of FERA:

- **Identify fire and explosion hazards:** This involves pinpointing materials, processes, and equipment that could pose a risk of fire or explosion.
- **Analyze likelihood and impact:** FERA assesses the probability of a fire or explosion occurring and the potential consequences, considering factors like damage to property, injuries, and business disruptions.
- **Develop mitigation strategies:** Based on the risk assessment, FERA recommends actions to minimize the likelihood and severity of fire and explosion events. This could involve implementing control measures like improved ventilation, proper storage of flammable materials, and robust safety procedures. [15, p. 5]

3. General Requirements:

- The FERA study should be done at least for the Upper Tier Major Hazard Facilities and as required for the Lower Tier Major Hazard Facilities. These facilities include process units, equipment, piping, and buildings.
- The FERA study shall be conducted by competent personnel.
- The FERA study shall not be conducted in isolation. It shall consider all other engineering issues and related studies.
- The FERA study shall use appropriate data and the correct level of detail.
- The FERA study shall use appropriate software/models.
- The FERA study shall represent the reality, and the objectives shall be to reduce risk rather than prove acceptability. [15, p. 8]

4. Brownfield:

Fore Existing operating facilities and under development or new expansion projects, the following should be considered:

4.1 For Existing Facilities Where FERA is not Available:

The FERA study shall be carried out at the first available opportunity (earliest).

4.2 For Existing Facilities and a New Expansion to be Established:

An integrated FERA study for the existing and planned facilities shall be carried out.

4.3 For Existing Facilities Where FERA is Available:

The FERA study shall be reviewed and revalidated or updated, if required, based on the following:

- If significant changes happened to the facilities (e.g., modification in process, feed changes, new technology, barriers changes, manning level, fire protection measures, building functionality or building occupancy, etc.) are observed or carried out.
- Every five years to ensure integrated Risk from all existing facilities, including modification and brownfield projects, is considered.
- During developing and updating the COMPANY Safety Case study, if the FERA study is required in the Safety Case.

Suppose no significant changes have been identified over five years, and the outcomes of previous FERA studies are still valid and technically robust. In that case, no update is required for the FERA. The COMPANIES shall develop a technical justifying note for revalidation of the study with relevant supporting documents. [15, p. 9]

5. FERA Methodology:

The basis of the FERA study methodology is to identify incident scenarios and evaluate the risk by defining the frequency of failure, the probability of various consequences, and the potential impact of those consequences on different facilities. The Methodology of the FERA study could be summarized in the following main tasks:

1. Set the FERA scope and define the assumption register contents.

2. Hazard identification, including defining the potential event sequences and potential incidents.

3. Evaluate the incident outcomes (consequences) using typical tools, including vapor cloud dispersion modeling and fire and explosion effect modeling.

4. Identify different receptors to be evaluated (e.g., hydrocarbon handling equipment, critical structures, buildings, etc.).

5. Estimate the incident impacts (consequences) on different receptors against the plant/structure vulnerability criteria.

6. Estimate the failure case frequencies.

7. Combining the potential consequence for each event with the event frequency over all events.

8. Estimate the risk for each of the different receptors against the risk tolerability criteria.

9. Identify and prioritize potential Risk Reduction Measures if required.

The FERA study methodology flowchart is illustrated in Figure 11. [15, pp. 9,10]

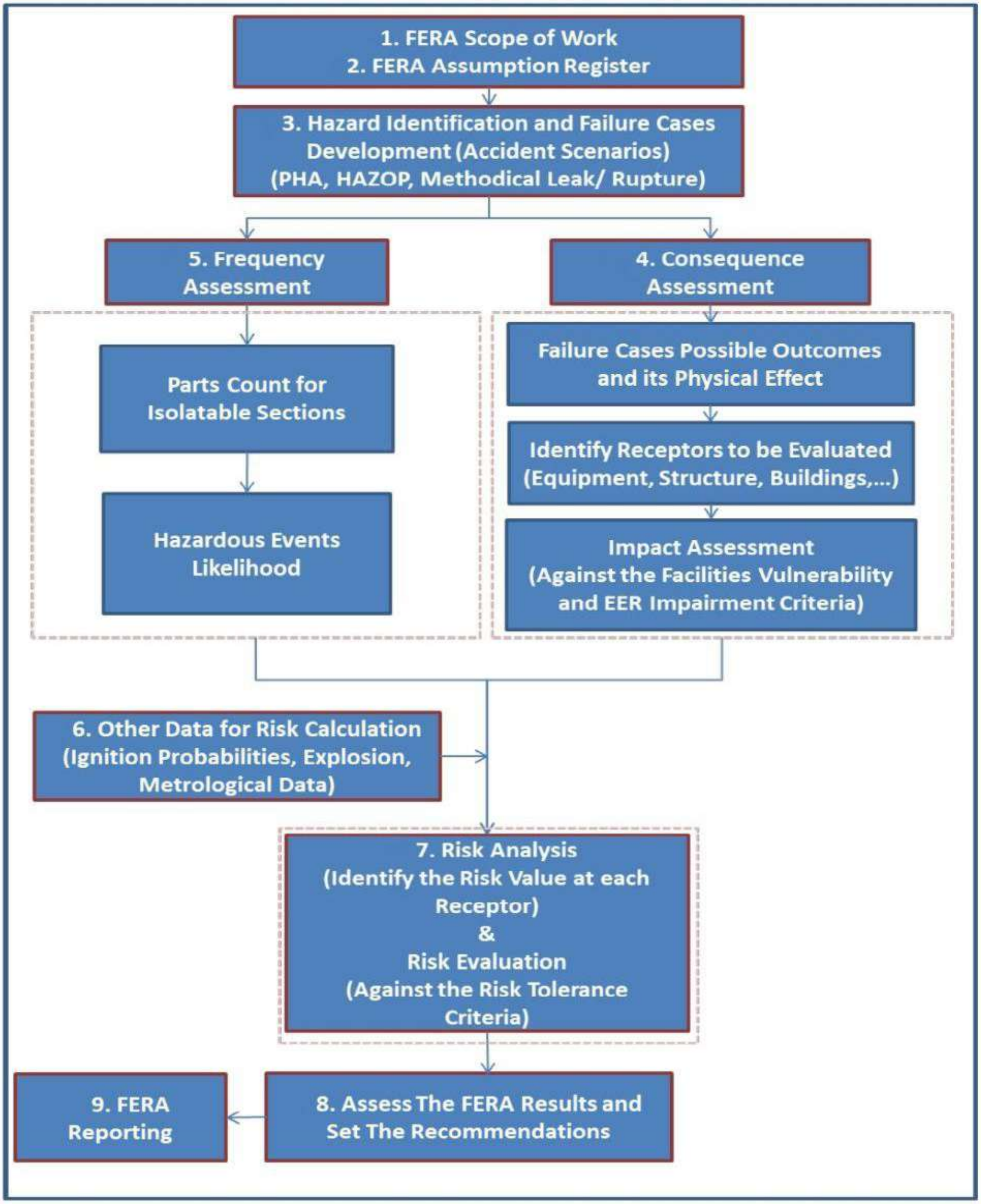


Figure 11: The FERA study methodology flowchart. *[15, p. 10]*

5.1 FERA Study Scope of Work :

The COMPANY is responsible for identifying the FERA study scope of work and submitting it to the FERA consultant/executor to prepare the assumption register to start the execution of the study. The scope of the study shall be submitted to or prepared in co-operation with the COMPANY' Process Safety internal concerned department. The scope of work of a FERA study includes the necessary details to define the FERA as a single document and includes:

- The Objective of the FERA Study
- The Facility Description
- Different Receptors to be evaluated
- Types of Risks to be evaluated:

The FERA study identifies the Major Hazards, evaluates the associated likelihood and consequences to the different facilities, and calculates the risk levels of facilities in a numerical way for comparing with the:

- The vulnerability criteria (consequence approach).
- The risk tolerability criteria (risk-based approach).

- FERA Deliverables:

The scope of work must define the FERA study Report main deliverables, which shall include:

- Hazard identification (potential hazardous events).
- The incident scenarios include the causes and the consequences/impact analysis.
- Estimate the likelihood of events.
- Risk estimation and evaluation for all receptors.
- Input for assessing the requirements of passive and active fire protection (PFP & AFP).
- Input for the evaluation of the requirements of blast protection for the buildings.
- Input for the EER Assessment.
- Providing inputs for developing the fire zones.
- Proposal for Risk-reduction measures.
- Re-evaluation of the Risk considering the study recommended risk reduction measures.

- Boundaries of the FERA study:

The boundaries of the FERA study should clearly define which facilities' hazards (including neighboring facilities) are to be included, or excluded, from the study.

- The Software Requirements and the Study Copies:

The software to be used for the FERA study should be valid, internationally recognized, and licensed. The consultant should provide the software name, version, license number, and validation certificate.

- Identification of Resources
- Kick-Off Meeting
- Finalize the Scope of Work [15, p. 11.12.13.14]

5.2 The Assumption Register:

After the kick-off meeting and finalize the scope of work between the COMPANY and the consultant, the consultant shall establish the study Assumption Register to show:

- The study has different assumptions.
- The available data to be used.
- The alternatives and assumptions for the missing data (if any).
- The references to be used. [15, p. 14]

5.3 Hazard Identification:

All potential Major Accident Hazards associated with the facility or operation shall be taken forward for FERA assessment. The potential hazardous event is usually called the 'top event'.

Hazard Identification techniques (e.g., QRA, HAZOP) along with the COMPANY Major Accident Hazard (MAH) list and the accidents that have occurred in the oil and gas industry and are relevant to the COMPANY operations are used to identify the Major Hazards associated with project. [15, p. 16]

5.4 Consequence Assessment:

The FERA study uses Event Trees to model the chronological series of events. The Event Tree provides a systematic method to ensure all potential outcomes because of a specified top event are identified. The most common possible outcomes from different hydrocarbons releases are:

- **Jet Fire:** A jet fire is a turbulent diffusion flame resulting from the combustion of a high velocity, usually from a pressurized source of fuel continuously released with significant momentum in a particular direction. The flame can emit high levels of radiant heat into the surrounding area. Jet fire events are considered to occur following the immediate ignition of a continuous release involving flammable fuel.
- **Pool Fire:** A pool fire is a type of diffusion flame that occurs when a flammable liquid fuel spills or leaks onto a horizontal surface and ignites. The fuel vaporizes and burns above the liquid pool, creating a radiant heat source.
- **Flash fire:** A flash fire is a rapid, short-lived combustion event that happens when a flammable vapor-air mixture encounters an ignition source. The vaporized fuel rapidly ignites, creating a sudden surge of heat and radiation. Flash fires are often characterized by their intense radiant heat, which can cause severe burns and even ignite clothing over long distances.
- **Explosion (VCE - Vapor Cloud Explosion):** A VCE occurs when a flammable vapor cloud formed from a leaked or spilled hydrocarbon ignites and undergoes a rapid, violent combustion. This rapid combustion creates a pressure wave that can cause significant structural damage, injuries, and even fatalities.
- **Fireball / BLEVE (Boiling Liquid Expanding Vapor Explosion):** A fireball is a burning fuel-air cloud whose energy is emitted primarily from radiant heat. Fireballs were considered to occur following the immediate ignition of large vapor releases. They were also possible

following the immediate ignition of a large release of liquefied gas. Fireball durations are typically 5–20 seconds; thus, the heat loads are unlikely to damage any equipment

- **Flammable Gas Dispersion:** flammable gas dispersion is a critical aspect to consider. It refers to the process by which a released flammable gas spreads and mixes with the surrounding air. Understanding dispersion patterns is essential for evaluating the potential for fire and explosion hazards.

The possible outcomes (consequences) of various failure cases (accident scenarios) for a given release profile for each scenario under consideration are shown as a guide in Table 1. [15, pp. 16-20]

Table 1: Possible outcomes for each failure case category (typical industry practice). *[15]*

Failure Case Category	**Possible Outcomes (Consequences)**					
	Jet fires	**Pool fires**	**Fireballs**	**BLEVEs**	**Flash fires**	**Explosions**
1. Pipework, risers, valves, flanges, fittings, and associated equipment	Y	Y	N	N	Y	Y
2. Pressure vessels/tanks	Y	Y	Y	Y	Y	Y
3. Atmospheric storage tanks	N	Y	N	N	Y	Y
4. Intermediate bulk containers	N	Y	N	N	N	N
5. Pipelines	Y	Y	N	N	Y	Y
6. Flexible hoses	Y	Y	N	N	Y	Y

5.5 Frequency Assessment:

- **Hazardous Events Likelihood:**

There are two basic forms that the likelihood of an event may be expressed:

- Frequency: number of events or outcomes per defined unit of time (e.g., a 6-inch ESD valve has a failure frequency of 10-4 times per year).
- Probability: the measure of the chance of occurrence expressed as a number between 0 and 1, where 0 is an impossibility and 1 is an absolute certainty.
  - **Frequency Estimation:**

The failure frequency for each failure case for each isolatable section needs to be represented by one frequency value. The failure frequency for the failure case is the sum of the failure frequencies of the base elements multiplied by the number of base elements. In general, the failure case frequency is given by this simple equation:

$$F = \sum_{i=i}^{n} n_i f_i$$

Where:

F: is the frequency of incidents.

$n_{i:}$ is the number of base elements i.

f_i: is the frequency of failure for base elements i. [15, p. 25]

5.6 Other Data for Risk Calculation:

To complete the Risk Calculation, some other data should be collected, calculated, and considered (e.g., Process and Plant Data, Chemical Data, Environmental Data). Hereafters are some of the most important required data:

5.7 Risk Analysis & Evaluation:

The outputs from the previous sections are combined in the risk model (the software) to create the risk values for each different failure scenarios category (i.e., jet fire, pool fire, and explosion) which are used for assessing the risk at different receptors.

Once risks are identified and analyzed for different failure scenarios categories, the risks should be evaluated against set Criteria.

Table 2: Facilities risk tolerability criteria. *[15, p. 27]*

	Onshore and offshore receptors/components
Unacceptable Risk (Exceeding the Upper Tolerability Limit)	**$\geq 10^{-3}$ (0ccurance per Year)**
ALAR P	**$< 10^{-3}$ & $> 10^{-5}$ (0ccurance per Year)**
Broadly Acceptable Risk (Under the Lower TolerabilityLimit)	**$\leq 10^{-5}$ per year (0ccurance per Year)**

5.8 Assess the FERA Study Results and Set the Recommendations:

Once you've completed the FERA (Fire and Explosion Risk Assessment) study, it's crucial to analyze the results and translate them into actionable recommendations for improving safety.

5.9 FERA Reporting:

FERA (Fire and Explosion Risk Assessment) reporting is a crucial step in effectively communicating the findings and recommendations of a FERA study to relevant stakeholders. A well-structured FERA report ensures that the identified hazards, potential risks, and mitigation strategies are clearly understood and actionable steps can be taken to improve safety. [15, p. 34]

SECTION II: Overview of Quantitative Risk Assessment (QRA) Method

1. History of QRA method:

The terms QRA (Quantitative Risk Assessment), PSA (Probabilistic Safety Assessment) and PRA (Probabilistic Risk Analysis) are used synonymously in different industries to describe various techniques for evaluating risk. Whilst quantification of risk for specific issues has been around for a long time, the grandfather of modern probabilistic assessment of the overall risk for an entire major hazard facility.

Is generally accepted to be WASH- 1400, commissioned by the US Nuclear Regulatory Commission in 1975. This quantified the safety risks associated with the operation of all electricity generating nuclear power plants in the US. The nuclear industry led the way, motivated by a desire to demonstrate that the actual risk was less than other industrial facilities and counter the public's perception that nuclear stations are very risky because the worst case consequences are potentially so catastrophic. It is not surprising that the petro- chemical industry followed suit shortly after, since the toxic effects of large chemical releases can disperse many miles and affect large numbers of people in local towns and cities. Explosion effects can also be devastating. For example, an explosion in 1974 at the Flixborough chemical plant in the UK killed 28 people. One of the first major QRAs for petrochemical installations was of the highly industrial area of Canvey Island near London, in 1978. [16]

2. What is QRA? :

Is a systematic approach used to evaluate risks associated with a process, activity, or system. It involves the quantitative estimation of the probability of occurrence of adverse events and the magnitude of their consequences, and the frequency at which a release of the hazard may be expected to occur. These aspects are then combined in order to obtain numerical values for risk – usually risk of fatality. QRA includes consideration of all identified hazardous events in order to quantify the overall risk levels. QRA is commonly used in various industries, including chemical, nuclear, aerospace, and finance, to ensure safety, reliability, and regulatory compliance.

QRA is probably the most sophisticated technique available to engineers to predict the risks of accidents and give guidance on appropriate means of minimising them. Nevertheless, while it uses scientific methods and verifiable data, QRA is a rather immature and highly judgemental technique, and its results have a large degree of uncertainty. Despite this, many branches of engineering have found that QRA can give useful guidance. However, QRA should not be the only input to decision-making about safety, as other techniques based on experience and judgement may be appropriate as well. [17]

3. The Key Components of QRA:

Figure 12 illustrates the classical structure of a risk assessment. It is a very flexible structure, and has been used to guide the application of risk assessment to many different hazardous activities. With minor changes to the wording, the structure can be used for qualitative risk assessment as well as for QRA.

The first stage is system definition, defining the installation or the activity whose risks are to be analysed. The scope of work for the QRA should define the boundaries for the study, identifying which activities are included and which are excluded, and which phases of the installation's life are to be addressed.

Then hazard identification consists of a qualitative review of possible accidents that may occur, based on previous accident experience or judgement where necessary. There are several formal techniques for this, which are useful in their own right to give a qualitative appreciation of the range and magnitude of hazards and indicate appropriate mitigation measures. This qualitative evaluation is described in this guide as 'hazard assessment'. In a QRA, hazard identification uses similar techniques, but has a more precise purpose - selecting a list of possible failure cases that are suitable for quantitative modelling.

Once the hazards have been identified, frequency analysis estimates how likely it is for the accidents to occur. The frequencies are usually obtained from analysis of previous accident experience, or by some form of theoretical modelling.

In parallel with the frequency analysis, consequence modelling evaluates the resulting effects if the accidents occur, and their impact on personnel, equipment and structures, the environment or business. Estimation of the consequences of each possible event often requires some form of computer modelling, but may be based on accident experience or judgements if appropriate.

When the frequencies and consequences of each modelled event have been estimated, they can be combined to form measures of overall risk. Various forms of risk presentation may be used. Risk to life is often expressed in two complementary forms:

- Individual risk - the risk experienced by an individual person.
- Group (or societal) risk - the risk experienced by the whole group of people exposed to the hazard.

Up to this point, the process has been purely technical, and is known as risk analysis. The next stage is to introduce criteria, which are yardsticks to indicate whether the risks are acceptable, or to make some other judgement about their significance. This step begins to introduce non-technical issues of risk acceptability and decision-making, and the process is then known as risk assessment.

In order to make the risks acceptable, risk reduction measures may be necessary. The benefits from these measures can be evaluated by repeating the QRA with them in place, thus introducing an iterative loop into the process. The economic costs of the measures can be compared with their risk benefits using cost-benefit analysis.

The result of a QRA is some form of input to the design or on-going safety management of the installation, depending on the objectives of the study. [17]

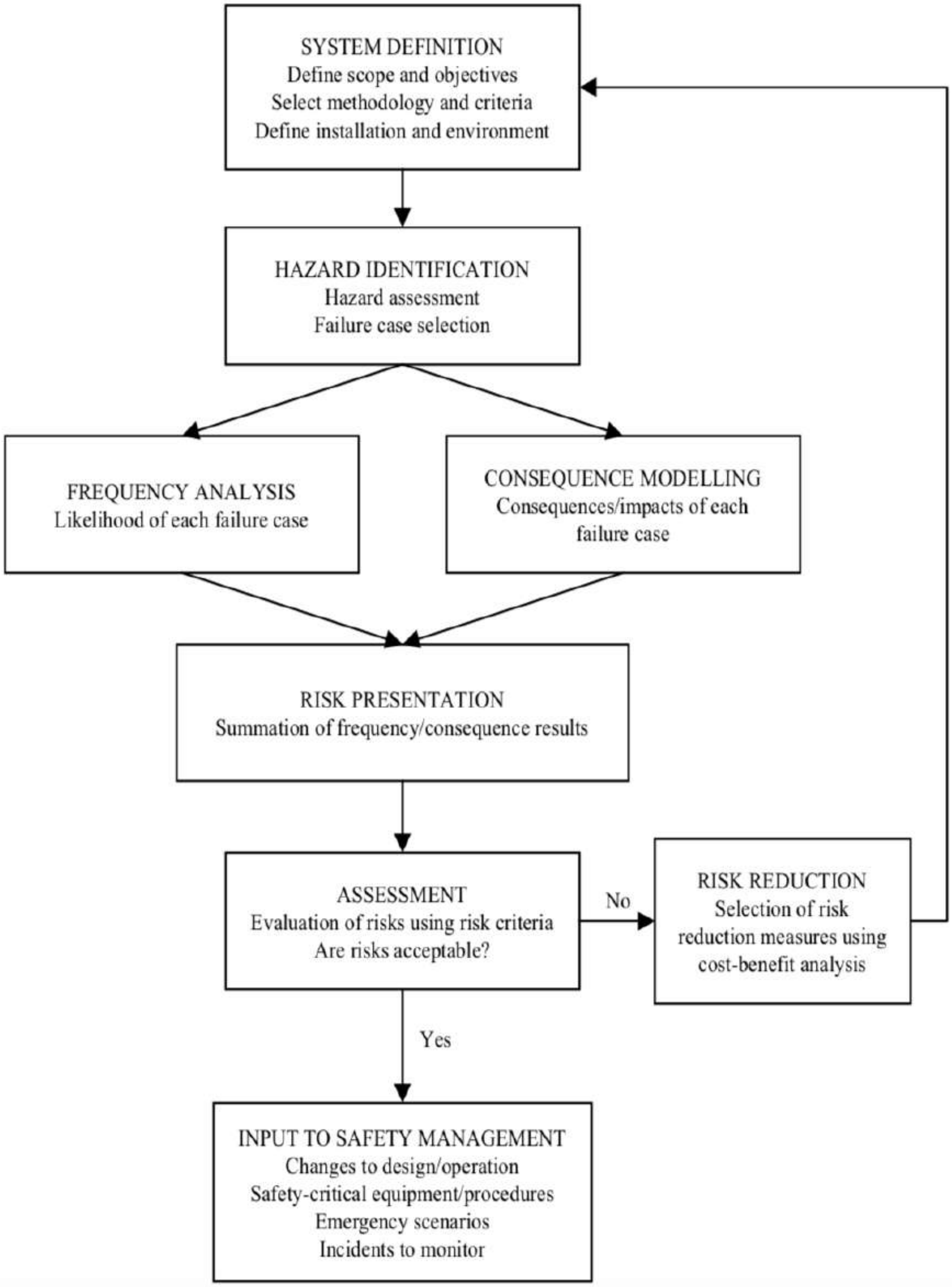


Figure 12: *The QRA study methodology flowchart.* [17]

4. Objectives of QRA :

The risk management approach planned as part of the study of dangers and environmental impacts of industrial processes provides for the quantitative analysis of risks and the identification of measures to prevent major technological accidents. Its objectives are:

- Identify the different sources of potential dangers and nuisances generated by the classified establishment.
- Reduce risks at source: better knowledge of risks makes it possible to make modifications to the process under study (reduction in the quantity of dangerous materials, modification of the location of equipment, etc.).
- Inform public authorities: knowledge of risks allows responsible authorities to judge the environmental acceptability of the project and/or process under study by considering safety and the proposed management measures.
- Inform the public: public participation is an essential dimension of the procedure for studying environmental hazards and impacts; risk analysis is a public information tool which must be easily accessible.
- Plan emergency measures taking into account major risks: the project owner must, in consultation with public authorities, develop intervention plans for accidents with major consequences in order to adequately prepare those involved. [18]

5. Advantages of Quantitative Risk Assessment (QRA):

❖ **Precision and Objectivity:**

- **Advantage:** Utilizes numerical data to provide precise and objective risk estimates.
- **Impact:** Facilitates informed decision-making based on concrete evidence.

❖ **Early Risk Identification:**

- **Advantage:** Enables early identification of potential hazards and risk scenarios.
- **Impact:** Allows for preventive measures to be implemented before incidents occur.

❖ **Resource Optimization:**

- **Advantage:** Helps allocate resources effectively by focusing on the highest risks.
- **Impact:** Enhances the efficiency of investments in safety and risk management.

❖ **Regulatory Compliance:**

- **Advantage:** Assists in meeting safety and environmental regulations and standards.
- **Impact:** Reduces the risk of legal penalties and improves the organization's reputation.

❖ **Continuous Improvement:**

- **Advantage:** Provides a basis for continuous improvement in safety and risk management practices.

- **Impact:** Enables learning from previous analyses and optimizing processes accordingly.

❖ **Decision Support:**

- **Advantage:** Supplies detailed information to support strategic and operational decision-making.
- **Impact:** Improves decision quality through a deep understanding of risks.

❖ **Effective Risk Communication:**

- **Advantage:** Facilitates the communication of risks and management measures to stakeholders.
- **Impact:** Increases transparency and builds stakeholder trust.

6. Disadvantages of Quantitative Risk Assessment (QRA):

❖ **Complexity and Cost:**

- **Disadvantage:** QRAs can be complex and expensive to conduct, requiring specialized skills.
- **Impact:** May represent a financial and resource burden for small organizations.

❖ **Data Availability and Quality:**

- **Disadvantage:** The accuracy of QRA depends on the availability and quality of data.
- **Impact:** Incomplete or poor-quality data can lead to inaccurate risk estimates.

❖ **Assumptions and Uncertainties:**

- **Disadvantage:** QRAs often rely on assumptions and models that can introduce uncertainties.
- **Impact:** Results can be sensitive to variations in the assumptions and parameters used.

❖ **Time-Consuming:**

- **Disadvantage:** QRAs can be time-consuming, especially for complex systems.
- **Impact:** May delay decision-making and the implementation of risk management measures.

❖ **Resistance to Change:**

- **Disadvantage:** Recommendations based on QRAs may sometimes face organizational resistance.
- **Impact:** Can limit the effectiveness of proposed risk reduction actions.

- ❖ Over-Reliance on Models:
  - **Disadvantage:** There is a risk of over-reliance on models and quantitative results.
  - **Impact:** May lead to underestimation of unmodeled risks or important qualitative aspects.
- ❖ **Technological Dependence:**
  - **Disadvantage:** QRAs often depend on advanced software and technological tools.
  - **Impact:** Requires additional investments in technology and training.

SECTION III: Overview of Hazards and Operability Study (HAZOP)

Among the most important elements and methods of risk analysis is HAZOP, as it is considered to be the basis for industrial safety and security systems and policies of several companies, whether in Algeria or worldwide. Given the great importance of the HAZOP risk analysis method, we provide some basic information and concepts related to this efficient and reliable method in the field of industrial safety and security. And a Hazards and Operability Study (HAZOP), conducted by a team, is a detailed process for identifying hazards and operational problems. The HAZOP study focuses on identifying potential deviations from design intent, examining their probabilities of occurrence and possible causes, and assessing their consequences.

1. History of HAZOP:

The HAZOP study method was developed by Imperial Chemical Industries (ICI) in the 1960s and its use and development was encouraged by the Chemical Industries Association (CIA) Guide published in 1977. Since then it has been become the technique of choice for many people involved in designing new processes and operations. [19]

2. Definition of HAZOP:

HAZOP study is a process hazard analysis procedure originally developed by ICI in the 1970s. The method is highly structured and divides the process into different operational nodes and studies the behavior of different parts of each node over the basis of a set of possible deviation conditions or guide words. [20, p. 21]

3. Characteristics of the HAZOP study:

The main characteristics of a HAZOP study include:

- ❖ Study is a creative process. It involves using a series of guide words to identify potential deviations from the design intent and using these deviations as “triggers” to stimulate the imagination of team members in investigating the causes of the deviation and in the evaluation of the consequences that they may generate.
- ❖ The study takes place under the direction of a qualified and experienced study leader. This ensures that an exhaustive examination of the system is carried out using logical and analytical thinking. Preferably, the study leader is assisted by a scribe who notes the dangers and/or disturbances identified with a view to their evaluation and the search for solutions.

- ❖ The quality of the study is based on the qualifications and experience of the specialists forming the team. These specialists from various disciplines must demonstrate intuition and insight.
- ❖ The examination should be carried out in a climate of positive thinking and frank discussion. When a phenomenon is identified, it is noted for later evaluation and resolution.
- ❖ Problem solutions are not the primary focus of the HAZOP study, but may, if appropriate, be noted and passed on to the design team. [21]

4. Objectives of the HAZOP:

- ➢ HAZOP identifies potential hazards, failures and operability problems.
- ➢ For identifying cause and the consequences of perceived mal-operations of equipment and associated operator interfaces in the context of the complete system.
- ➢ Analyze deviations from the intended design or operational intent that could lead to hazardous situations.
- ➢ To check adequacy of existing safeguards and propose new safeguards to reduce risk.
- ➢ Structured & Systematic Qualitative approach to identify:
    - Risk to personnel
    - Risk to environment,
    - Risk to equipment,
    - Operability issues.
- ➢ Its use results in fewer commissioning and operational problems and better informed personnel, thus confirming overall cost effectiveness improvements. [21]

5. Procedure of HAZOP:

A study can only be carried out when a detailed description of the process and a complete design are available. Study boundaries must be defined covering the items of equipment to be examined and the modes of operation that must be examined. The study itself is carried out by a team of experienced personnel, mainly from the factory itself, chosen for their knowledge of the factory, the process and the site, the operating and control systems, the potential hazards and other problems.

Important elements of a HAZOP study include its specification, team composition, study preparation, detailed analysis in team meetings, and report preparation. [19]

To carry out a HAZOP analysis, this method must be structured in a table:

Table 3: HAZOP template *[22]*

Study Node	Process Parameter	Guide Word	Deviation	Possible Causes	Possible Consequences	Action Required	Responsible	Target Date	Completed Date
1	2	3	4	5	6	7	8	9	10

5.1 Explanation of the table:

1) Study Node:

The first step in HAZOP is breaking down the overall process into a number of simpler elements that are called nodes. Nodes could be the item in the Process Flow Diagram (PFD) or the Piping and Instrument Diagram (P&IDs).

2) Parameter:

Lists all related process parameters for an individual node. The parameters are physical or chemical characteristics of the machine, equipment that is used in the node.

3) Guide Word:

The guide words are adjectives or adverbs used with the parameters to direct the deviation. Below is a list of guide-words, that include but not limited to the following list:

Table 4: Guide Word of HAZOP [22]

Guide Word	Meaning
NO	None of the designed parameter
MORE	Quantitative increase of the parameter
LESS	Quantitative decrease of the parameter
AS WELL AS	Additional activities
PART OF	Part of the designed intent is achieved
REVERSE	Opposite of the design intention
OTHER THAN	Another activity takes place
EARLY	Earlier than a design intention
LATE	Later than a design intention
BEFORE	Relating to the sequence in the process
AFTER	Relating to the sequence in the process
FASTER	Happen but in a less time
SLOWER	Happen but in a longer time

4) Deviation:

The team determines the deviation by combine guide-words and process parameters. Not all combinations exist in an actual process. Process deviation is a combination of process parameters and guide-words.

Combine a guide-word with a parameter to identify the deviations of the process parameter form the design intent.

Example: The process parameter is Air Flow Rate, Guide word is Low -> Deviation (potential) is Low Air Flow Rate.

5) Possible Cause:

"Cause" is always the hard part of HAZOP. Finding the cause of a potential failure mode requires experience and a deep understanding of the process being analyzed. This is also where the team knowledge is needed the most.

6) Possible Consequence:

The consequence of the deviation is defined to determine the severity of the risk if the deviation happens.

7) Action Required:

If there is no existing control for the deviation or existing controls is not enough to prevent or detect the deviation. The action is required to reduce the chance of deviation occur or consequence of the deviation.

8) Responsibility:

A person who has the responsibility for the required actions. The team should clarify the name of the person to prevent a vague understand of responsibility.

9) Target Finished Date:

The date that the responsible person plans to finish the action.

10) Actual Finished Date:

The date that the responsible person finishes the action. [22]

6. Advantages and Disadvantages of HAZOP:

6.1 The benefits:

- Useful in dealing with hazards that are difficult to quantify:
  - Hazards rooted in human performance and behaviour.
  - Hazards that are difficult to detect, analyze, isolate, count, predict, etc.
  - The methodology does not require you to assess or measure the probability of occurrence of the deviation, the severity of the impact or the ability to detect
- Integrated brainstorming methodology
- Systematic and comprehensive methodology
- Simpler and more intuitive than other commonly used risk management tools. [19]

6.2 The inconvenients :

- No way to assess hazards involving interactions between different parts of a system or process
- No ability to rank or prioritize risks; Teams can optionally integrate the required capacity
- No way to assess the effectiveness of existing or proposed controls (safeguards)
- May need to interface HAZOP with other risk management tools (e.g. HACCP) for this purpose. [19]

7. HAZOP Study Applications:

Originally, the HAZOP study was a technique developed for systems involving the treatment of a fluid medium or other material flows in processing industries, particularly the chemical and petroleum process industries. However, its field of application has continued to expand in recent years, and the HAZOP technique is applied today, for example:

- Software applications, including programmable electronic systems.
- Systems ensuring the movement of people by different modes, such as road transport and rail transport.
- Examining different manufacturing sequences and operating procedures.
- The evaluation of administrative procedures in different industries.
- The evaluation of specific systems, such as medical devices.

The HAZOP study is particularly useful in identifying weaknesses in systems requiring the movement of materials, people or data, requiring a certain number of events or activities in a planned sequence or procedures controlling this sequence. The HAZOP study is not only a valuable tool for the design and development of new systems. It can be used profitably to examine potential hazards and problems associated with different operating states of a given system (starting, waiting, normal operation, normal shutdown, emergency shutdown, etc.). It can also be used in batch and steady state manufacturing processes and sequences, as well as continuous sequences. The HAZOP study can be considered as an integral part of the overall process of good engineering and risk management. [21]

8. Relationship with other analysis tools:

The HAZOP study can be used in combination with other operational safety analysis methods, such as failure modes, effects and criticality analysis (FMECA) and fault tree analysis (AAP). Such combinations can be used in the situations set out below:

- The HAZOP study clearly indicates that the operating qualities of a specific entity of the equipment are critical and must be examined in depth. In this case, it is advantageous to complete the HAZOP study with an FMEA from the same entity.
- Following the HAZOP study of deviations by element or characteristic, it is possible to analyze the effect of multiple deviations or to quantify the possibility of failures using an AAP.

The HAZOP study is an approach centered essentially on the system, unlike the FMEA which is centered on the component. Indeed, FMEA starts from a possible failure of a component, to then study the consequences of this failure on the entire system. The study is therefore only in the direction of cause and effect. This concept differs from that of a HAZOP study which begins by identifying possible deviations from the design intent and, from there, proceeds in two directions, one to look for possible causes of the deviation and l 'other to deduce the consequences. [21]

9. Limitations of the HAZOP study:

- Although HAZOP studies have demonstrated extreme utility in different environments, the technique has limitations that must be taken into account when choosing its application:
- The HAZOP study is a hazard identification technique that methodically examines the effects of deviations on each party. Sometimes a danger comes from an interaction between a numbers of parts of the system. This requires a more detailed study of the danger, using techniques such as event tree analysis or fault tree analysis.
- As with any technique for identifying hazards or operational problems, there is no guarantee that the HAZOP study will identify all hazards or all operational problems. Therefore, it is preferable that the study of a complex system does not rely solely on a HAZOP study. In general, this technique is used in combination with other techniques appropriate to the system studied. It is essential to integrate other relevant studies to obtain an effective risk management system.

- A large number of systems are closely interrelated and a deviation in one of them can have a cause elsewhere. Appropriate local intervention may not target the actual cause and may not prevent an accident from occurring later. Many accidents have occurred following minor local modifications whose knock-on effects elsewhere had not been anticipated. Although this problem can be remedied by shifting the implications of deviations from one party to another, this is often not achieved in practice.
- The success of a HAZOP study depends largely on the ability and experience of the study leader, the knowledge of the team members and their interactions.
- The HAZOP study only considers the parts that appear on the design plans. Activities and operations that do not appear there or are not mentioned by team members are not taken into account. [21]

Conclusion:

In this chapter, we explored some of the different methodologies and tools for conducting risk assessments, with an emphasis on Fire and Explosion Risk Assessment method.

The insights gained from this chapter underscore the importance of a structured and systematic approach to managing risk, which is vital for ensuring safety, compliance, and operational efficiency.

CHAPTER III:

Presentation of ENAFOR Company, Application of Fire and Explosion Risk Assessment for drilling rig and simulation by aloha software.

Introduction

In this chapter we covered all the information about the ENAFOR Company and rig site ENF51, starting with its history, Missions, then we finished this Section 1 with Organizational Structure of ENAFOR and in section 2 we made example for application of the Fire and Explosion Risk Assessment study on drilling rig ENF51.

We finished this chapter by explain the Software programme and simulation results.

SECTION I: *Presentation of ENAFOR Company*.

1. General presentation of ENAFOR:

- Entreprise nationale algérienne du forage (ENAFOR) in French.
- Algerian National Drilling Company (ENAFOR) In English.

The National Drilling Company ENAFOR is a responsible actor committed to the path of economic, social, and sustainable development progress. Its main mission is to carry out drilling and workover services to actively contribute to the development and replenishment of energy reserves for current and future generations. These missions must always remain present in the management's mind so that all actions are undertaken in line with the overall strategy outlined by SONATRACH. [23, p. 2]

1.1 History of the company:

- On April 28, 1966, ALFOR, a joint venture between SONATRACH and SEDCO, was established. The company's capital was owned 51% by SONATRACH and 49% by SEDCO.
- The National Drilling Company (ENAFOR), resulting from the restructuring of SONATRACH, was created by decree No. 81.170 on August 1, 1981, and was established on January 1, 1982, by ministerial decree of December 31, 1981, with the effective date of substitution of the ENAFOR Company for SONATRACH in some of its competencies: ENAFOR thus took over all human, material, and infrastructural resources of the ALFOR Company (a subsidiary of SONATRACH and SEDCO).
- On November 26, 1989, ENAFOR became an autonomous company in the form of a joint-stock company (SPA), with a capital of 20,000,000 Algerian dinars, owned by the Mines Fund at 40%, the Chemical/Petrochemical/Pharmaceutical Fund at 30%, and the Agri-food Fund at 30%.
- In 1995, as part of the company's restructuring measures, ENAFOR's share capital was increased to 400 million Algerian dinars. At the same time, the Chemical-Petrochemical and Pharmaceutical and Agri-food Funds, which were the primary shareholders of the company, were replaced by the Mines Fund, which became the sole shareholder.
- In 1996, the Holding Company "Realizations and Major Works (R.G.T.)" replaced the Mines Fund to become the main and sole shareholder of ENAFOR.

- On March 30, 1998, SONATRACH (Holding SSP) became the majority shareholder with 51% of the shares. The remaining 49% of shares were held by the Holding Company "R.G.T.", then by the Holding Company "R.M.C." during the year 2000.
- On July 3, 2001, An Extraordinary General Meeting of the company's shareholders held, decided to increase the share capital to 660 million Algerian dinars, by incorporating legal and optional reserves.
- On June 17, 2002, an Extraordinary General Meeting of Shareholders decided on:
    - Bringing ENAFOR's statutes into compliance by the effective transfer of shares from the holding company S.S.P. to the holding company S.P.P. attached to SONATRACH and from the Holding R.M.C. to the holding S.G.P.-Traven, following a redeployment.
    - Increasing the company's share capital from 660 million Algerian dinars to billions of Algerian dinars. Shares held by each of the two Holding Companies were maintained in proportions of 51% and 49%, respectively, for SONATRACH S.P and S.G.P. Traven.
- In 2005, the 49% of shares held by S.G.P. Traven were transferred to the Holding Company "INDJAB".
- In 2006, the holding company SONATRACH S.P.P. became the main and sole shareholder by acquiring the 49% shares held by S.P.P. "INDJAB".
- On December 31, 2007, the General Assembly of Shareholders decided on the revaluation surpluses of tangible assets within the framework of executive decree No. 07/210 of 07/04/2007 and the increase of the share capital from 4 to 14.8 billion Algerian dinars. Since October 16, 2019, the company's share capital has increased from 14.8 billion to 50 billion Algerian dinars. [23, p. 2]

1.2 Equipment Park:

ENAFOR has a fleet of 52 heavy, medium, and light-duty equipment, their types are listed in the following table:

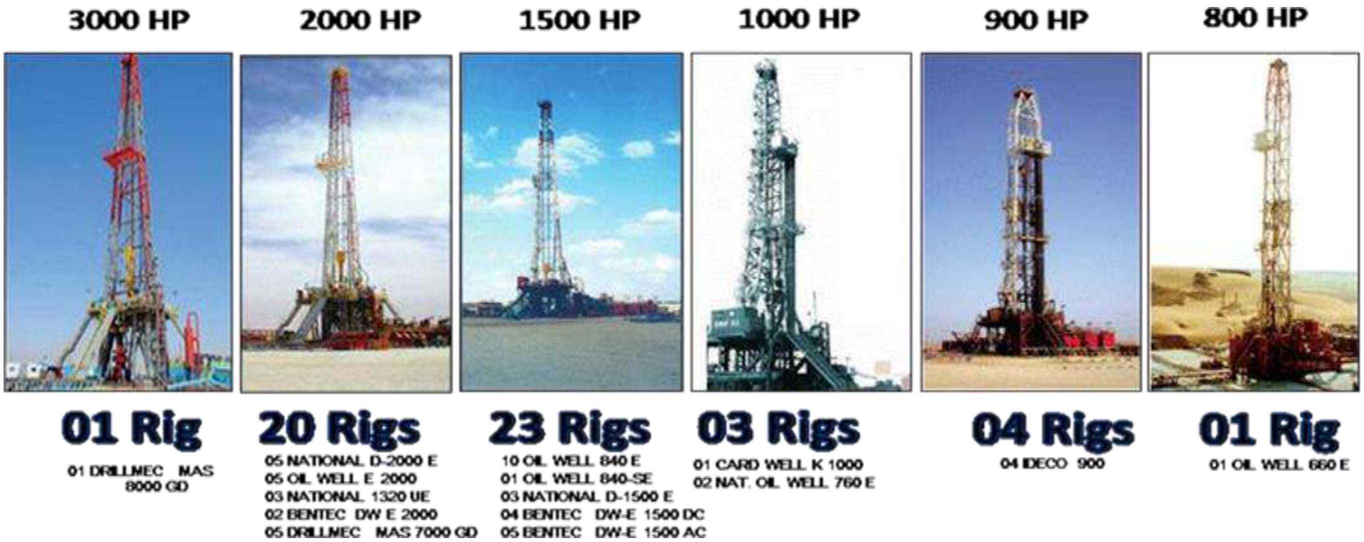


Figure 13: Types of ENAFOR Rigs [23, p. 4]

Table 5: List of Rigs types *[23, p. 4]*

ype d'appareil	3000 HP	2000 HP	1500 HP	1000 HP	900 HP	800 HP	Total
DRILLMEC MAS 8000 GD	1						**1**
NAT OIL WELL D-2000E		5					**5**
OIL WELL E-2000		5					**5**
NATIONAL 1320 UE		3					**3**
BENTEC DW E 2000		2					**2**
DRILLMEC MAS 7000 GD		5					**5**
OIL WELL 840-SE			1				**1**
OIL WELL 840- E			10				**10**
NATIONAL OIL WELL D-1500 UE			3				**3**
BENTEC E-1500 DC			4				**4**
BENTEC E-1500 AC			5				**5**
CARDWELL K 1000 E				1			**1**
NATIONAL OILWELL 760E				2			**2**
IDECO 900 E					4		**4**
OILWELL 660 E						1	**1**
Total	**1**	**20**	**23**	**3**	**4**	**1**	**52**

1.3 Company logo:

Figure 14: ENAFOR logo *[23]*

2. presentation of Rig sit ENF51:

The site is approximately 27 km northwest of the town of Hassi Messaoud.

Between Hassi Messaoud and Ouragla.

Latitude: 31°46'44.16''N

Longitude: 5°50'15.72''E

Figure 15: *The location of the Rig sit ENF51*

2.1 technical sheet of the device ENF 51:

ENTREPRISE NATIONALE DE FORAGE
ENAFOR
BP 211 - HASSI MESSAOUD, OUARGLA

Technical sheet - ENF # 51

MAIN SPECIFICATION

MANUFACTURER	NOW
DATE OF CONSTRUCTION	2002
RATING	1000HP
THEORICAL DEPTH (ft m)	
MAST:	NOW
Type	Telescopic
Clear Height (ft)	136
Static Hook Load with 10lines (Lbs)	700 000
SUBSTRUCTURE :	
Type	SLING SHOT
Height (ft -m)	25
Clear Height under rotary beams (ft)	22
Rig Floor Set Back Load (Lbs)	430 000
Rig Floor Casing Load (Lbs)	700 000
DRAWWORKS :	
Make & Type	N.O.W. 760 E
Horsepower Capacity (HP)	1000
Hoisting Capacity (lbs) - 10 Lines	534 000
Drilling line diameter(inche)	1 1/4"
Main Braking	Band System
Auxiliary Braking	BAYLOR 5032
HOISTING EQUIPMENT:	N.O.W.
Crown Block (Tons)	350
Sheaves quantity	5
Traveling Block, Capacity (Tons)	545G350
Hook, Capacity (Tons)	350
ROTARY TABLE:	
Make & Type	N.O.W. C-275
Maximum opening	27 ½
Maximum Static load (Tons)	500
Max table speed (RPM)	400
Gear ratio	3.16
TOP DRIVE SYSTEM:	
Make & Type	
load Capacity (Tons)	
Power (HP)	
Drilling Torque (ft.lbs)	
IRON ROUGHNECK:	
Make & Type	
Pipe range (inch)	
Make-uptorque (ft lbs)	
ROTARY SWIVEL:	
Make & Type	N.O.W. P-300
Rated capacity (Tons)	272
RIG POWER / Drive Group:	
system make	Ross Hill 1400
Engine Make& type	CATERPILLAR 3508 DITA
Generator Sets quantity & model	03 CAT.3508 Diesel Engines + 03 KATO AC
Total Continuous Power	2580 hp
Horse power rating for each set (HP)	860HP
	Complete Rig Camp
	Desert Condition

PUMP Make & Type:	N.O.W. 9-P-100 Triplex
Horsepower Capacity (HP)	1000 HP
Quantity	2
Liner Size INCH	MIN 4 TO MAX 6 3/4
Stroke INCH	9
Max Pressure PSI	5 000
Max Delivery L/MIN	2 441
MUD SYSTEM:	
MUD TANKS:	
Number of ActiveTanks	5
Suction tank (m3)	70
Shaker tank (m3)	70
Reserve tanks Qty/(m3)	3(70)
Total Capacity (m3)	350
Trip tank (m3)	12
SOLIDS CONTROL EQUIPMENT:	
Shale Shaker	
Make & Type	DERRICK / FLC 504
Quantity & Capacity (gpm)	2
Desander:	
Make & Type	BRANDT SRS – 2 x 12"
Quantity & Capacity (gpm)	/
Mud Cleaner / Desilter:	
Make & Type	DERRICK 16 x 4
Quantity & Capacity (gpm)	
Mud Degasseur :	
Make & Type	SWACO/DEG-M-777
Capacity (gpm)	/
WELL HEAD EQUIPMENT	
ANNULAR	13 5/8" - 5000Psi
DOUBLE RAM	13 5/8" - 5000Psi
SINGLE RAM	
CHOKE MANIFOLD ASSEMBLY	4 1/16"- 5000 Psi

Figure 16: Technical sheet of the device ENF 51 [24]

2.2 Rig layout:

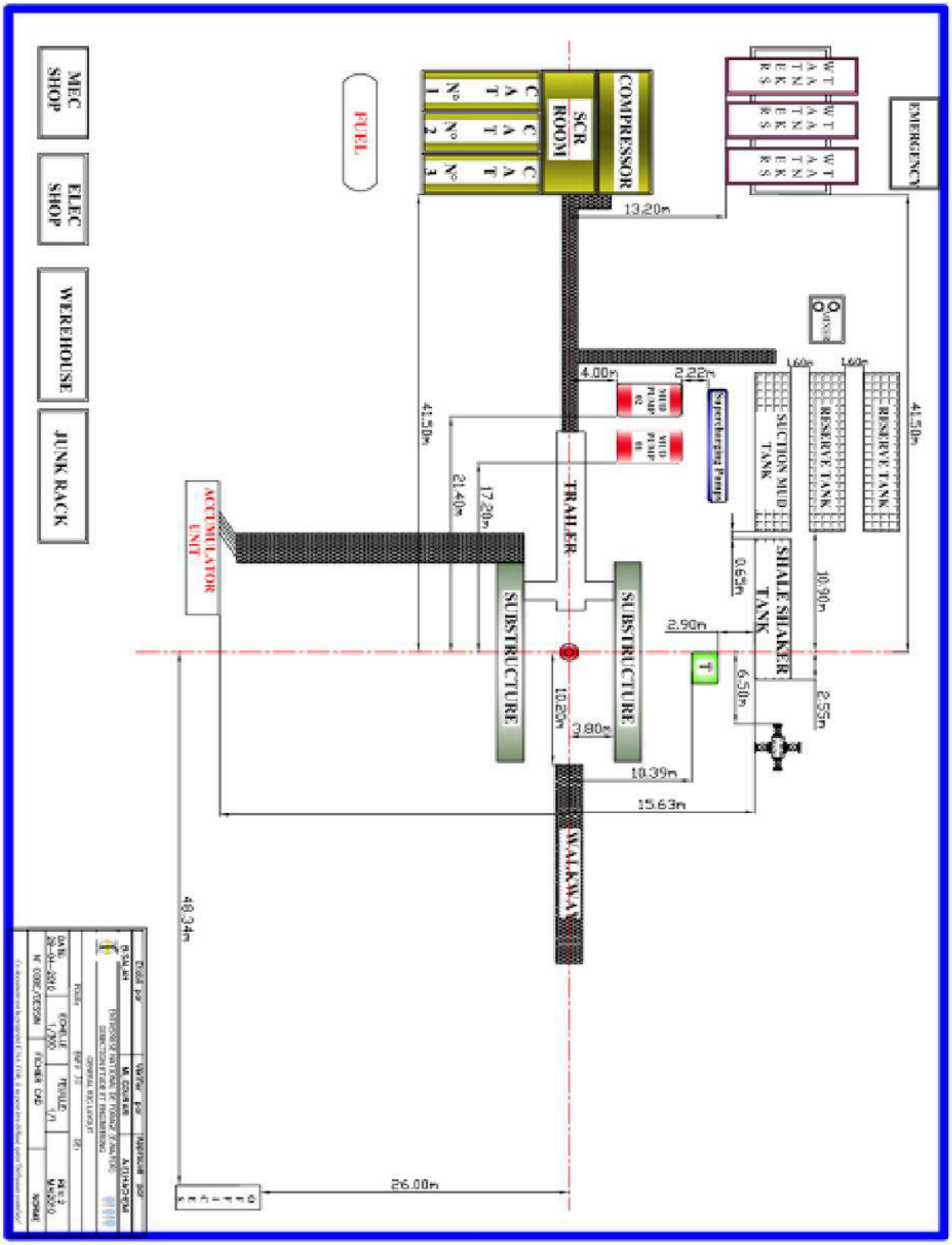


Figure 17: Rig layout of site ENF 51. [24]

3. Organization of ENAFOR:

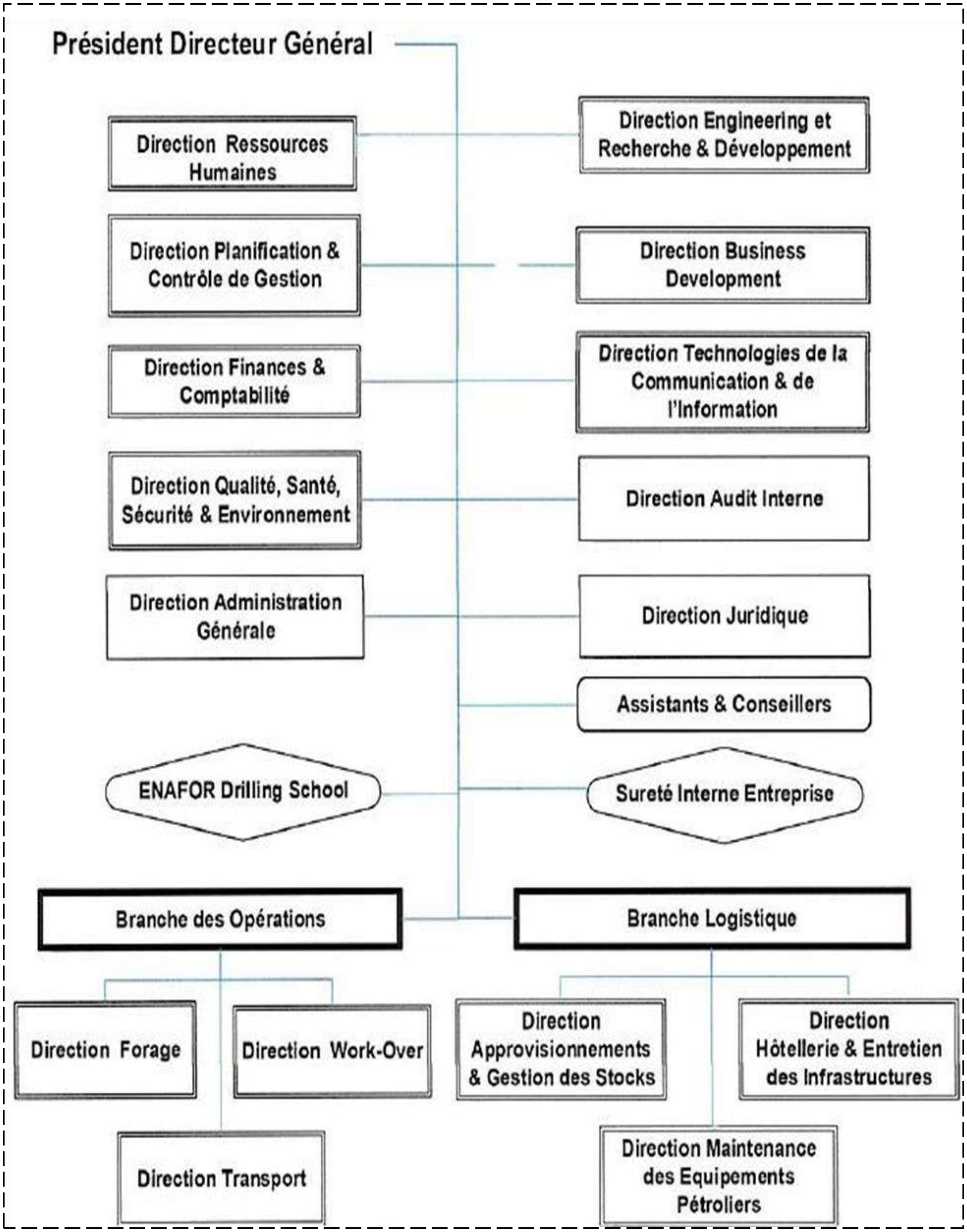


Figure 18: Organization of ENAFOR [23, p. 31]

SECTION II: Application of Fire and Explosion Risk Assessment for drilling rig and simulation by aloha software.

1. Application of Fire and Explosion Risk Assessment for drilling rig ENF 51:

1.1 Context:

The site is approximately 27 km northwest of the town of Hassi Messaoud.

The objective of the Project for a resumption of the MD 743 well in Side Track with the aim of recovering its potential oil flow rate of 6.7 m3/h illustrated during the DST test during drilling before deepening, while eradicating production of reservoir water.

As part of the project, application of a fire and explosion risk assessment, to take into account the impacts of potential major explosions and fire dangers.

1.2 Presentation of the MD 743 well:

The MD743 oil producing well was drilled on 10/27/2019, the DST test carried out at 3494m/TR before deepening gave an oil flow of 6.7m3/h. Then it was deepened to 3624m/TR where the body of water is seen (The oil/water contact at 3550m), hence the need to isolate the aquifer with a cement plug up to the coast. 3526m after covering the reservoir with a 4"½ perforated cement liner.

The start of production of the well turned out to be negative following a return of 90% of reservoir water observed during the nitrogen start-up attempts. A fracturing operation was canceled on 05/24/2024 following frank communication in both directions between the 4'"½ and the 4"½ * 9"5/8 ring finger.

The goal of this Workover program is to take over the well in Side Track in order to recover its potential illustrated during the DST test by eradicating the production of reservoir water.

Well parameters according to the last gauging (DST) on 21-10-2019			
Flow rate	6.7m^3/h	**Head pressure**	56.2 bars
GOR	120	**Reservoir pressure**	356.66 bars

1.3 List the team of the ENF 51 device WORK OVER:

- Senior Tool Pusher
- Junior Tool Pusher
- HSE Supervisor
- Medic
- Chief mechanic
- Chief Electrician
- Driller
- Assistant Driller
- Derrick man
- Floor man
- Rest-bout
- Mechanic
- Electrician.
- Crane operator
- Fork lift operator

1.4 IDENTIFICATION OF RISKS:

The potential for intrinsic dangers was identified before the risk analysis sessions. Their identification is based on initial work which will firstly focus on the analysis of past accidents and incidents carried out on accidentology, the dangers linked to dangerous products used within the installation under study and the reactions dangerous chemicals, the dangers associated with the storage installation of dangerous products in high temperature conditions.

I. Identification of Potential Ignition Sources:

Table 6: Sources of inflammation.

Sources of inflammation	Description	Comment
Hot surfaces	Electric motors, power supply box, the electric cables, machine bearing, heat engines	Lightning, electromagnetic waves and electric current can create hot surfaces when passing through conductors
Flames and hot gases	Welding or cutting beads,cigarettes	The hot gases obtained, the incandescent solid parts and the soot can ignite an ATEX
Sparks of mechanical origin	Friction, shock and abrasion	These sparks can ignite the gases

Electrical equipment	Electrical circuits Loose connections Stray current	These electrical sparks are likely to ignite the ATEX
Stray electric currents	Short circuit Grounding damaged Magnetic induction Return current	May create sparks, electric arcs
Static electricity	Egret discharge Cone discharge Spark discharge Surface sliding discharge	From an insulating surface to a conductor; When filling silos Between two conductors, one of which is insulated Which occurs on the surface of thin insulating material
Lightning	Electric shock following lightning strike	
Waves electromagnetic radio frequency 10^4-3.10^{12}HZ	Mobile phones, radio transmitters	Power of electromagnetic field may ignite
Waves electromagnetic $3.\ 10^{11}$-3.10^{15}HZ	Lamps, electric arcs, lasers	
Ionizing radiation	Radioactive source	Can heat an environment by internal absorption of energy until a flame appears
Ultrasound	Electroacoustic transmitter	

II. Photos-Sources of inflammation:

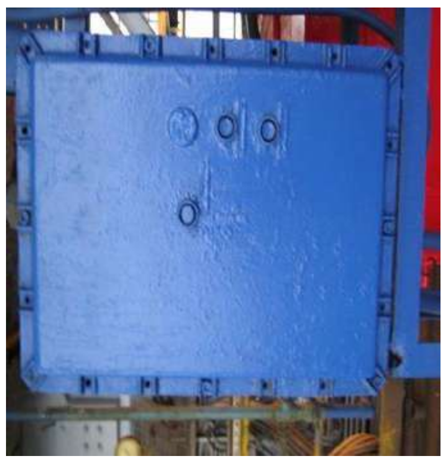
		
#1	#2	#3
		
#4	#5	#6
		
#7	#8	#9

Figure 19: Photos-Sources of inflammation.

1.5 Scenarios:

From the analysis of risk factors, five (04) reference scenarios are identified as well as their causes. It also led to the identification of dangerous phenomena; each dangerous phenomenon was assigned a probability, intensity, severity and kinetics. Modeling with ALOHA software made it possible to evaluate the distance of effec To study in detail the conditions of occurrence and the possible effects of dangerous phenomena as to provide a more precise demonstration of the mastery of the scenarios leading to it, it may be necessary to develop a complementary approach to the method used in the preliminary risk analysis and in particular to visualize possible accidental sequences using a representation of the "bow tie"« nœud papillon ».

The use of such a tool based on tree-based methods such as the failure tree and/or the event tree (l'arbre des défaillances et/ou l'arbre d'événements) makes it possible to better describe the scenarios but also to provide valuable evidence concerning the mastery of each of these scenarios.

From the analysis of risk factors, five (04) reference scenarios are identified as well as their causes. It also led to the identification of dangerous phenomena; each dangerous phenomenon was assigned a probability, intensity, severity and kinetics. Modeling with ALOHA software made it possible to evaluate the distance of effect.

1.6 SUBSTANCES STUDIED:

Table 7: CHARACTERISTICS OF PRODUCTS USED ON SITE

	Point d'éclair (°C)	Auto-inflam-mation (°C)	Point d'ébulliti on (°C)	LIE % volume	LES % volume	Densité	Ten-sion de vapeur	Solubilité dans l'eau
Pétrole Brut	< -20	260	230	1	6	0,8 à 15°C	750g/c m3	ND
Gaz naturel	-	530-630	-160	5	15	0,61 à 20°C	/	Faible à nulle
Gasoil	Min 55	250	≥150	0.5	5	0.83 à 15°C	/	Pratique-ment non miscible

Crude oil is a flammable product at ambient temperature and pressure; it emits flammable vapors under certain conditions of temperature, pressure and concentration. The density of these vapors is greater than that of the air: they therefore tend to accumulate in the lower parts.

Natural gas is extremely flammable; it can ignite under certain conditions in the presence of air and a heat source. Its lower flammability limit (L.I.E) is 5% and its upper flammability limit (L.S.E) is 15%.

Diesel is a combustible product at a temperature above its flash point (55°C), the same goes for lubricating and control oils which only ignite from 190°C.

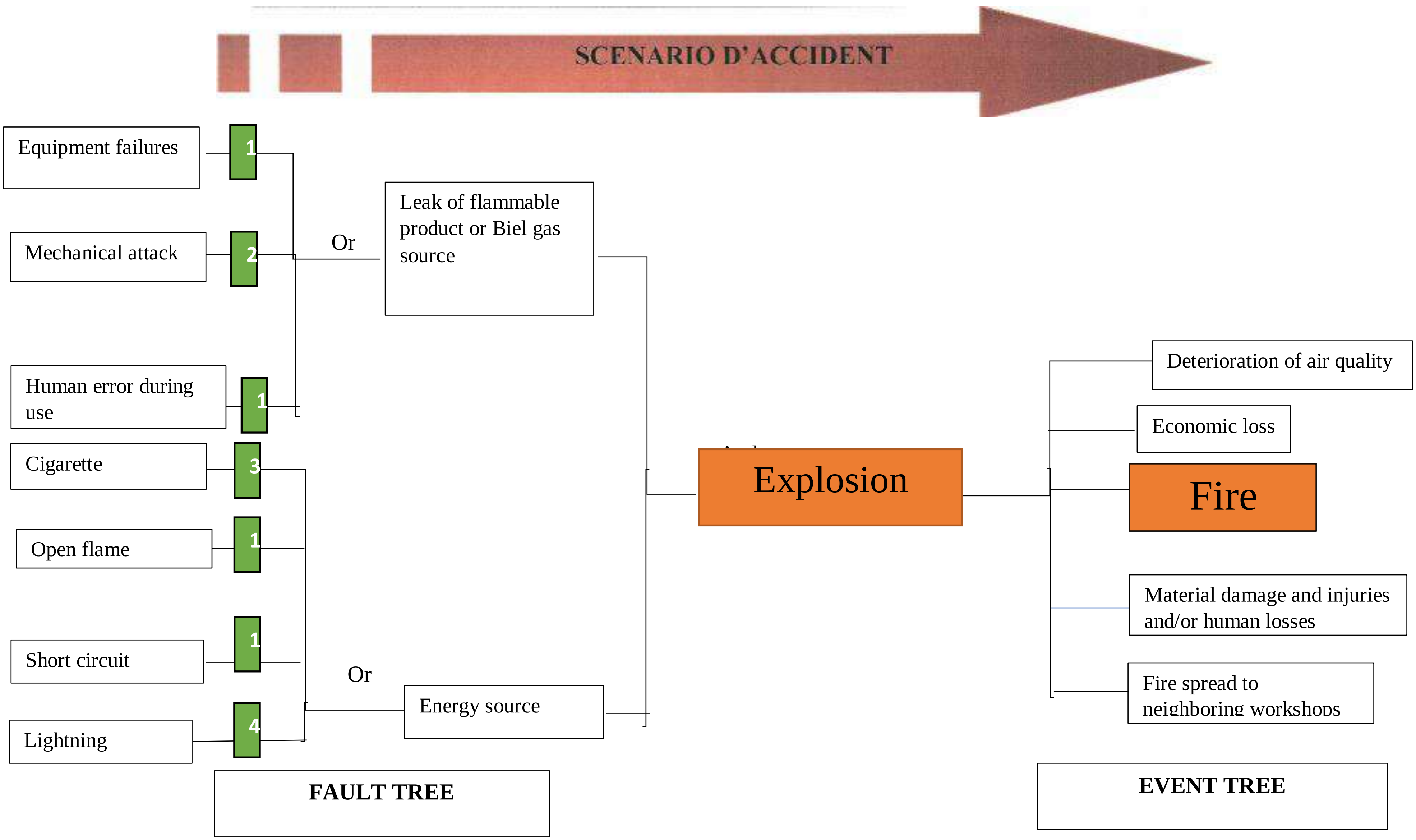
All of the products used are stable at usual storage, handling and use temperatures. Furthermore, their incomplete combustion and their thermolysis produce more or less toxic gases such as CO, CO2, various hydrocarbons and soot.

- **Components of natural gas:**

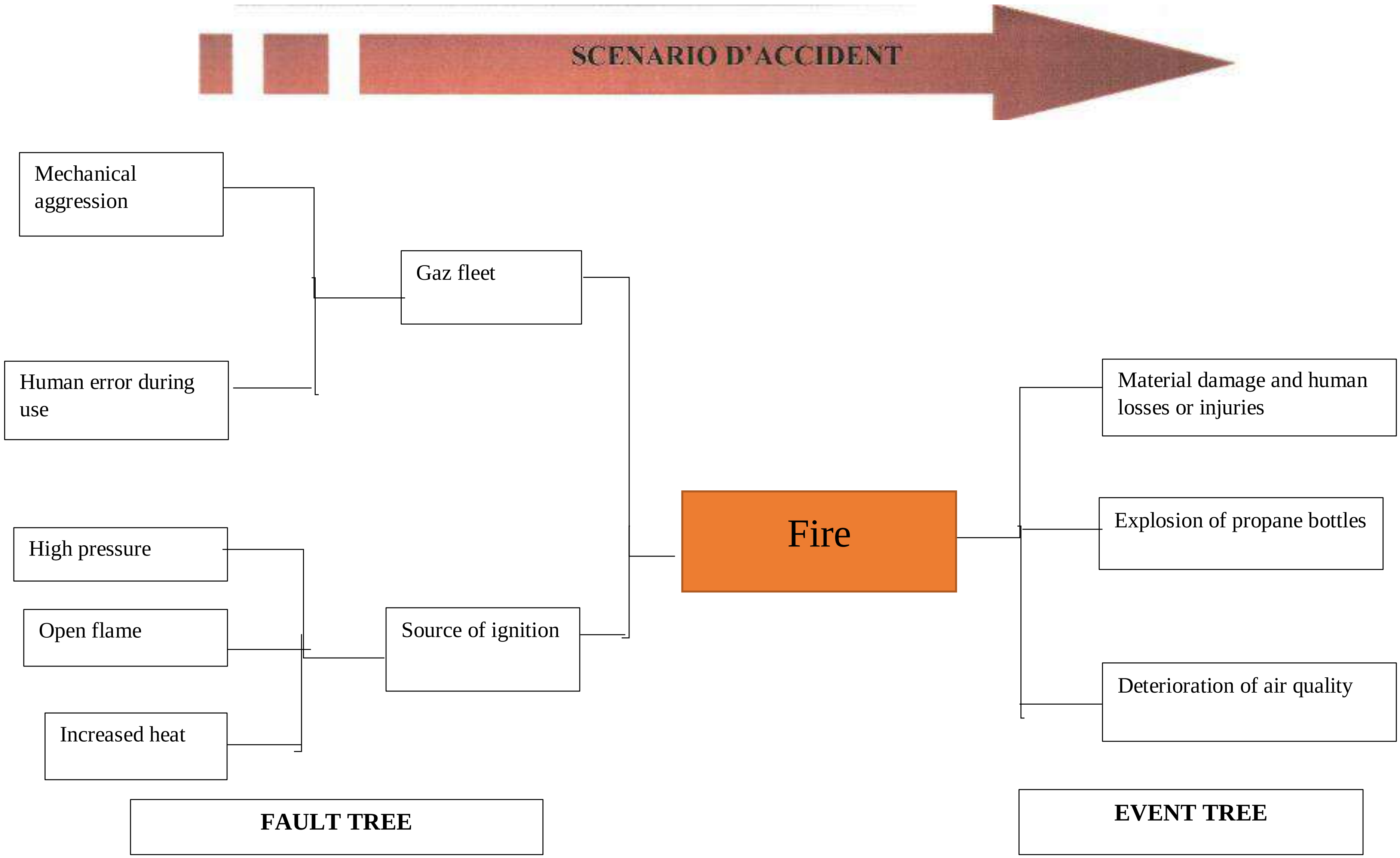
Table 8: Components of natural gas.

Component	*unit*	*Percent*
Azote	% Molar	2.103
Dioxyde de carbone	% Molar	1.126
Méthane	% Molar	63.626
Ethane	% Molar	21.071
Propane	% Molar	8.788
i-Butane	% Molar	0.713
n-Butane	% Molar	1.856
Neo-Pentane	% Molar	0.003
i-Pentane	% Molar	0.233
n-Pentane	% Molar	0.323
n-Hexane	% Molar	0.116
Benzène	% Molar	0.005
n-Heptane	% Molar	0.028
Toluène	% Molar	<0.001
n-Octane	% Molar	0.005
E-Benzène	% Molar	<0.001
m- et p-Xylène	% Molar	0.001
o-Xylène	% Molar	<0.001
n-Nonane	% Molar	0.002
n-Decane	% Molar	0.001
C11	% Molar	0.000
C12 +	% Molar	0.000
Total	% Molar	100.000

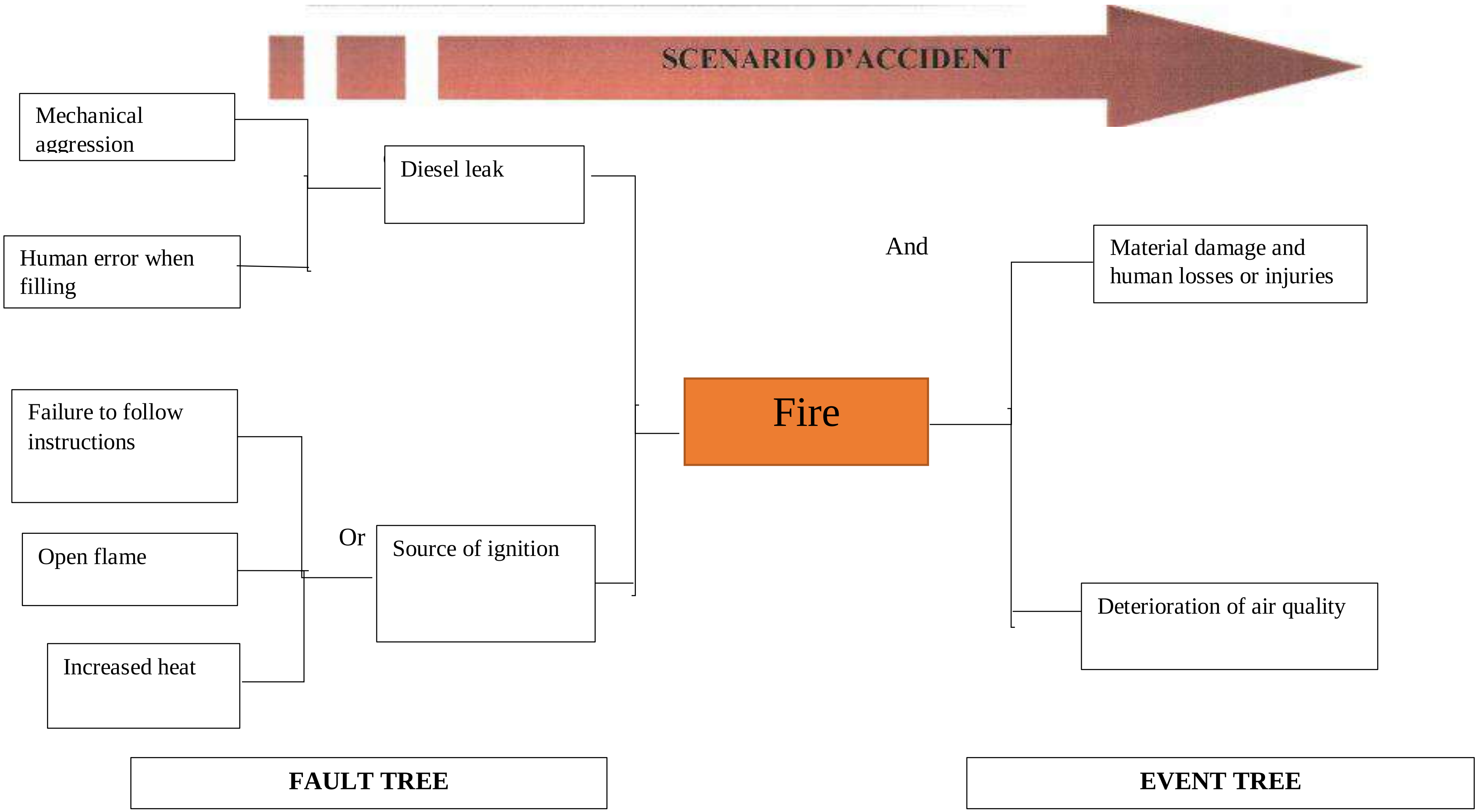
1.7 Accident scenario:



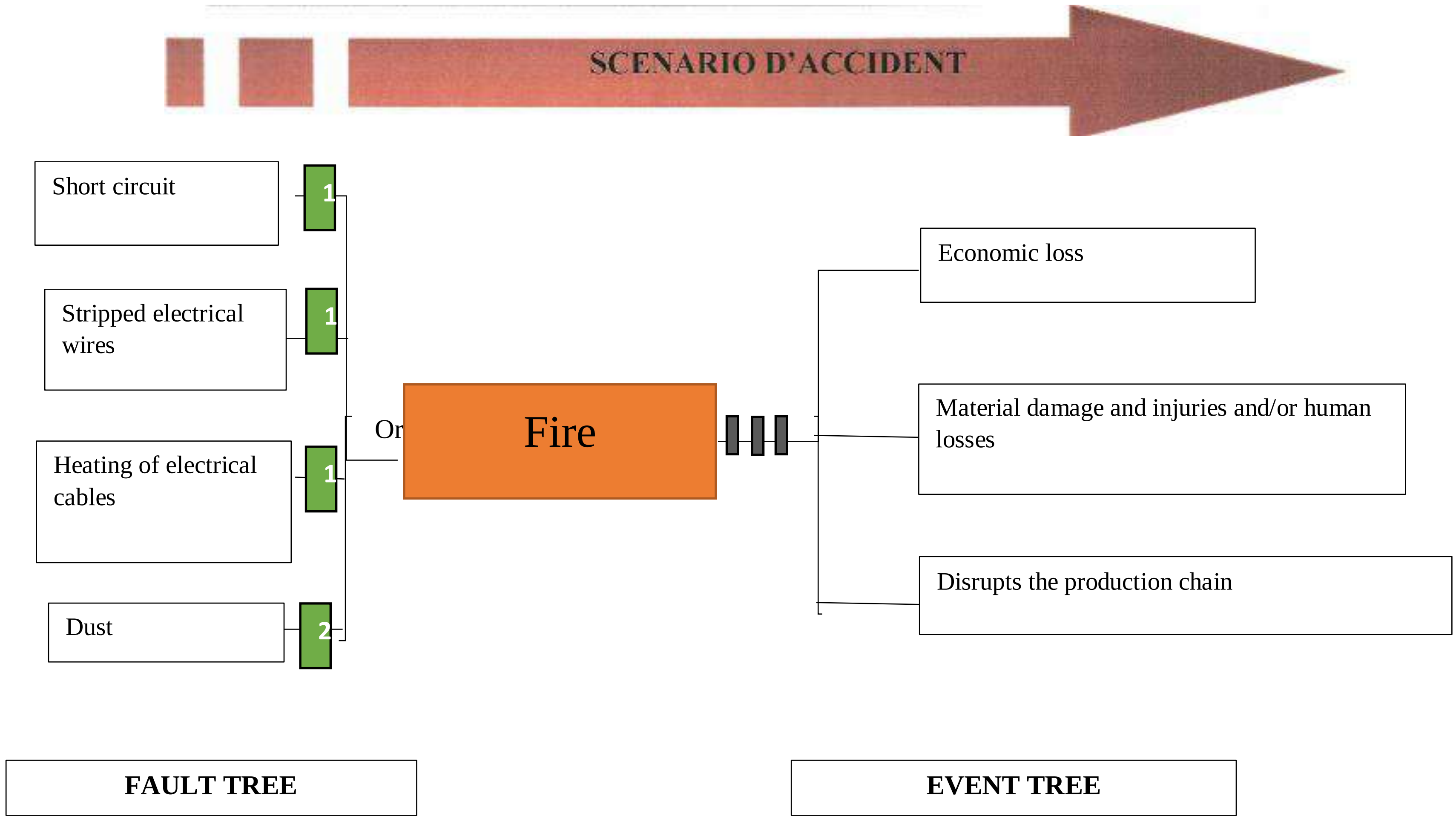
Scenario n1: Drilling rig explosion



Scenario n2: Fire at the gas cylinders industrial



Scenario n3: Fire at the diesel tanks



Scenario n4: Fire in electrical equipment Electrical cabinet or transformer

1.8 The consequences:

The accident scenarios likely to be retained involve the following physical effects:

- Toxicity: release of toxic components by atmospheric dispersion with consequences.
- Overpressure wave (mass explosion), confined explosions: this scenario will be used for mass explosions of explosive substances.
- Thermal flows or for widespread fire in a storage of flammable products (examples, pool fires generated by an accident in storage)
- Missile effect (fragments or projections): no threshold can be set for this particular effect.

These physical effects can cause damage to potential targets such as: human beings, buildings, property, and the environment. This damage is classified into 6 families:

- ❖ **Direct lethal risk for humans:**
  - Pulmonary blast by overpressure wave
  - Toxic dose
  - 3rd degree burns
- ❖ **Indirect lethal risk for humans:**
  - Receiving an object on the head, object detached by overpressure wave.
  - Speeding up of the human body leading to collision with structures or objects.
- ❖ **Risk of injury to humans:**
  - Non-lethal burns following exposure to thermal flow,
  - Rupture of the eardrum by overpressure wave.
- ❖ **Destruction of buildings, property or equipment:**
  - Destruction by explosion wave of premises, etc.
  - Destruction of installations or property by explosion effect.
- ❖ **Repairable damage to property or equipment:**
  - By explosion wave: broken windows, frames, frames or roofs damaged; instrumentation, electrical boxes, etc.
- ❖ **Reversible or non-reversible effects on the environment.**

1.9 Analysis of potential impacts in the event of fire or explosion:

❖ **Impacts on the population:**

The platform is 20KM in the northeast of the Hassi Messaoud desert outside the residential areas. The impact on the population in the event of an accident is moderate.

❖ **Impacts on staff:**

After analyzing the risks, the potential impacts in the event of accidents on the personnel of the establishment, Potential impacts in the event of fire or explosion:

Burns, asphyxia, death

- **Environmental impacts:**

The platform is located in vacant land not occupied by industrial activities. Generally speaking, the project will have a significant impact on the environment (emissions of gases, smoke, waste and risks, etc.).

- **Predictable economic and financial impacts in the event of an accident:**

An accidental event would produce more or less significant financial and economic impacts depending on the number of workers affected, the nature of the affected areas, the equipment and systems damaged.

The establishment must be insured against such losses. The insurance premium will be used for the renewal of damaged equipment in the event of an accident, however the impact of the disaster depending on its severity and extent would result in work stoppages for staff.

2. Simulation by aloha software:

2.1 Presentation of ALOHA simulation software:

ALOHA is a stand-alone software application developed for the Windows and Macintosh operating systems. It was developed and is supported by the Emergency Response Division1 (ERD), a division within the National Oceanic and Atmospheric Administration (NOAA) in collaboration with the Office of Emergency Management of the Environmental Protection Agency (EPA). Its primary purpose is to provide emergency response personnel estimates of the spatial extent of some common hazards associated with chemical spills. The ALOHA development team also recognizes that ALOHA can be an appropriate tool for training and contingency planning, but users should remain aware of its primary purpose in spill response. ALOHA provides estimates of the spatial extent of some of the hazards associated with the short-term accidental release of volatile and flammable chemicals. ALOHA deals specifically with human health hazards associated with inhalation of toxic chemical vapors, thermal radiation from chemical fires, and the effects of the pressure wave from vapor-cloud explosions.

Since ALOHA is limited to chemicals that become airborne, it includes models to assess the rate at which a chemical is released from containment and vaporizes. These “source strength” models can be critical components in the process of assessing hazards. ALOHA links source strength models to a dispersion model to estimate the spatial extent of toxic clouds, flammable vapors, and explosive vapor clouds. However, ALOHA does not model all combinations of source strength, scenario, and hazard category for combustion scenarios. The user must choose a specific combination from a limited selection. Table 9 shows the combination of source strength models, scenarios, and hazard categories allowed in ALOHA.

ALOHA uses a graphical interface for data entry and display of results. The area where there is a possibility of exposure to toxic vapors, a flammable atmosphere, overpressure from a vapor cloud explosion, or thermal radiation from a fire are represented graphically as threat zones. Threat zones represent the area within which the ground-level exposure exceeds the user-specified level of concern at some time after the beginning of a release. All points within the threat zone experience a transient exposure exceeding the level of concern at some time following the release; it is a record of the predicted peak exposure over time. In some scenarios, the user can also view the time dependence of the exposure at specified points. [25, p. 2]

Table 9: Hazard categories modeled in ALOHA *[25, p. 3]*

Scenario\Source	*Direct source*	*Tank*	*Puddle*	*Gas Pipeline*
Vapor cloud	Toxic vapors	Toxic vapors	Toxic vapors	Toxic vapors
Vapor cloud (flash fire)	Flammable area	Flammable area	Flammable area	Flammable area
Vapor cloud (explosion)	Overpressure	Overpressure	Overpressure	Overpressure
Pool fire	NA	Thermal radiation	Thermal radiation	NA
BLEVE (fireball)	NA	Thermal radiation	NA	NA
Jet fire	NA	Thermal radiation	NA	Thermal radiation

2.2 Calculations:

All the characteristics necessary for ALOHA are then provided. The user can then decide to apply a Gaussian model, a heavy gas model or let ALOHA decide.

Subsequently, he can then ask ALOHA to plot 3 types of threats: the toxic zone, the potential flammability zone or the explosion zone according to the characteristics of the pollutant and we obtain the following type of graph:

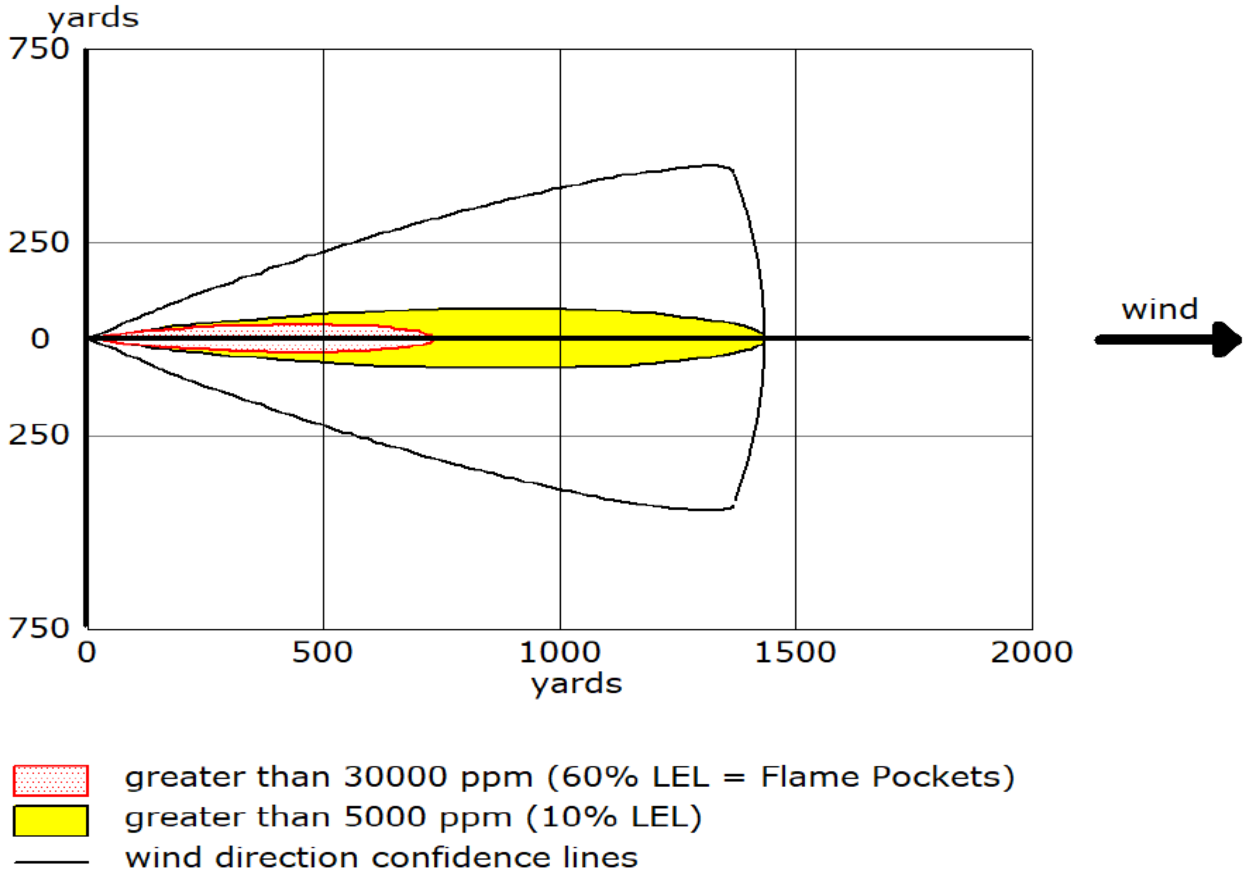


Figure 20: presentation of the results.

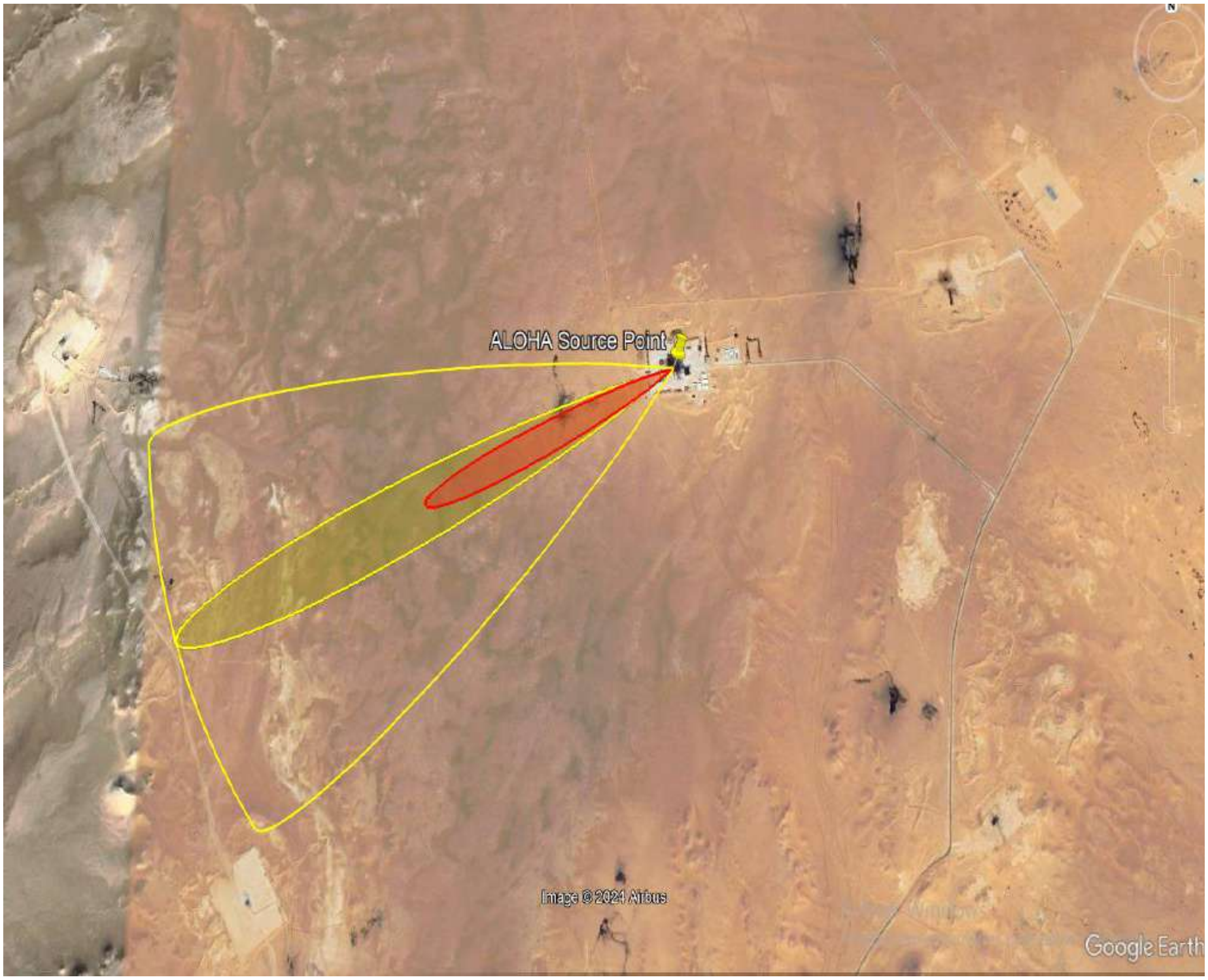


Figure 21: presentation of the results in google earth

3. RECOMMENDATIONS:

❖ **Comprehensive Data Collection:**

- **Historical Data:** Gather and analyze historical data on equipment performance, failures, and maintenance records.
- **Real-Time Monitoring:** Implement real-time monitoring systems to collect data on critical parameters such as pressure, temperature, and vibration.

❖ **Detailed Failure Mode Analysis:**

- **Identify Potential Failures:** Use techniques such as Failure Modes and Effects Analysis (FMEA) to identify potential failure modes in the drilling rig components.

- **Criticality Assessment:** Assess the criticality of each failure mode based on its impact on safety, environment, and operational efficiency.

❖ **Risk Assessment and Mitigation:**

- **Probability and Consequence:** Evaluate the probability and consequences of identified failure modes to prioritize risks.
- **Mitigation Strategies:** Develop and implement mitigation strategies for high-risk failure modes, such as redundancy, preventive maintenance, and design improvements.

❖ **Stakeholder Involvement:**

- **Interdisciplinary Team:** Form an interdisciplinary team including engineers, operators, safety experts, and maintenance personnel to contribute diverse perspectives.
- **Training and Awareness:** Provide training to all stakeholders on the importance of FERA and their roles in mitigating risks.

❖ **Regular Review and Updates:**

- **Periodic Reviews:** Conduct regular reviews of the FERA study to incorporate new data, technology advancements, and changes in operational conditions.
- **Continuous Improvement:** Foster a culture of continuous improvement by regularly updating risk assessments and mitigation plans based on feedback and new information.

❖ **Technology Integration:**

- **Advanced Analytics:** Utilize advanced analytics and machine learning techniques to predict potential failures and optimize maintenance schedules.
- **Automation and Remote Monitoring:** Implement automation and remote monitoring systems to enhance real-time detection and response to potential issues.

❖ **Regulatory and Compliance Considerations:**

- **Compliance with Standards:** Ensure that the FERA study complies with relevant industry standards and regulatory requirements.
- **Documentation and Reporting:** Maintain comprehensive documentation and reporting of all FERA activities and findings for regulatory audits and internal reviews.

❖ **Emergency Response Planning:**

- **Contingency Plans:** Develop and regularly update emergency response plans to address potential high-risk failure scenarios.

- **Drills and Simulations:** Conduct regular drills and simulations to ensure preparedness and effective response to emergencies.

❖ **Collaboration with Equipment Manufacturers:**

- **Manufacturer Insights:** Collaborate with equipment manufacturers to gain insights into common failure modes and recommended maintenance practices.
- **Upgrades and Modifications:** Discuss potential equipment upgrades or modifications to enhance reliability and reduce the risk of failures.

❖ **Environmental and Safety Considerations:**

- **Environmental Impact Assessment:** Evaluate the potential environmental impacts of drilling operations and implement measures to minimize adverse effects.
- **Safety Protocols:** Establish and enforce stringent safety protocols to protect personnel and equipment during drilling operations.

3. 1 Arrangement of fire-fighting resources on site:

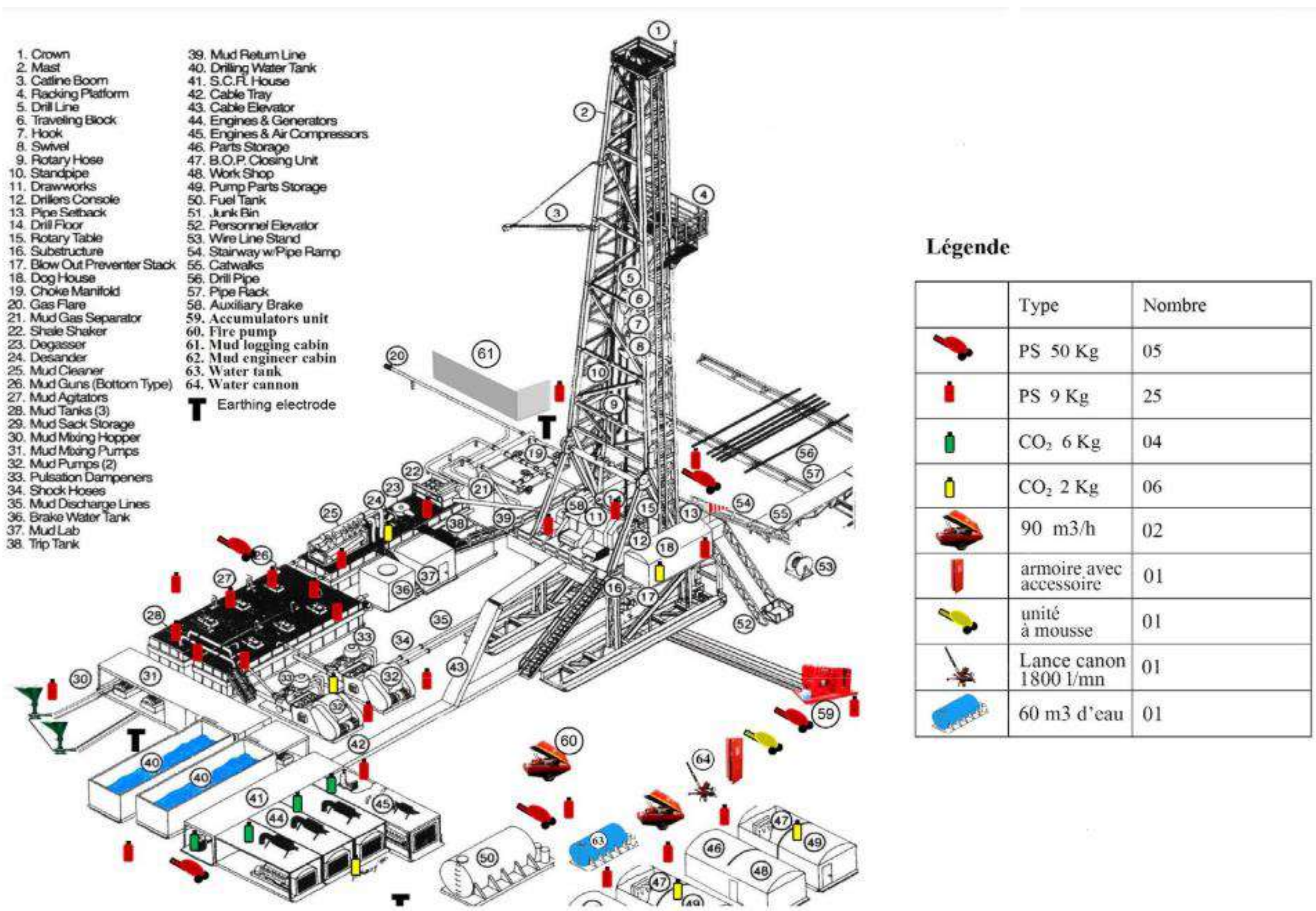


__Figure 22:__ Arrangement of fire-fighting resources on site

CONCLUSION:

The application of Fire and Explosion Risk Assessment (FERA) in drilling rig operations, coupled with simulations using ALOHA software, has proven to be an invaluable approach for enhancing safety and mitigating risks. This chapter has explored the critical aspects of integrating FERA methodologies and advanced simulation tools to effectively identify, assess, and manage potential fire and explosion hazards in drilling environments.

General Conclusion

The study on the Application of Fire and Explosion Risk Assessment (FERA) on a drilling rig has provided comprehensive insights into the identification, evaluation, and mitigation of hazards associated with fire and explosion in drilling operations. Throughout this dissertation, we have systematically explored the methodologies and tools essential for enhancing safety and minimizing risks in such high-stakes environments. , Summary of Findings:

Systematic Risk Identification:

The study utilized FERA to systematically identify potential fire and explosion hazards inherent in drilling operations. By examining historical data, operational processes, and equipment specifications, we have been able to map out the main risk scenario that could potentially occur.

Detailed Risk Analysis:

A thorough analysis of identified risks was conducted to understand their causes, consequences, and probabilities. This analysis was crucial in prioritizing risks and developing targeted mitigation strategies. The use of risk matrices and other analytical tools helped in visualizing and managing the risks effectively.

Simulation with ALOHA Software:

The integration of ALOHA software for simulating fire and explosion scenarios proved to be highly beneficial. The simulations provided a visual representation of potential incidents, allowing for a better understanding of their impact. This facilitated the development of more robust emergency response plans and mitigation measures.

This dissertation underscores the critical role of proactive risk management in mitigating hazards and protecting both personnel and assets in the challenging environment of drilling operations.

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