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# Final year project

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**To obtain the degree of**

# Master 2 in oil well drilling

## Theme

**Exploration drilling of gas wells: techniques and data analysis**

## Jury

| | |
|---|---|
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## Dedication

We dedicate this work to Almighty God, for His infinite blessings, guidance, and the strength He has bestowed upon us to accomplish this achievement.

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## Abstract

This thesis presents a comprehensive study of exploratory drilling operations for gas wells, covering the fundamental principles, equipment, procedures, and practical field applications. The work introduces the origin, composition, and classification of natural gas, followed by the exploration process including geological and geophysical methods, with emphasis on seismic techniques and exploratory drilling. A detailed description of drilling rig systems is provided—hoisting, rotary, circulation, power, and safety equipment—along with drill stem testing procedures and well completion techniques. This study compares two exploration wells in Algeria's Illizi Basin: Well-1 targeting the deep Cambro-Ordovician formation, and Well-2 targeting the shallower Devonian F2. Based on Drill Stem Test (DST) results, Well-1 shows excellent pressure maintenance, rich wet gas, and ultra-light, high-value condensate at high flow rates. Well-2, although a successful discovery, exhibits greater pressure loss, leaner gas, lower liquid yields, and continuous wellhead decline, indicating limited reservoir support. The study concludes that Well-1 is superior and should be prioritized for development, while Well-2 remains viable but requires careful production management. Both wells confirm the basin's gas potential, and the complete absence of $H_2S$ is a major economic and safety advantage.

**Key words:** Exploration equipments, Drilling exploration, Gas well, Oil well,

Illizi basin, Well completion

## Résumé

Cette thèse présente une étude exhaustive des opérations de forage exploratoire de puits de gaz, abordant les principes fondamentaux, les équipements, les procédures et les applications pratiques sur le terrain. Elle introduit l'origine, la composition et la classification du gaz naturel, puis décrit le processus d'exploration, incluant les méthodes géologiques et géophysiques, avec un accent particulier sur les techniques sismiques et le forage exploratoire. Une description détaillée des systèmes de forage est fournie – équipements de levage, de rotation, de circulation, d'alimentation électrique et de sécurité – ainsi que les procédures de test de la tige de forage et les techniques de complétion des puits. Cette étude compare deux puits d'exploration dans le bassin d'Illizi en Algérie: le puits 1, ciblant la formation profonde cambro-ordovicienne, et le puits 2, ciblant la formation dévonienne F2, moins profonde. D'après les résultats du test de la tige de forage, le puits 1 présente un excellent maintien de la pression, un gaz humide riche et un condensat ultra-léger de grande valeur à des débits élevés. Le puits 2, bien qu'ayant permis une découverte fructueuse, présente une perte de pression plus importante, un gaz plus pauvre, des rendements en liquides plus faibles et une baisse continue de la pression en tête de puits, indiquant un support limité du réservoir. L’étude conclut que le puits 1 est supérieur et devrait être développé en priorité, tandis que le puits 2 demeure viable mais nécessite une gestion rigoureuse de sa production. Les deux puits confirment le potentiel gazier du bassin, et l’absence totale de $H_2S$ constitue un atout majeur en termes d’économie et de sécurité.

**Mots clés:** Équipements d'exploration, Forage d'exploration, Puits de gaz, Puits de pétrole, Bassin d'Illizi, Complétion de puits.

## الملخص

تُقدّم هذه الأطروحة دراسة شاملة لعمليات الحفر الاستكشافي لآبار الغاز، مُغطيةً المبادئ الأساسية والمعدات والإجراءات والتطبيقات العملية الميدانية. يُعرّف العمل بأصل الغاز الطبيعي وتكوينه وتصنيفه، ثم يُقدّم عملية الاستكشاف بما في ذلك الأساليب الجيولوجية والجيوفيزيائية، مع التركيز على التقنيات الزلزالية والحفر الاستكشافي. كما يُقدّم وصفًا تفصيليًا لأنظمة منصات الحفر - معدات الرفع والدوران والتدوير والطاقة والسلامة - بالإضافة إلى إجراءات اختبار أنابيب الحفر وتقنيات إكمال الآبار. تُقارن هذه الدراسة بين بئرين استكشافيين في حوض إليزي بالجزائر: البئر 1 الذي يستهدف الأقل عمقًا. بناءً F2 تكوين كامبرو الأوردوفيشي العميق، والبئر 2 الذي يستهدف تكوين ديفونيان على نتائج اختبار أنابيب الحفر، يُظهر البئر 1 ثباتًا ممتازًا للضغط، وغازًا رطبًا غنيًا، ومكثفات خفيفة للغاية وعالية القيمة بمعدلات تدفق عالية. أما البئر 2، فعلى الرغم من كونه اكتشافًا ناجحًا، إلا أنه يُظهر فقدانًا أكبر للضغط، وغازًا أقل كثافة، وإنتاجية سوائل أقل، وانخفاضًا مستمرًا في ضغط رأس البئر، مما يُشير إلى دعم محدود للمكمن. خلصت الدراسة إلى أن البئر رقم 1 متفوق ويجب إعطاؤه الأولوية في التطوير، بينما يظل البئر رقم 2 قابلاً للاستغلال ولكنه يتطلب إدارة دقيقة للإنتاج. ويؤكد كلا البئرين إمكانات الغاز في الحوض، كما أن الغياب التام لكبريتيد الهيدروجين يُعد ميزة اقتصادية وأمنية هامة.

### الكلمات المفتاحية

الكلمات المفتاحية: معدات الاستكشاف، استكشاف الحفر، بئر غاز، بئر نفط، حوض إليزي، إكمال البئر.

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**Abbreviations**

**LNG:** Liquefied Natural Gas.

**LWD:** Logging-While-Drilling.

**MDT:** Modular Formation Dynamics Tester.

**DST:** Drill Stem Test.

**API:** American Petroleum Institute.

**BOP:** Blowout Preventer.

**BHA:** Bottom Hole Assembly.

**VSP:** Vertical Seismic Profiling.

**2D:** Two dimensions.

**3D:** Three dimensions.

**4D:** Four dimensions.

**HP:** Horsepower.

**RPM:** Revolutions per minute.

**ROP:** Rate of Penetration.

**SCR:** Silicon Controlled Rectifier.

**HPHT:** High Pressure, High Temperature.

**MUX:** Multiplex.

**DC:** Direct Current.

**AC:** Alternating Current.

**ID:** Internal Diameter.

**OD:** Outside Diameter.

**HWDP:** Heavyweight Drill Pipe.

**PDC:** Polycrystalline Diamond Compact.

**GOR:** Gas-Oil Ratio.

**WHP:** Wellhead Pressure.

**PPG:** Gas Producer Well (Puits Producteur de Gaz).

**MOE:** Millout Extension.

**HSC:** High Strength Connection.

**N. Vam:** New Vam (thread connection type).

**MP1, MP2:** Mud Pump 1, Mud Pump 2.

**DWK:** Draw Works.

**RT:** Rotary Table.

# Introduction

Natural gas plays a central role in the global energy landscape. As a relatively clean fossil fuel, it serves as a key transitional energy source in the shift toward more sustainable energy systems. However, accessing natural gas reservoirs requires advanced technical knowledge, careful planning, and specialized equipment. This is particularly true for exploratory drilling, where the primary objective is to confirm the presence of hydrocarbons, evaluate reservoir potential, and determine commercial viability.

The Illizi Basin, located in southeastern Algeria, is one of the country's most prolific hydrocarbon provinces. It has attracted the attention of geologists and petroleum engineers for decades due to its complex geological history, favorable structural framework, and significant proven reserves of both natural gas and condensate. Within this basin, exploration wells continue to play a critical role in identifying new reservoirs, evaluating their potential, and guiding future development strategies.

This graduation memoir focuses on the comparative study of two exploration wells drilled in the Illizi Basin: Well-1, targeting the deep Cambro-Ordovician formation, and Well-2, targeting the shallower Devonian F2 formation. The main objective is to assess and compare their reservoir characteristics, fluid properties, pressure behavior, and long-term production potential based on Drill Stem Test (DST) results.

The work is structured into four complementary chapters. The first chapter presents a detailed geological description of the Illizi Basin, including its lithostratigraphy, tectonic evolution, and structural elements. The second chapter provides general background information on natural gas exploration, drilling objectives, and the exploration process. The third chapter describes the technical aspects of drilling rigs, their main systems (hoisting, rotary, circulation, power, and safety), as well as the principles of drill stem testing and well completion. The fourth and final chapter presents and interprets the DST data from both wells, followed by a direct comparison of their pressure behavior, fluid quality, and reservoir sustainability.

# Chapter I: Description of Illizi basin

## I.1 Introduction

The Illizi Basin constitutes one of the major sedimentary basins of the Algerian Sahara. It is a geologically complex region that has attracted the attention of geologists for several decades. Its long and diverse geological history dates back millions of years and is characterized by a series of tectonic and geodynamic events. The characterization of the key aspects of its geology requires studies of its regional geological framework, its geological structure, its sedimentary cover, as well as its geodynamic evolution over time. Understanding these aspects of its geology allows for a better assessment of its potential in terms of natural resources such as oil, gas, and groundwater resources. [1]

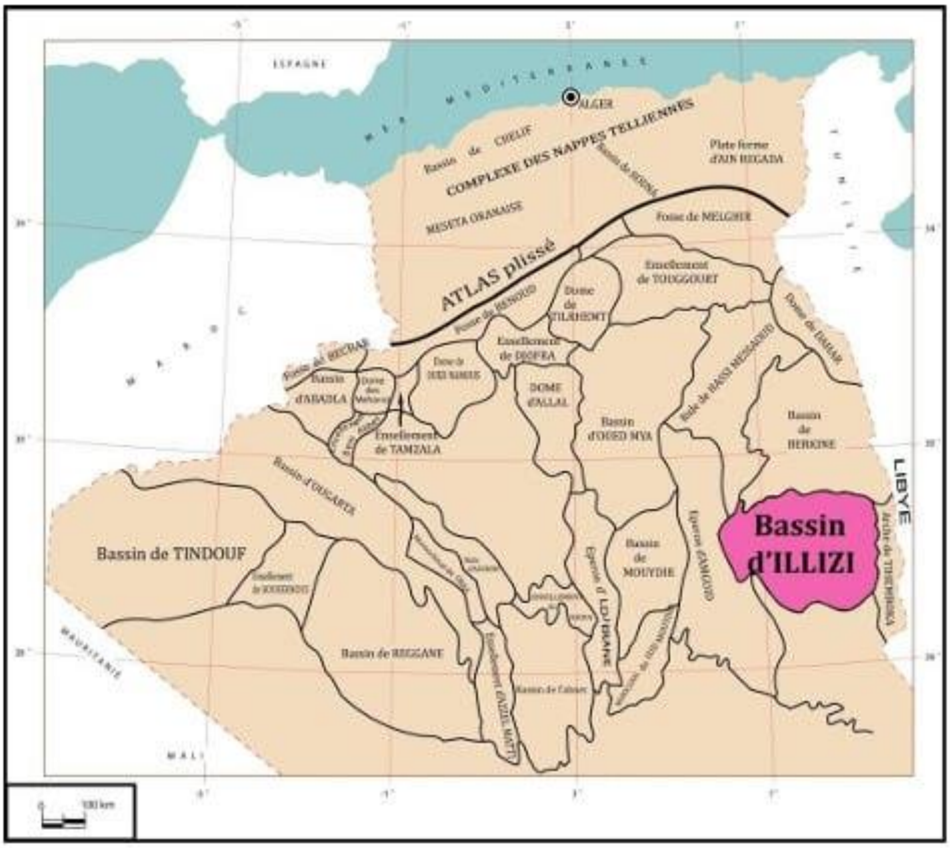


**Figure I.1:** Illizi basin. [1]

## I.2 Presentation of the study region:

The Illizi Basin constitutes one of the major oil and gas provinces of Algeria. It is located in the southeastern part of the Algerian Sahara. It covers approximately 108,424 km², between latitudes 26°30' and 29°30' North and longitudes 6° and 10° East. It is bounded to the north by the Berkine Basin, to the east by the Tihemboka High, to the south by the outcrops of the Tassili N'Ajjer, and to the west by the Amguid El Biod ridge, which separates it from the Mouydir Basin. This basin extends as far as Libya to the east, but the larger part lies within Algeria. The Illizi Basin largely extends within the administrative boundaries of the Illizi Province (wilaya) [2]. The latter is bordered by:

- Tunisia to the northeast, for nearly 25 km;
- Libya to the east, for nearly 1,000 km;
- Niger to the south, for nearly 102 km.

Within the country, the wilaya is bordered by two other wilayas:

- The wilaya of Tamanrasset to the west;
- The wilaya of Ouargla to the north.

It is divided into six communes, namely:

- Bordj Omar Idriss;
- Deb Deb;
- In Aménas;
- Djanet;

- Bordj El Houes."

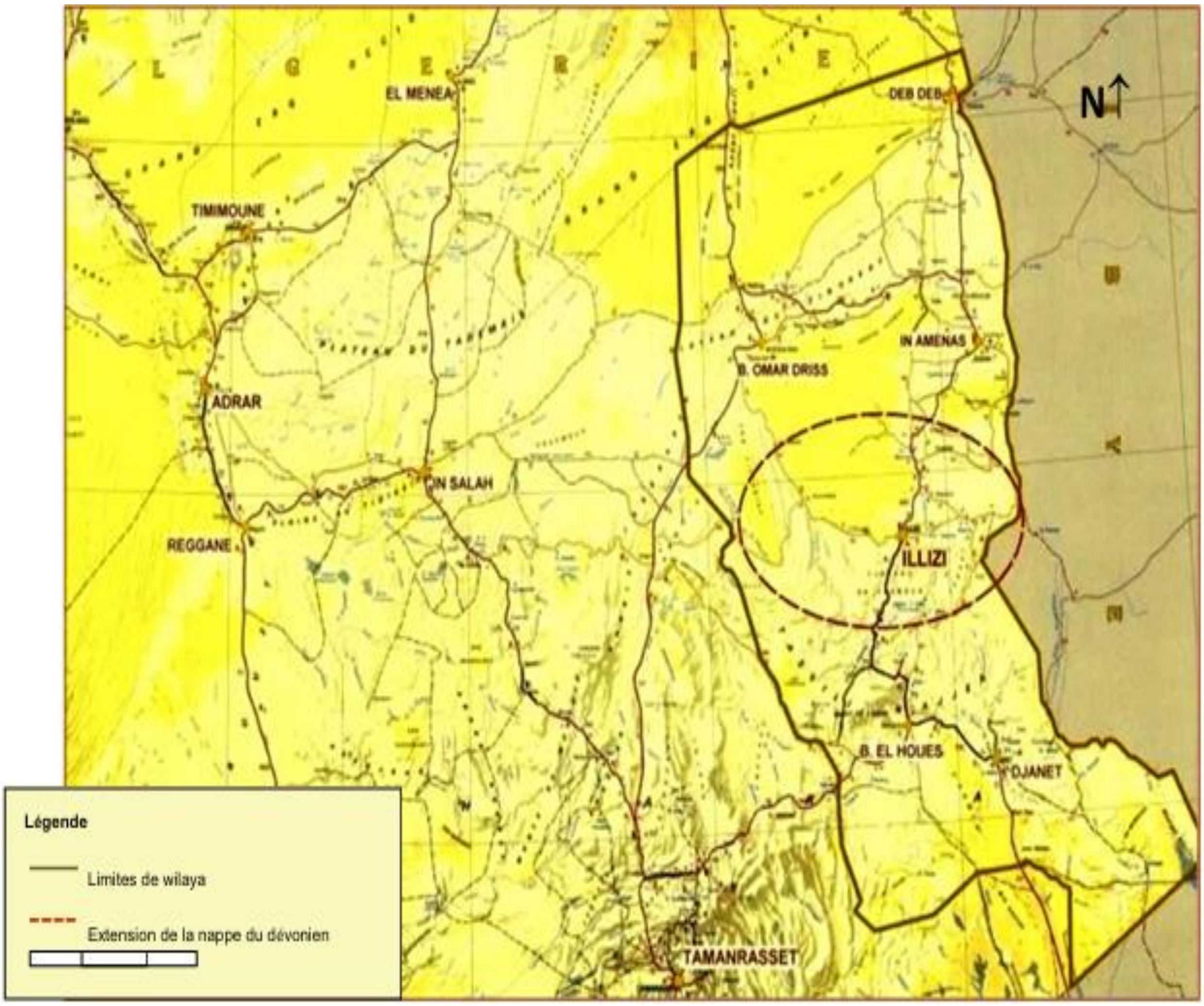


**Figure I.2:** Geographical location of the city of Illizi. [2]

**I.3 Geological Framework:**

The Triassic province is located in the northeastern part of the Saharan platform. It is an east-west trending anticlinoriumThe Triassic province was established on several structural elements of Hercynian or older origin, ranging from the Foum Belrem–Mzab ridge in the west to the Ghadames Basin, which it completely covers in the east. A large part of these various structural elements is widely covered by Upper Cretaceous and Tertiary sediments, which even extend beyond the Touareg Shield. [3]

The sedimentary succession of the Triassic province exceeds 4,500 m in thickness in the northern part; it is characterized by a significant evaporite formation ranging from the Triassic to the Dogger. The isobaths of the Hercynian unconformity indicate a regular deepening from the southwest toward the northeast and the presence of a central trough-oriented NE-SW. The major structural feature consists of a fault network about one hundred kilometers wide, trending N-S in the southern part and NE-SW in the central and northern parts. These faults play an important role in sedimentation, structuring, and the location of hydrocarbon deposits. [3]

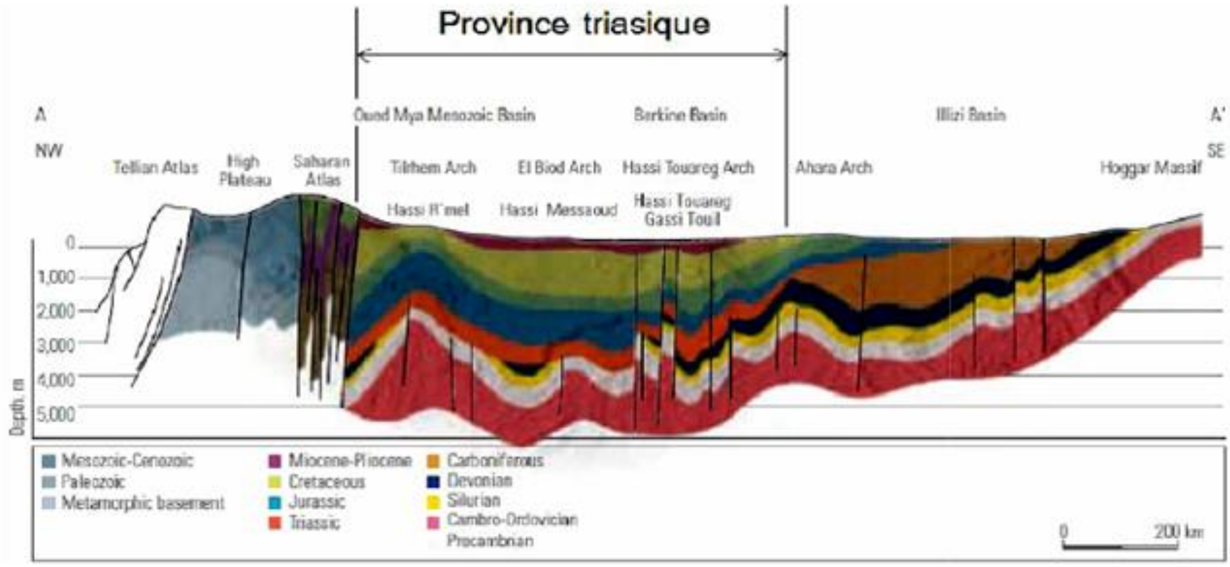


**Figure I.3:** The regional geological cross-section of the Triassic province.

**I.4 The Sedimentary Cover:**

This cover is mainly composed of sedimentary rocks that overlie the crystalline basement. The following are found successively:

- **The Paleozoic:** comprising the Cambro-Ordovician, Silurian, Devonian, and Carboniferous.
- **The Mesozoic:** comprising the Triassic, Jurassic, and Cretaceous.

In certain regions such as In Aménas and Stah, a specific part of the sedimentary cover, called the Zarzaitine series, includes the Jurassic and Triassic. In Ohanet and Stah, another part, named the Taouratine series, encompasses the Malm, Barremian, and Albian. Sometimes, these two series combine to form what is locally called the Continental Intercalary.

## I.5 Geology of the Illizi region:

### I.5.1 Lithostratigraphy of the Illizi Basin:

The sedimentary cover of the Illizi Basin rests with a major unconformity on the Infra-Tassilian surface, which levels a folded basement composed of metamorphic sedimentary rocks, crystalline schists, and volcanic rocks.

The typical lithological section of the Illizi Basin consists of an overall detrital sedimentary succession ranging from the Cambrian to the Paleogene, in which the Paleozoic terrains occupy two-thirds of the total thickness of the succession.

The lithostratigraphy of the Tassilian Paleozoic series was established through studies carried out on outcrops by Beuf et al. (1963, 1971), Dubois (1967) [4], and Biju-Duval et al. (1968) [2].

The lithostratigraphic division is mainly based on a morphological description of the sedimentary series. The type stratigraphic succession of the Illizi Basin, which is more than 3000 m thick, is as follows:

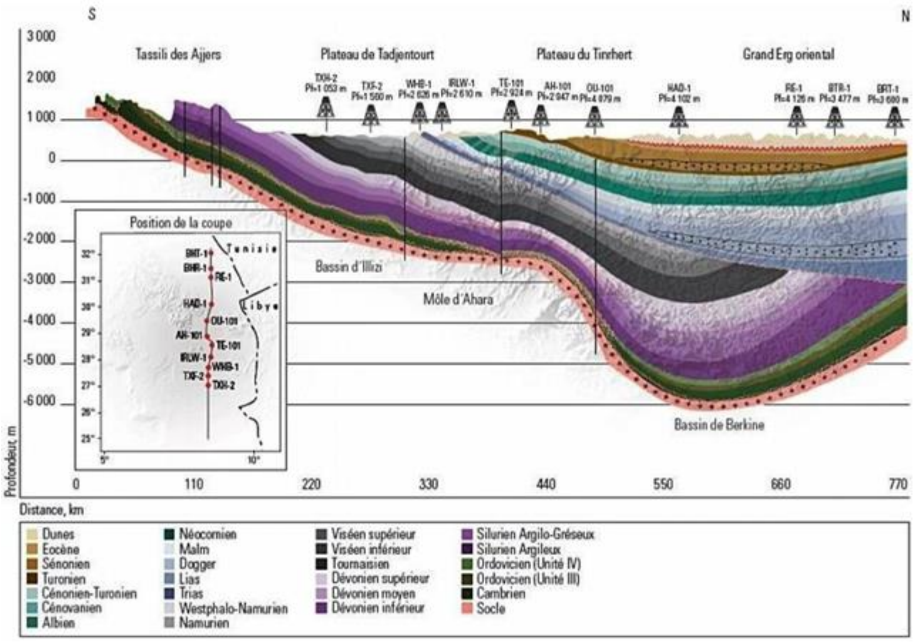


**Figure I.4**: South/North geological cross-section of the Illizi Basin. [5]

**Cambrian:**

The Cambrian is a period in Earth's history. In this region, we mainly find rock layers composed of sand and gravel.

- **Unit I:** called the El Moungar conglomerates, is quite thick (approximately 300 m) and consists primarily of coarse sand grains mixed with pebbles. It represents the last remnants of rocks originating from ancient mountains.

- **Unit II:** has a thickness of about 200 to 300 m. It contains medium to coarse sand layers, often cross-bedded, with some coarse pebbles and quartz pebbles. Towards the top of this unit, the sand becomes finer and sometimes contains silica, with thin clay layers. These layers show signs of ancient biological activity. These rocks are estimated to date from the Cambrian.

**Ordovician:**

In this region, the Ordovician is divided into four parts:

- **Unit III-1:** is variable in thickness and dates from the Tremadocian. It consists of alternating fine cross-bedded sand and clay pebbles, sometimes with silt layers. Traces of ancient biological activity are also found here.

- **Unit III-2:** is mainly made of fine to coarse sand with abundant silica. In a shallow marine environment, this sand can transform into very hard rock.

- **Unit III-3:** varies in thickness from 40 to 200 m. It consists of sand containing mica and clay or silica. Traces of burrows from ancient organisms are sometimes found here.

- **Unit IV:** with an average thickness of 100 to 300 m, is composed of sand and clay deposited by ancient glaciers. It rests unconformably on Unit III-3.

**Silurian:**

The Silurian is composed of several rock layers:

- The Oued Imirhou Formation is mainly made of clay containing fossils. It is approximately 300 m thick.

- The Passage Zone, about 100 m thick, consists of alternating cross-bedded layers of sand, clay, and silt.

- The Lower Bar is a cross-bedded sand layer about 30 m thick.

- The Tigillites Slope is a layer of argillaceous sand alternating with silty clay and burrows, 40 to 50 m thick.

**Devonian:**

The Devonian is divided into several parts:

- The Middle Bar is made of fine to coarse cross-bedded sand, approximately 50 m thick.

- The Trottoirs consist of alternating sand and clay, indicating a fluvio-estuarine environment.

- The Upper Bar is mainly composed of sand and is 80 to 100 m thick.

**Carboniferous:**

The Carboniferous is a series of clayey and sandy rocks with limestones and continental sediments. This includes different formations such as the Tournaisian, Visean, Westphalian, and the Tiguentourine series.

**Triassic, Jurassic, Malm:**

The Triassic is characterized by alternations of argillaceous sand and clay, overlain by carbonate rocks. The **Jurassic** consists mainly of sandy clay with sand and dolomitic limestone. The **Malm** represents a transition to the Cretaceous, with sands, sandstones, and clays.

**Barremian, Albian:**

The Barremian is composed of sand, argillaceous sand, and clay, with a thickness of about 300 m. The Albian is mainly sandy and clayey-sandy, with thicknesses varying by region.

**Cenomanian, Turonian, Senonian:**

The Cenomanian is characterized by marine deposits of clay and gypsum. The Turonianis predominantly limestone, while the Senonian consists of limestone, dolomite, and clayey sediments, sometimes with rock salt.

**Eocene:**

The Eocene consists mainly of dolomitic limestones with a thickness of 50 to 100 m.

**Mio-Pliocene:**

The Mio-Pliocene is recognized in the northwestern part of the province (Rhourd Nouss region) through oil and water boreholes. It appears as a detrital sequence composed of siliceous sands with intercalations of clays and sandstones. It thins towards the south and disappears on the Tinhert plateau. The **Terminal Complex** includes the Turonian, Senonian, Eocene, and Mio-Pliocene.

These rock and sediment layers form a complex geological history of the region, reflecting environmental changes through the ages.

These rock and sediment layers form a complex geological history of the region, reflecting environmental changes through the ages.


**Figure I.5:** Lithological column of the Illizi Basin. [5]

## I.6 Structure and tectonics of the basin:

The Illizi Basin represents only one entity of the Saharan platform. It falls into the category of stable intracratonic basins of the synéclise type that formed in the northern part of Gondwana, including, from east to west: the Kufra and Murzuk basins (Libya), the Mouydir, Ahnet, Sbaa, Reggane, and Tindouf basins (Algeria). The current structural image is linked to the various tectonic phases that have affected the region from the Cambrian to the Quaternary. The basin's individualization occurred at the end of the Silurian and during the early Devonian. [5]

The Illizi Basin is crossed by sub-meridian faults, most of them Pan-African (600 Ma). In the north, this region is covered by the Upper Cretaceous Tinhert plateau. At its far south, the Paleozoic formations offer exceptionally high-quality outcrops on the northern edge of the Hoggar. [5]

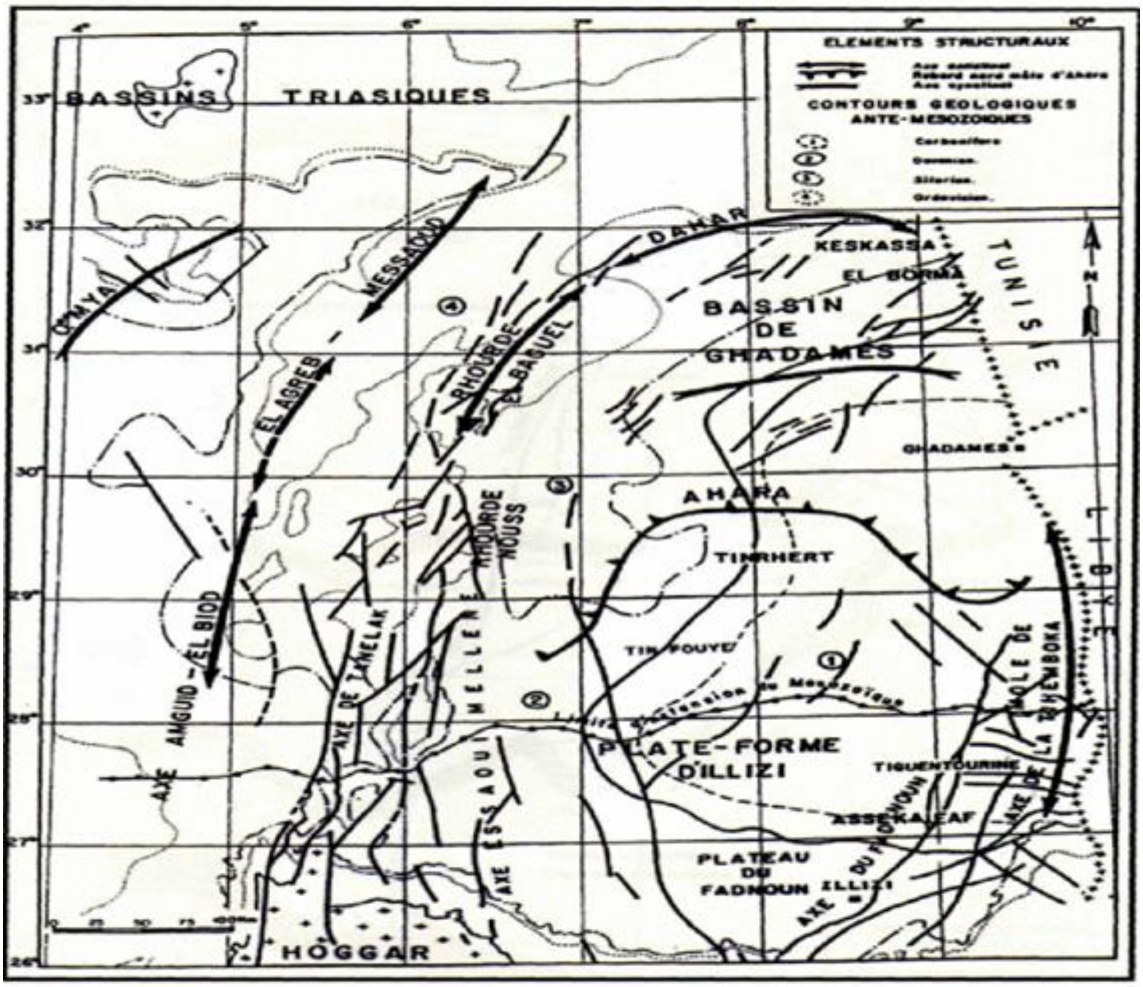


**Figure I.6:** schematic structural map of the synéclise.

### I.6.1 The main structural elements of the Illizi Basin:

The Illizi Basin is a geological zone with specific characteristics. It is formed by various elements such as uplifts and folds, which create depressions and troughs. These elements are separated by several major axes, running from west to east:

✓ The Amguid El Biod axis, which forms the western border of the basin and separates it from the Mouydir Basin to the east.

✓ The Tan Elak axis.

✓ The Essaoui Méllene axis.

✓ The axis passing through Maouar Tin Tayart.

✓ The Fadnoun axis.

✓ The Tihemboka axis.

The main directions of the axes are north-south and are accompanied by significant faults resulting from past tectonic movements. These movements occurred at different times and caused compressions, extensions, and lateral motions. The geological structures, such as folds, are often linked to these faults. Examining the structure of the basin reveals three main regions[5]:

- To the west, the Amguid El Biod region, between the Oued Miya - Mouydir depressions to the west and the Tin Tayart fold to the east.
- In the center, the Illizi Basin itself, less structured, with the Ahara fold in the middle, between the previous trends and the Fadnoun fault zone.
- To the east, the Tihemboka fold, between the Fadnoun trend and the Algerian-Libyan border. This region exhibits a different structural style, with varying fault directions.

This region shows a structural style different from the previous one; it is characterized by three fault directions: meridional to sub-meridional for the major faults, and NW-SE to WNW-ESE and E-SW for the secondary faults. It is within this particular context of this region that our study area is located, since it lies within the In Amenas permit, which roughly corresponds to the Tihemboka High. The thicknesses of all the Paleozoic series decrease over its highest central part. [5]

From south to north, the local structures present are: Collenias Domes, Tan Amellel, Edjeleh, Tihalatine, and Zarzaïtine.

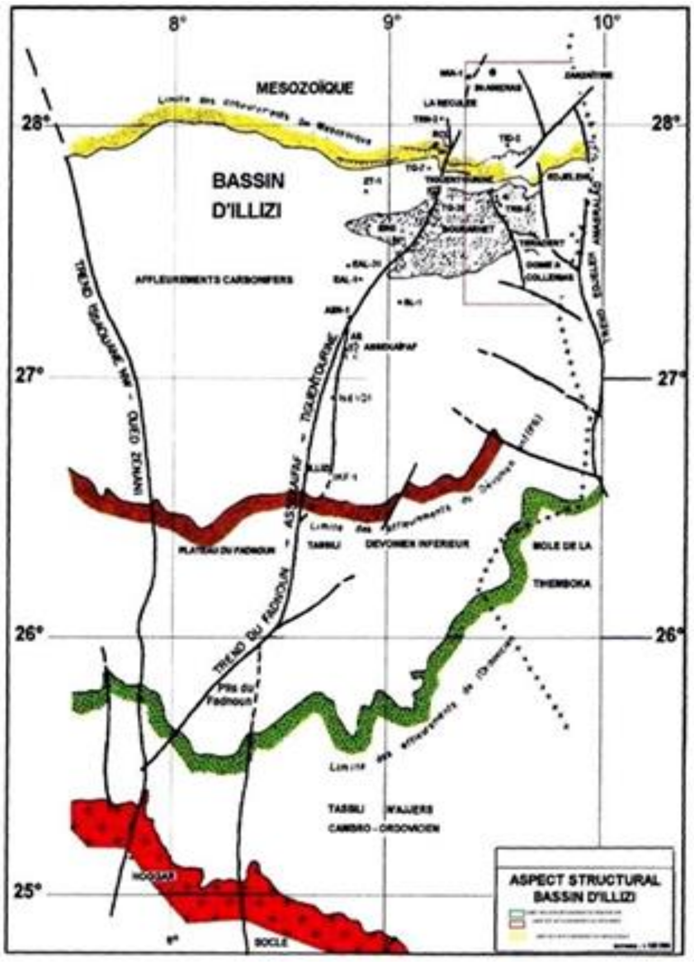


**Figure I.7:** Structural diagram of the Illizi Basin.

## I.7 Conclusion:

The Illizi Basin presents a major geological interest, attracting the attention of researchers for many years. Its strategic geographical location on the southeastern border of Algeria makes it a region of both geological and geopolitical importance. This area, characterized by a complex geological history dating back millions of years, has been the site of various tectonic and geodynamic events that have shaped its current landscape.

Understanding the different geological aspects of the Illizi Basin, such as its regional geological framework, its structure, its sedimentary cover, and its geodynamic evolution, is crucial for assessing its potential in natural resources, particularly oil and gas.

The lithostratigraphy of the Illizi Basin provides valuable information on the different rock layers that compose it, allowing researchers to reconstruct its geological history and identify the key structures that have influenced its formation and development.

# Chapter II: General information on exploration drilling of gas wells

## II.1 Introduction:

Petroleum is a naturally occurring liquid fossil fuel composed mainly of hydrocarbons. It is formed from the decomposition of prehistoric organic matter over millions of years under high pressure and temperature conditions. It accumulates in underground geological formations and is often associated with natural gas, as well as impurities such as water, carbon dioxide, and sulfur compounds.

Natural gas is one of the most important primary energy sources in the world. It is widely distributed across different regions and plays a crucial role in meeting global energy demand. Over the past decades, its consumption has increased significantly due to its relatively clean combustion, economic competitiveness, and versatility in use.

Compared to other fossil fuels, natural gas produces fewer pollutants such as sulfur dioxide ($SO_2$), nitrogen oxides ($NO_x$), and carbon dioxide ($CO_2$), making it a preferred transitional energy source in the shift toward more sustainable energy systems.

## II.2 Origin and Formation:

Natural gas is a fossil fuel formed over millions of years from the decomposition of organic matter such as plants and microorganisms. This process occurs under high pressure and temperature conditions deep within the Earth's crust.

It is often found in association with other fossil fuels such as petroleum and coal (including lignite), either in the same reservoirs or in nearby geological formations. The accumulation of natural gas occurs in porous rock formations sealed by impermeable layers, forming gas reservoirs.

### II.3 Composition and Properties:

Natural gas is not a single compound but a mixture of gases. Its primary component is methane ($CH_4$), which generally accounts for 75% to 95% of its composition. [6]

Other components may include:

- Ethane ($C_2H_6$)
- Propane ($C_3H_8$)
- Butane ($C_4H_{10}$)
- Small quantities of nitrogen, carbon dioxide, and hydrogen sulfide

**Key properties:**

- Colorless and odorless in its natural state
- Highly flammable
- Lower density than air
- High calorific value

For safety reasons, an odorant is added before distribution to detect leaks.

### II.4 The Natural Gas Value Chain:

The exploitation of natural gas requires advanced technical control across the entire gas chain:

#### II.4.1 Exploration and Extraction:

Natural gas is extracted from underground reservoirs using drilling techniques. These reservoirs may be conventional or unconventional (such as shale gas formations).

### II.4.2 Processing:

Raw natural gas contains impurities such as water vapor, $CO_2$, and hydrogen sulfide. These are removed in processing plants to meet commercial quality standards.

### II.4.3 Storage:

Gas is stored in underground reservoirs (depleted fields or salt caverns) or in liquefied form (LNG tanks) to ensure supply stability.

### II.4.4 Transportation:

Natural gas is transported through pipelines or as Liquefied Natural Gas (LNG), which allows long-distance shipping by reducing its volume.

### II.4.5 Distribution:

Finally, gas is distributed to consumers, including households, industries, and power plants.

## II.5 Types of Natural Gas:

Natural gas is classified based on its composition and behavior during production:

### II.5.1 Dry Gas:

Dry gas remains entirely in the gaseous phase under both reservoir and surface conditions. It contains mainly methane and very small amounts of heavier hydrocarbons.

### II.5.2 Wet Gas:

Wet gas produces liquid hydrocarbons at the surface, although no condensation occurs within the reservoir. It contains a higher proportion of heavier hydrocarbons.

### II.5.3 Condensate Gas:

Condensate gas forms liquid hydrocarbons within the reservoir as pressure decreases. These liquids, known as condensates, are rich in heavier components and have significant economic value.

### II.5.4 Associated Gas:

Associated gas is found in the same reservoir as crude oil. It can exist:

- Dissolved in oil (solution gas)
- As a gas cap above the oil layer

## II.6 Uses of Natural Gas:

Natural gas is used in multiple sectors:

### II.6.1 Energy Production:

It is widely used for electricity generation in gas-fired power plants due to its high efficiency.

### II.6.2 Residential and Commercial Use:

- Heating
- Cooking
- Water heating

### II.6.3 Industrial Applications:

- Fuel for industrial processes
- Production of hydrogen
- Manufacturing of fertilizers (ammonia)

### II.6.4 Petrochemical Industry:

Natural gas is a key raw material for producing plastics, chemicals, and synthetic materials.

## II.7 Advantages of Natural Gas:

- Cleaner than coal and oil
- High energy efficiency
- Abundant and widely available
- Flexible use across sectors
- Competitive cost

## II.8 Environmental Impact:

Although natural gas is cleaner than other fossil fuels, it still contributes to greenhouse gas emissions. Methane, its main component, is a powerful greenhouse gas if released into the atmosphere.

Environmental concerns include:

- Methane leakage during extraction and transport
- Impact of drilling activities
- Contribution to climate change

## II.9 Challenges and Future Outlook:

Despite its advantages, natural gas faces several challenges:

- It is a non-renewable resource
- Reserves are gradually declining
- Extraction is becoming more complex (deep offshore, unconventional sources)

However, technological advancements and improved environmental regulations are helping to make its production safer and more efficient.

Natural gas is expected to remain a key energy source during the global transition toward renewable energy systems.

### II.10 Definition of Exploration Activity and Its Missions:

In this section, a detailed presentation of the exploration activity and its fundamental missions will be provided.

#### II.10.1 Definition of Natural Gas Exploration:

Natural gas exploration refers to the set of scientific, technical, and economic activities aimed at identifying, locating, and confirming the presence of natural gas deposits in the subsurface, as well as assessing their potential and economic viability. It represents a fundamental stage in the energy industry, occurring after the prospecting phase and before exploitation.

The primary objective of natural gas exploration is to reduce uncertainties related to the presence, quantity, and recoverability of resources, while taking into account technical feasibility, economic profitability, and environmental constraints. This phase plays a crucial role in ensuring the sustainability of energy supply and guiding future development strategies. [7]

#### II.10.2 Oil and gas exploration process:

Oil and gas exploration is a complex process aimed at locating and confirming the presence of hydrocarbon deposits beneath the Earth's surface. This scientific and technical approach includes several phases, from initial surveys to drilling, to determine the commercial viability of a site**.** [7]

**Step 1: Geological Studies**

Geologists first study rock formations and structures to identify sedimentary basins likely to contain oil and gas. They analyze surface samples and historical data to locate potential source rocks, reservoir rocks, and trapping mechanisms capable of holding hydrocarbons.

**Step 2: Geophysical Surveys**

Next, geophysical methods like seismic surveys are used to create images of the subsurface. Sound waves are sent into the ground, and their reflections are captured to map underground rock layers and identify promising geological structures that may contain oil and gas.

**Step 3: Exploratory Drilling**

Once a potential site is identified, a well is drilled to confirm the presence of hydrocarbons. This costly and risky step involves extracting rock and fluid samples to determine the quantity and quality of the reservoir.

**Step 4: Well Testing and Evaluation**

Finally, the well is tested to assess its commercial viability. Engineers measure the flow rate of oil or gas and analyze reservoir pressure. These data determine if the discovery is significant enough to justify the substantial investment required for large-scale development.

### II.10.3 Objectives of the exploration activity:

Exploration continues its development plan, which reserves a significant place for short-term foreign partnerships. It sets the following objectives:

- The re-evaluation of existing fields;
- The discovery of new fields, prospecting in underexplored areas;

The promotion of blocks, particularly those distant from existing exploration and transport infrastructure;

- The search for new prospecting opportunities outside Algeria.

This research effort aims to renew reserves, ensure the country's long-term supply, and allow future generations to benefit from the national energy heritage

### II.10.4 Methods of exploration activity:

#### II.10.4.1 The geological method:

Geological exploration involves observing and describing surface samples (outcrops) and subsurface samples (cores and well cuttings), followed by laboratory analysis. From the results of seismic interpretation of field and well data, a multidisciplinary synthesis is developed. [8]

**Main Tools Used:**

The primary tools employed are:

- Field samples.
- Well cores and cuttings.
- Well logs (in-situ recordings in wells).
- Well seismic (sonic logging; VSP - Vertical Seismic Profiling).

**Geological Studies:**

These studies are dictated by the level of knowledge of the sedimentary basin. The more explored the site, the more refined the surveys become. This approach helps verify:

- Hydrocarbon formation and maturity.
- Presence of reservoir rocks capable of containing them and trapping mechanisms to retain them.

### II.10.4.2 Geophysical Methods:

Since the information gathered by geological methods only concerns the surface of the terrain, it is then supplemented by other subsurface-related techniques through geophysical methods. [9]

#### II.10.4.2.1 Magnetometry:

This method, used for recognizing subsurface formations, involves variations in the Earth's magnetic field caused by differences in the magnetic susceptibility of rocks a coefficient whose values are significant only for ferromagnetic rocks, but become weak for crystalline rocks and very weak for sedimentary rocks.

#### II.10.4.2.2 Gravimetry:

consists of measurements of the Earth's gravitational field. This parameter is measured through variations in gravity from one point to another, allowing us to infer the densities, shapes, and nature of subsurface layers.

#### II.10.4.2.3 The electrical method:

The objective is to measure electrical resistivities on the surface, based on which the subsurface characterization is performed. The resistivity of rocks depends on their type as well as the fluids present in the pores; the main factors determining rock resistivity are the salt concentration, chemical composition, and temperature of the solution.

#### II.10.4.2.4 The seismic method:

Unlike the previous prospecting methods, which are reconnaissance studies of the terrain, seismic methods are more refined and primarily intended for oil exploration. They are based on the emission of elastic seismic waves by shaking sources (explosives or vibrators), followed by the recording of reflected or refracted waves using appropriate surface devices. The study of these recordings allows for a precise reconstruction of subsurface structural shapes and the location of structures that could act as traps for hydrocarbons.

The geometry of wave acquisition determines the methods used. These include:

- **2D seismic (2 dimensions)**: Traditional method providing measurements along a single plane. It yields results but has limitations in certain cases.
- **3D seismic**: A newer method that provides spatial information of the prospected terrain. It offers high resolution.
- **4D seismic** (also called reservoir seismic): Combines 3D seismic with a time dimension. It is used to monitor a producing reservoir over time. Its application is still in early stages.

These methods produce subsurface trace maps after processing the acquired data. These maps can be considered as an ultrasound of the subsurface. They enable the extraction of a structural image of the subsurface, sometimes locating reservoirs and identifying various contacts.

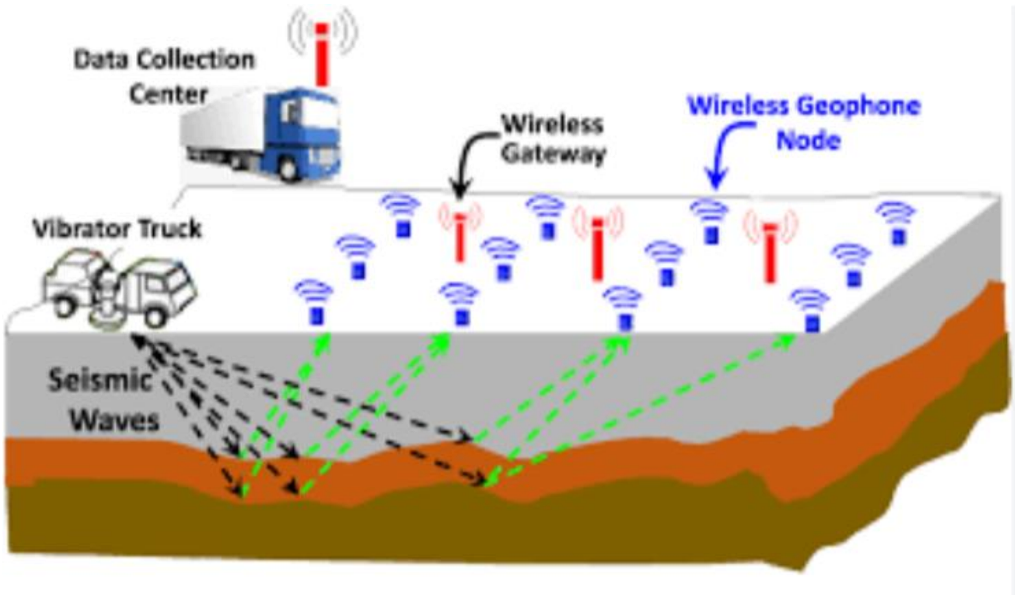


**Figure II.1:** Seismic method.

## II.11 Drilling Activity Description:

Drilling is the mechanical process of creating a wellbore through subsurface layers using a drilling rig, and it represents the only way to definitively confirm the presence of a hydrocarbon reservoir after surface and seismic studies. A drilling program is first established, outlining the well objectives, planned depth, trajectory (vertical, deviated, or horizontal), casing design, mud properties, cementing schedule, and blowout prevention equipment. Once drilling begins, a set of complementary studies is carried out both during and after the operation. While drilling, logging-while-drilling (LWD) tools and mud gas analysis provide real-time data on lithology, pressure, and hydrocarbon shows. After reaching total depth, wireline logging tools measure resistivity, density, neutron porosity, and natural gamma radiation to identify pay zones. Coring recovers intact rock samples for laboratory analysis of porosity and permeability, while formation testers (such as MDT or DST) directly sample reservoir fluids and measure pressure. Together, these techniques allow geoscientists to certify whether hydrocarbons are present, assess reservoir quality, and decide whether to complete the well for production or plug and abandon it**.** [10]

### II.11.1 Definition of oil drilling:

Oil drilling is a set of operations that can reach porous and permeable rocks in the subsurface, which contain liquid or gaseous hydrocarbons.

The main objective of these operations is to search for deposits, develop them, and bring them into production.

An oil well is determined based on geological and geophysical studies of the sedimentary basin to gain an understanding of the composition of the subsurface soils. [10]

Drilling can be diversified into three types:

- **Vertical drilling**: allows drilling a well directly above the vertical projection of the reservoir zone where oil is likely to be present in the subsurface.
- **Deviated drilling**: allows drilling multiple targets from a single drilling site. This reduces the number of surfaces sites and makes it possible to use existing facilities.
- **Horizontal drilling**: allows reaching multiple subsurface targets from a single site, maximizes the contact surface area with the reservoir, and thus reduces the number of wells.

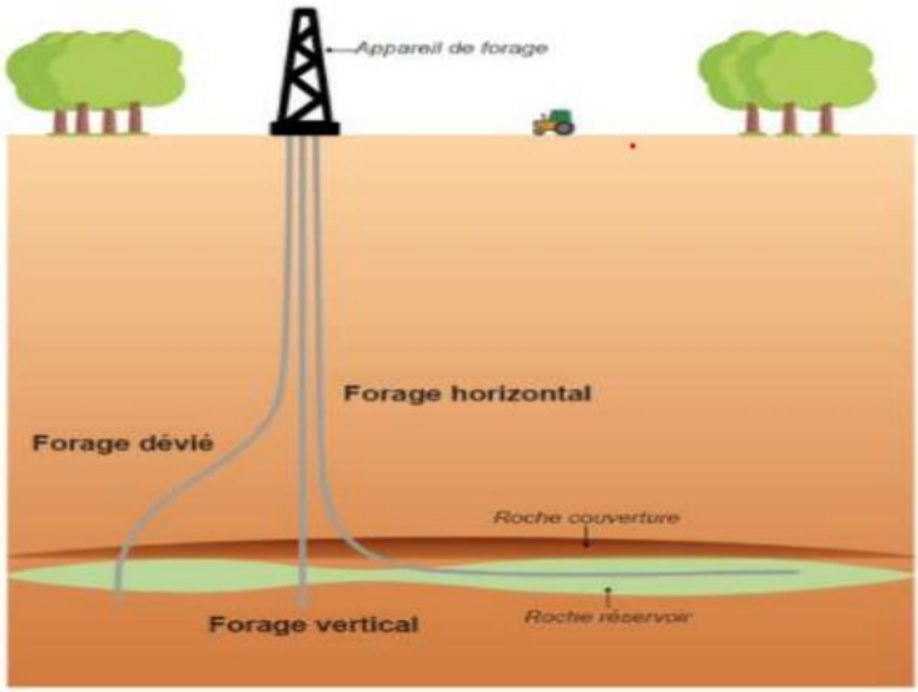


**Figure II.2:** Types of drilling.

### II.11.2 Drilling program:

The objective is to define the well's construction parameters in a way that meets all specifications while ensuring the best possible economic outcome.

The parameters to be determined include:

- The respective diameters of the drill bits and casing strings.
- The number of casing strings and their setting depths.
- The cement heights behind each casing string.

It is crucial to recognize that a well-designed drilling and casing program has a major impact on the success of the borehole, the safety of operations, and the final casing cost. Such a program is typically developed as follows:

➢ First, the diameters of the final casing string are established.
➢ Then, the shoe depths and diameters for each casing string and drilling phase are selected. This process works backward: starting from the last drilling phase at the target depth, the required diameters are determined as you move up toward the surface.

**II.11.3 Casing and Tubing Technology:**

Casings and tubings are manufactured according to API standard 5CT. They are defined by three main characteristics:

➢ Pipe body geometry.

➢ Steel grade.

➢ Connection coupling geometry.

**II.11.3.1 Types of Casing Strings and Their Functions:**

**a) Conductor Pipe:**

This is a lightweight casing string driven or cemented into the ground to a depth of roughly ten meters. Its role is to direct mud flow during the initial drilling stage and to prevent surface unconsolidated formations from washing away. Typically, service companies run and cement the conductor pipe, which is then extended with a ditch pipe.

**b) Surface Casing:**

This is the first true casing string installed using standard oilfield practices. It serves several purposes: stabilizing shallow, unstable formations; isolating fresh water zones from drilling mud contamination; providing a mounting base for the blowout preventer (BOP); and supporting the hangers for deeper casing strings. Depending on local conditions, the surface casing may range from a few tens to several hundred meters in length.

**c) Intermediate Casing:**

This casing string is run to allow drilling to continue safely under challenging conditions, such as:

➢ When formation caving creates hazards during drilling or tripping operations.

➢ When drilling mud alone cannot provide sufficient protection—for instance, in highly hydratable clay formations that remain problematic even with calcium-based muds.

➢ When it is necessary to isolate zones containing high-pressure or low-pressure fluids. Drilling through such zones often involves partial or total mud losses, and running a casing string afterward helps prevent expensive mud losses.

**d) Production Casing:**

For development wells, production casing is essential. It fully protects the reservoir zone and allows production equipment to be installed. It is cemented under the same conditions as intermediate casing.

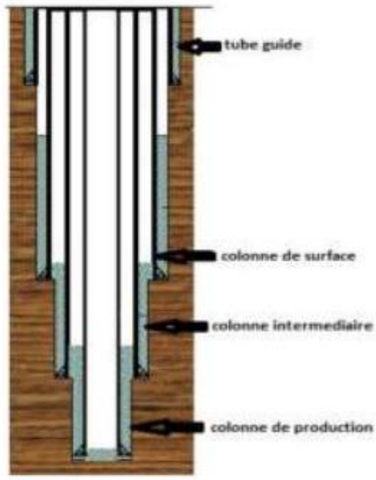


**Figure II.3:** Types of casing.

**e) Liner (Stuck Casing):**

Unlike full-length casing strings that extend from bottom to surface, a liner is hung mechanically (using a liner hanger) from the lower section of the existing casing string. Liners offer benefits such as reduced pipe consumption, lower overall weight, and a larger internal diameter between the surface and the liner top. However, they also have drawbacks: the hanging and cementing operations are more complex, and the parent casing must be designed to withstand the same burst pressure as the liner.

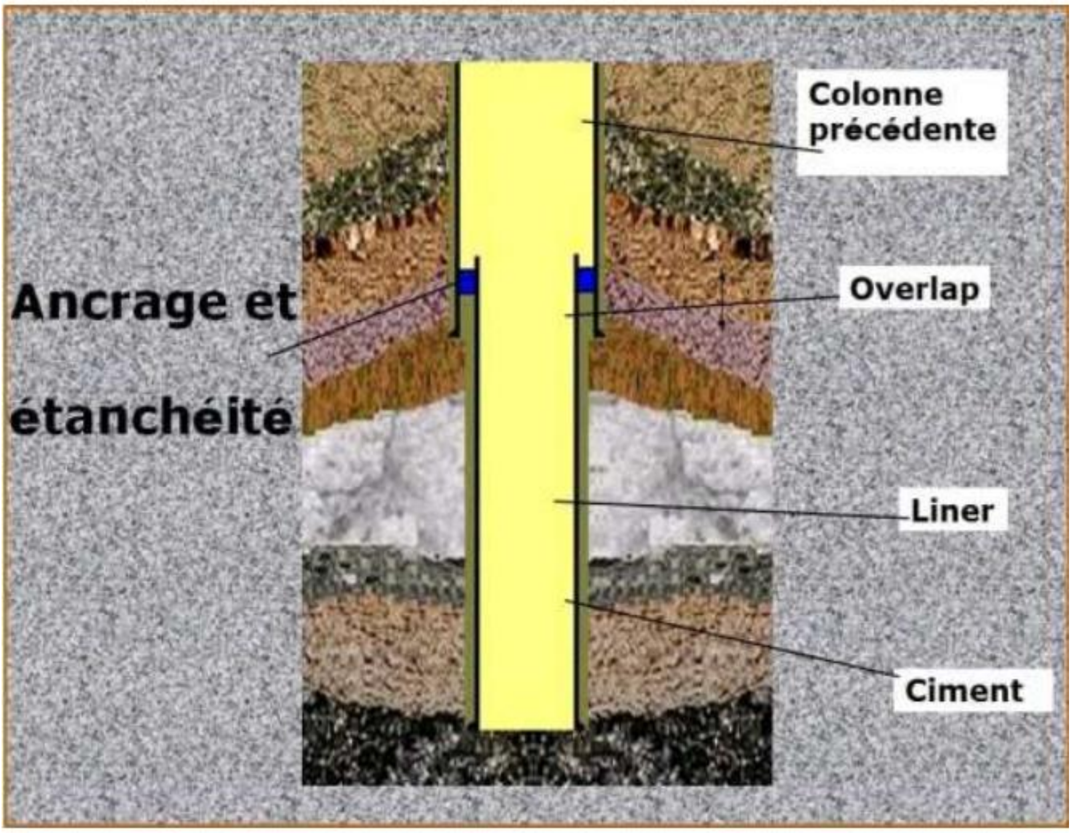

**Figure II.4:** Liner (Stuck Casing).

### II.11.3.2 Determining casing shoe depths:

A skilled driller — one who designs a proper well program — achieves the objective by using as few casing strings as possible while setting each shoe at the maximum feasible depth. Therefore, determining the depth of each casing shoe is a key factor for the well designer.

### II.11.3.3 Determining cementing heights:

The required cementing heights depend on the function and type of each casing string:

➢ Surface casing: This is cemented along its full length to ensure it can support surface safety equipment and remain firmly anchored at the wellhead.

➢ Intermediate casing: Depending on the situation, the intermediate casing may be cemented either in a single stage or in two stages.

➢ Production casing: Cementing is a critical operation here, as the cement must not only form a continuous column but also provide a long-lasting, effective seal between the borehole and the casing.

### II.11.4 Supporting studies:

Beyond the casing and drilling plan, several key supporting studies are necessary to anticipate both the methods and the equipment required to drill the well. These forecasts serve as the basis for estimating the final drilling cost.

#### II.11.4.1 Drill bit scheduling:

After the drilling program has set the hole diameters, the formation's drill ability must be evaluated in order to select the appropriate bits and their operating parameters. For development wells, analyzing past bit performance allows drillers to estimate penetration rates, bit quality, required quantity, and total footage.

#### II.11.4.2 Bottom hole assembly (BHA) design:

The drill stem is sometimes referred to as the drilling shaft, meaning the mechanical link between a rotary drive at the surface and the drill bit downhole. Its main roles are:

➢ Transmit the energy required for rock destruction by a drill bit.

➢ Guide and control the tool's trajectory.

➢ Apply a compressive force (weight on bit) to the drill bit.

➢ Allow drilling fluid circulation with minimum pressure loss.

The main bottomhole equipment consists of:

➢ Drill collars.

➢ Drill pipes.

➢ Auxiliary equipment.

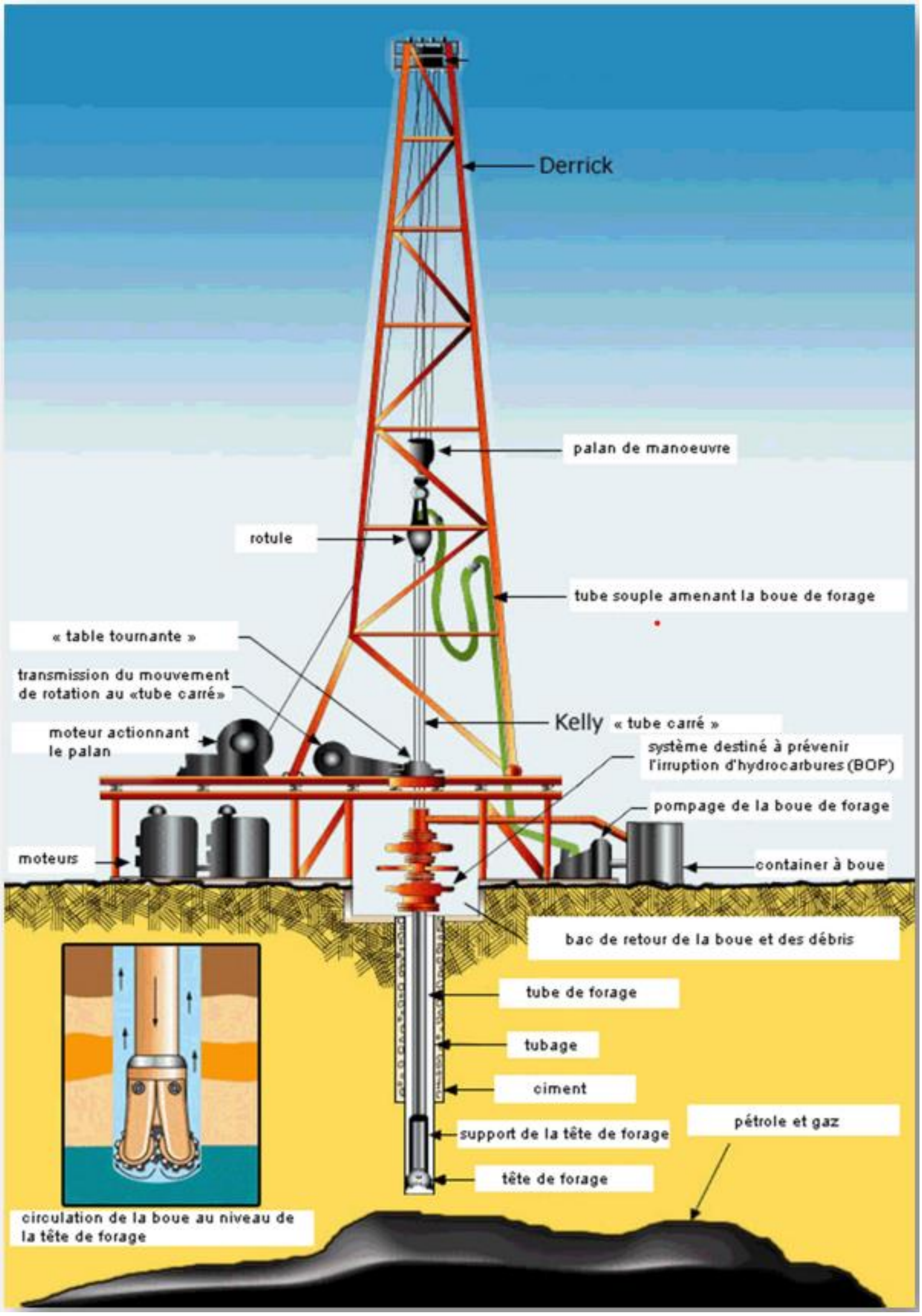


**Figure II.5:** Drilling rig.

### II.11.4.3 Mud program:

The circulation of drilling fluid during oil well construction is of great importance because it allows to:

- ➢ Bring cuttings to the surface;
- ➢ Keep cuttings in suspension after circulation stops;
- ➢ Cool the bit and reduce friction on the drill stem;
- ➢ Maintain the walls of the borehole;
- ➢ Control formation fluids through its pressure;
- ➢ Condition the rate of penetration of the drill bit;
- ➢ Transmit power to downhole motors.

The mud program must define the type and characteristics of the fluids used per phase, as well as possible conversions and any weighting (densifying) that may be necessary. The program therefore depends on the geology, the well architecture, the drilling objectives, and the measurements and operations required within productive zones. From this, the necessary volumes and flow rates will be deduced, which will guide the selection of water-based or oil-based mud products.

The ecological constraint is an increasingly decisive factor in the choice of mud types, given the rates, the nature of the discharges, and local regulations.

### II.11.4.4 Casing and cementing program:

These two operations are essential for well consolidation. In general, there is no casing installation in a borehole without it being cemented in place. Casing and cementing have the particularity that any incident during the operation risks having extremely unpleasant consequences for the continuation of drilling or for bringing the well into production. This therefore requires as careful preparation as possible.

**a) Casing operation:**

This is the action of running a casing string into the pre-drilled hole. It therefore involves:

**Hole preparation:**

- Performing logging operations;
- Checking the stability of the borehole walls;
- Circulating and possibly treating the mud;

**String preparation: installing accessories:**

- Shoe;
- Landing collar;
- Centralizers;
- Scratchers;
- Hydrobonders (turbulizers);
- Cementing baskets;
- Cementing head;
- Cementing plugs;
- Cementing equipment.

**b) Cementing operation:**

Cementing consists of placing an appropriate cement slurry at a specific well depth or in the annular space between the borehole and the casing in place.

There are different types of cementing, each addressing a particular problem. The cementing execution steps are as follows:

➢ Primary cementing: injecting cement slurry to displace the mud in place and simultaneously clean the borehole walls;

➢ Two-stage cementing;

➢ Liner cementing.

### II.12 Conclusion:

In a world facing ever more urgent energy and environmental challenges, oil exploration and drilling continue to serve as fundamental pillars of both our economy and society. Nevertheless, the future of this industry hinges on well-informed strategic decisions, major technological breakthroughs, and an increasing recognition of sustainability's importance. By bringing together innovation, accountability, and operational efficiency, oil exploration and drilling can remain key players in meeting our energy needs while adjusting to the evolving demands of a rapidly changing world.

# Chapter III: Exploration drilling procedures and equipments

## III.1 Introduction:

This study focuses on the drilling rig and the main systems that ensure its safe and reliable operation. A drilling rig is a complex piece of equipment used to drill wells for oil, gas, and other subsurface applications. Its performance depends on the integration of several essential components, including lifting equipment, power equipment, rotary equipment, circulation equipment, and safety equipment.

Understanding the role of a drilling rig is important because it allows us to identify how each system contributes to the drilling process. In addition, selecting the appropriate drilling rig is a critical decision that depends on technical, operational, and economic factors such as drilling depth and geological conditions. Each category of equipment plays a specific role: lifting systems handle heavy loads, power systems provide the necessary energy, rotary systems enable drilling action, circulation systems remove cuttings and cool the drill bit, and safety systems protect personnel and equipment.

Beyond the drilling phase itself, two further aspects are essential to evaluating well productivity and preparing it for production: the drill stem test and well completion. The drill stem test is conducted to obtain reservoir pressure, permeability, and fluid samples before casing is set, providing critical data on the well's potential. Well completion, on the other hand, involves the steps taken to transition a drilled well into a producing one, including casing, cementing, perforating, and installing production tubing and surface equipment.

## III.2 The role of a drilling rig:

The role of a drilling rig is to establish a connection between a hydrocarbon reservoir and the surface under the best possible technical, economic, and safety conditions.

**III.3 Classification of drilling rig:** There's a whole range of drilling rigs out there is light, medium, heavy and super heavy rigs.

There are two closely related features drive how rigs are classified:

- Maximum drilling depth capacity
- Drawworks horsepower

So that gives us:

**Table III.1:** Classification of drilling rig [22].

| | | |
|---|---|---|
| **Light rig** | 4,921' to 6,561' (1,500 to 2,000 m) | 650 HP |
| **Medium rig** | 11,482' (3,500 m) | 1,300 HP |
| **Heavy rig** | 19,685' (6,000 m) | 2,000 HP |
| **Super heavy rig** | 26,685' to 32,808' (8,000 to 10,000 m) | 3,000 HP |

### III.4 Choosing a Drilling Rig:

Selecting the optimal drilling rig that matches the power requirements of the drilling program is an ongoing concern. The goal is to achieve the highest quality/price ratio while meeting all safety standards. An oversized rig leads to unnecessary extra costs, while an undersized one poses constant risks and may limit pulling capacity in case of stuck pipe.

A drilling rig consists of two main parts:

#### III.4.1 Surface Equipment:

which includes:

- Hoisting equipment.

- Power equipment.
- Rotary equipment.
- Circulation equipment.
- Safety equipment.

#### III.4.1.1 Hoisting equipment:

The hoisting system is one of the main systems of a drilling rig, responsible for raising and lowering the drill string, casing, and other heavy equipment in the wellbore. It provides the lifting power needed to handle the entire weight of the drill string and associated tools safely and efficiently [11].

##### III.4.1.1.1 Drilling mast:

It's the derrick mast that supports the traveling block. Serving the same function as a derrick, the mast distinguishes itself through its lightweight design and mobility. It can be lowered, raised, and sometimes transported fully assembled. If there are transport constraints, it is divided into a very small number of sections.

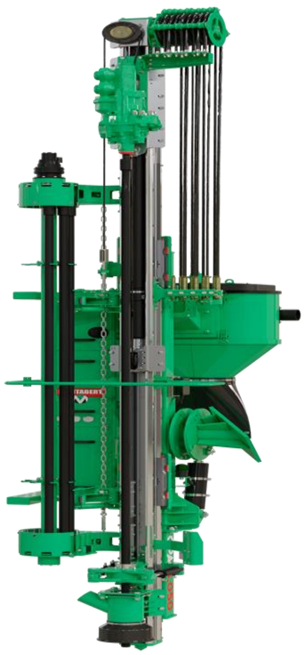

**Figure III.1:** Drilling mast.

**III.4.1.1.2 The block:** or (mouflage in French) is a mechanism used to multiply lifting power, allowing for the handling of extremely heavy loads by distributing the weight across multiple lines of cable. It also serves to [11]:

- **Reduce tension:** It lowers the stress exerted on the active (fast) line.
- **Distribute load:** It spreads the suspended weight across multiple strands of cable, which allows for smaller, more manageable drilling cable dimensions.
- **Adjust speed:** It allows for the multiplication of the traveling block's speed.

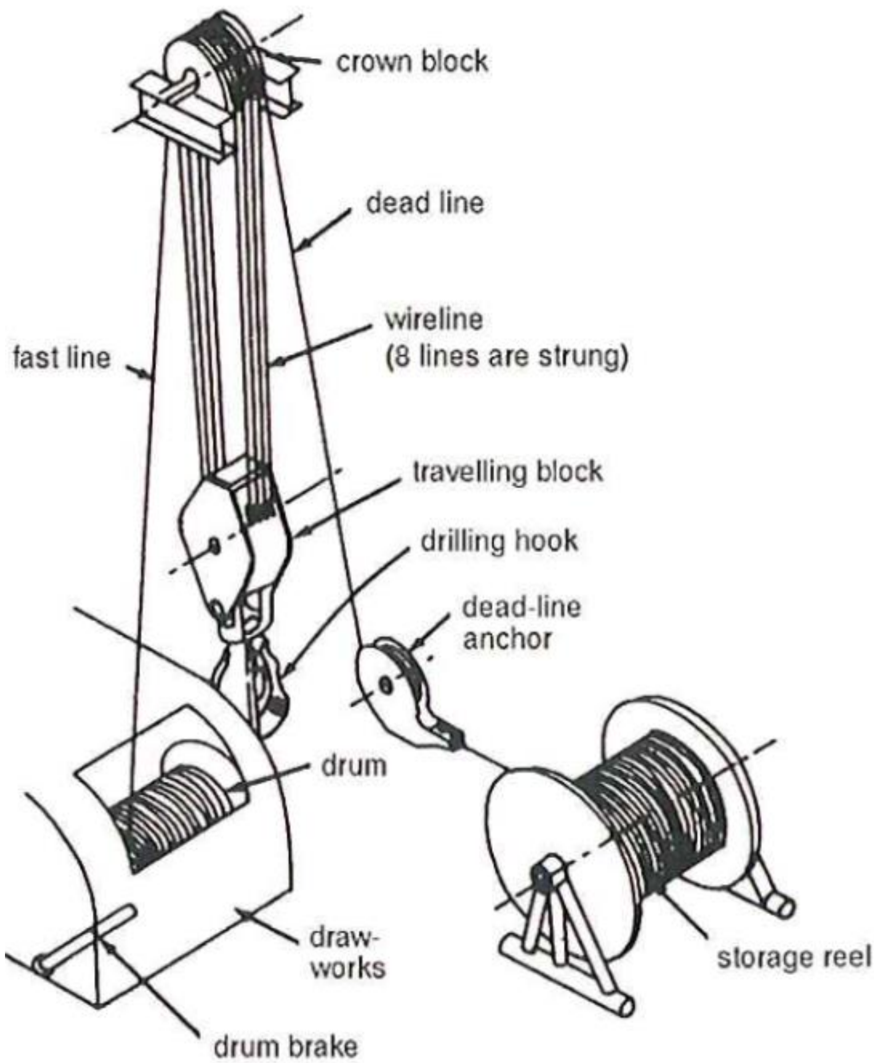


**Figure III.2:** Hoisting system. [11]

**III.4.1.1.3 Drilling Line:** The drilling line spools off the drawworks drum, passes through the sheaves of the stationary crown block at the top of the mast, and then threads through the sheaves of the traveling block. The final end of the cable is secured to a fixed anchor point. [11]

- **Number of lines:** The system typically uses between 4 and 14 lines (strands) to support the weight of the drill string.
- **Fast line:** The section of the cable connecting the drawworks drum to the crown block.
- **Dead line:** The section connecting the crown block to the fixed anchor point.
- **Weight monitoring:** The tension is measured at the dead line, which allows the operator to calculate the total weight currently suspended from the hook.

**III.4.1.1.4 Crown block:**

It is a set of pulleys supported on the upper platform of the mast. The pulleys are aligned on the same axis. The pulley shaft has perforations to allow lubrication of the various pulley bearings. The shaft is supported at its ends by two bearings mounted on beams fixed to the top of the mast. To extend the life of the pulleys and ensure even wear, it is recommended to swap the pulley positions (by switching the working and dead ends) once a year. The crown block has one more pulley than the traveling block. [11]

**III.4.1.1.5 Traveling block:**

This block is a set of sheaves (pulleys) that move up and down in the derrick. The drilling line is threaded (reeved) over the sheaves on the crown and through the sheaves in the traveling block. This provides a significant mechanical advantage to the drill line, enabling it to lift heavy loads of pipe and casing. The number of pulleys used on the traveling Block will be from five to eight, providing a variable capacity to the Hoisting system [11].

**Observation:** Traveling block specs are much similar to crown block. The diameter and groove of the pulleys will depend on the drilling line dimensions we plan to use. The manufacturer determines these values as per API RP 9B. Same as the crown block, the proportion of the sheave diameter to the drilling line should be between 30-40:1. The traveling blocks are built as per API Spec. 8A and 8C.

#### III.4.1.1.6 Drawworks:

This is the heart of the drilling rig, so the drawworks's capacity is what characterizes a drilling rig and indicates the depth class of the boreholes that can be drilled. Consisting of a large-diameter steel spool, brakes, a power source and assorted auxiliary devices

The drawworks comprises a set of mechanical components and performs several functions:

- Raising and lowering (lifting) the drill string at high speeds and safely, which is its primary function.
- Driving the rotary table when it is not driven by an independent motor.
- Curving and uncurling the drill string, as well as cleaning operations.

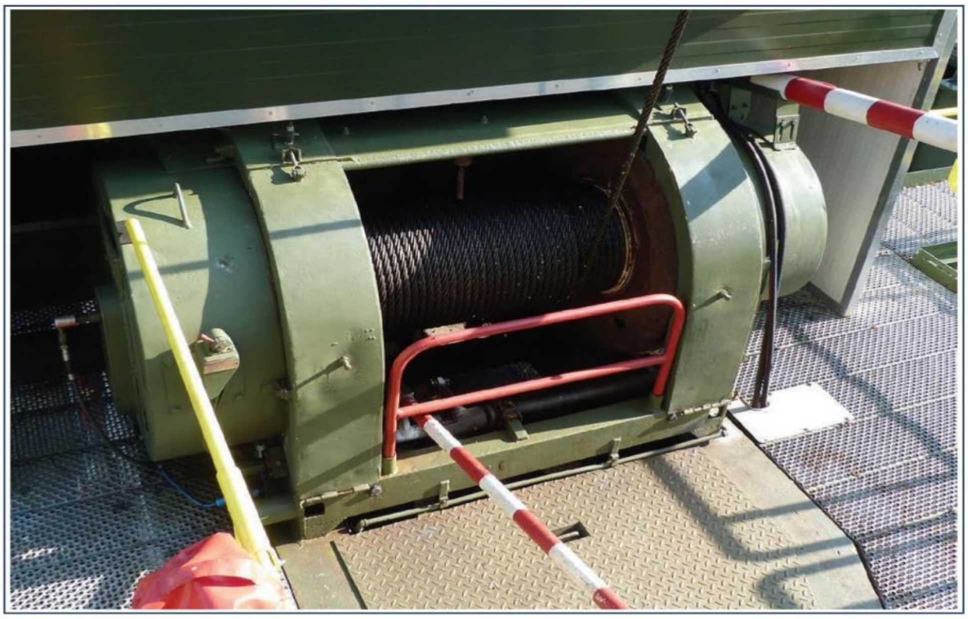

**Figure III.3:** Drawworks.

### III.4.1.1.6.1 The main components of the drawworks:

#### III.4.1.1.6.1.1 The drum:

The drum is the active part of the winch; the drilling cable is wound around this component. There are two types of operating drum: smooth or grooved.

For proper winding to prevent cable crushing when suspending heavy loads, the grooved drum is strongly recommended.

#### III.4.1.1.6.1.2 The shafts of the drawworks:

**III.4.1.1.6.1.2.1 Input shaft:** it's the one that receives the power from the power source then transmits it to the output shaft, dual chain of three rows is related to the engine allows it to turn at a speed of 602 RPM, an inert brake is placed nearby which allows rotation stop while changing the gears.

**III.4.1.1.6.1.2.2 Output shaft:** it's related to the input shaft with two chains each one with three rows, this configuration allows us to get two speed rations: High 457 rpm and Low 285 rpm.

**III.4.1.1.6.1.2.3 Drum shaft:** drum shaft assembly is the key component of drawworks, it allows the traveling system wireline onto the drum to be winded or withdrawn onto or from the drum by the clockwise or counter clockwise, its connected to the gearbox with two chains of 3 rows on opposite sides of the shaft (on the right side: high speed, left side: low speed) generating 4 speed rations. [12]

**Table III.2:** Drum shaft. [12]

| **SPEED (rpm)** | | **DRUM CLUTCH** | |
|---|---|---|---|
| | | **LOW** | **HIGH** |
| **INPUT SHAFT** | **LOW** | 65 | 243 |
| | **HIGH** | 105 | 393 |

**III.4.1.1.6.1.2.4 Cathead shaft:** it is related to the drum shaft with one chain of one row, generating two speed rations: LOW 102 rpm; HIGH 195 rpm.

**III.4.1.1.6.2 The different types of brakes on the drawworks:**

**III.4.1.1.6.2.1 The mechanical band brake:**

The mechanical band brake is used to control the drill bit's movement during drilling, for raising and lowering the drill string.

The mechanical band brake consists of two metal bands fitted with brake linings, which are secured by bolts or rivets. [12]

**III.4.1.1.6.2.2 The auxiliary brake:**

The auxiliary brake slows the movement of the traveling block to achieve a controlled speed of the lining during its descent (creating a movement opposite to that of the drum). There are two types of auxiliary brake:

**1-** Hydraulic retarder.

**2-** Electromagnetic retarder.

**III.4.1.1.6.2.3 Twin stop system:**

The twin stop protects the floor and both blocks by automatically engaging the drawworks's mechanical brake. The twin stop automatically brakes the movement of the traveling block in two preset positions: low and high, in both directions, on both the floor and fixed block sides.

The twin stop consists of:

- Mechanical control system.
- Pneumatic control system.

The twin stop is driven by a transmission chain from the drum.

**III.4.1.1.7 Hook:**

Generally, the hook, from which are suspended the various tools used for raising and lowering the drill pipe, drill collars, casing, etc..., is either suspended from the traveling block or is an integral part of it. It can rotate on bearings in its housing but can also be locked in various positions. [13]

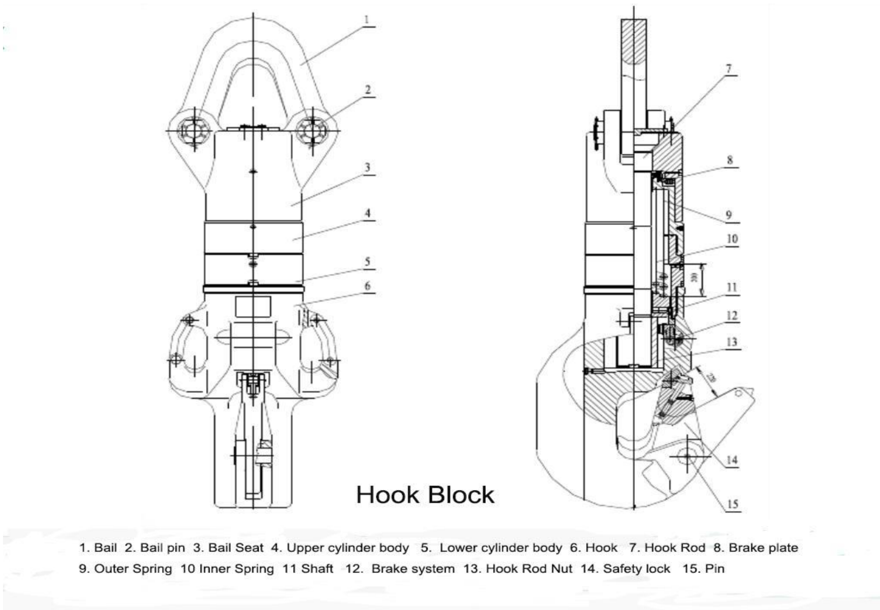


**Figure III.4:** Hook.

### III.4.1.2 Rotary equipment:

The rotary system is one of the key systems of a drilling rig, responsible for rotating the drill string and drill bit to penetrate the subsurface formations. This system enables the cutting action of the drill bit and the removal of drilled cuttings through the circulation of drilling fluid.

#### III.4.1.2.1 Top drive:

The Top Drive System used on oil drilling rig could drive the drilling drill string rotate from the top of drilling tool directly, it also could rotate and release the drilling bit, it could move along with the guide beam up and down to finish drilling. [14]

Mechanical structure of Top Dive Drilling System includes assembly and components as follows:

- Power swivel.
- Pipe handler System.

- Guide Beam and tackle.

**Figure III.5:** Top drive [15].

**III.4.1.2.2 Rotary table:**

The rotary table is a mechanical device on a drilling rig that transmits rotary motion to the drill string, it used to be the way to drill in the old days. There are still many rigs in the industry that use this technique, especially on smaller land rigs where they don't have enough space in the mast to house the traveling block, hook, swivel and top drive.

Most rotary tables are chain driven. Virtually all rotary tables are equipped with rotary locks, one for each direction. Engaging the lock can either prevent the rotary from turning in one particular direction or from turning at all.

The rotary bushings are located at the center of the rotary table. These bushings usually consist of the master bushing and the insert bowls. These can generally be removed in two separate pieces to facilitate large items, i.e. drill bits, to pass through the rotary table. [14]

In drilling engineering, rotational speed is measured in RPM and directly affects drilling performance and ROP. Rotary speed and torque must be selected together because higher torque is generally needed for harder formations or larger hole sizes. That is why rotary tables are sized according to both mechanical load and operational duty rather than only diameter.

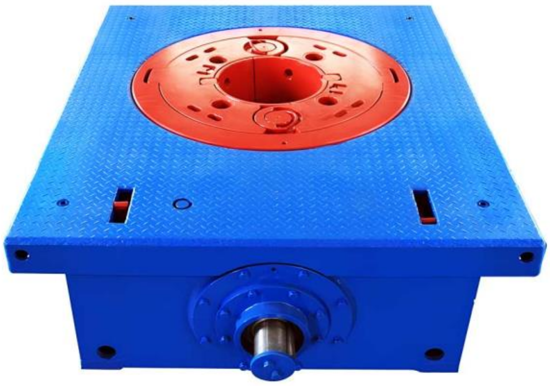

**Figure III.6:** Rotary table.

- The power of the table will be:

$$Pu = \left(\frac{L}{30} + 10\right)\frac{N \cdot Pd}{100 \cdot D} \qquad \text{(III.1)}$$

$\boldsymbol{Pu}$ **:** Useful power (hp)

$\boldsymbol{L}$ **:** Depth of the well (meters)

$\boldsymbol{N}$ **:** Rotary speed (RPM)

$\boldsymbol{Pd}$ **:** Weight on bit (tons)

$\boldsymbol{D}$ **:** Hole diameter (inches)

#### III.4.1.2.3 Swivel:

Swivel is a mechanical device used on a drilling rig that hangs directly under the traveling block and directly above the Kelly drive, that provides the ability for the Kelly (and subsequently the drill string) to rotate while allowing the traveling block to remain in a stationary rotational position (yet allow vertical movement up and down the derrick) while simultaneously allowing the introduction of drilling fluid into the drill string. [16]

**Figure III.7:** Swivel.

This table shows some types of swivels:

**Table III.3:** Swivel types. [16]

| Model | | SL 110 | SL 135 | SL 170 | SL 225 | SL 315 |
|---|---|---|---|---|---|---|
| Max Static load | kN | 1100 | 1350 | 1700 | 2250 | 3150 |
| | US ton | 120 | 150 | 200 | 250 | 350 |
| Dynamic load rating | kN | 600 | 1000 | 1300 | 1600 | 2100 |
| | US ton | 65 | 110 | 140 | 175 | 230 |
| Max Speed | rpm | 300 | 300 | 300 | 300 | 300 |
| Max Pressure | MPa | 35 | 35 | 35 | 35 | 35 |
| | psi | 5000 | 5000 | 5000 | 5000 | 5000 |
| Gooseneck connection | | 3LP | 4LP | 4LP | 4LP | 4LP |
| Sub connection | | 4-1/2 REG-LH | 6-5/8 REG-LH | 6-5/8 REG-LH | 6-5/8 REG-LH | 6-5/8 REG-LH |
| Applicable spinner model | | | XSL 135 | XSL 170 | XSL 225 | XSL 315 |

**III.4.1.2.4 Kelly:**

Kelly is a square or hexagonal pipe that fits into the drilling rig rotary table bushing (Rig components). They turn to the right as the rotary table turns. In other words, Kelly's mission is to transfer energy from the rotary table to the drill string.

The Kelly serves as the direct link between the rig's surface equipment and the drilling bit, making it an essential part of the rotary drilling system. On modern drilling rigs, this role is often replaced by a top drive system, power swivel, or power sub installed beneath a conventional swivel. In operations that use a downhole mud motor for directional drilling or similar applications, the drill string typically does not rotate.

The manufacturing of Kelly in oil and gas rigs will be with either square, triangular, or hexagonal (most common). [17]

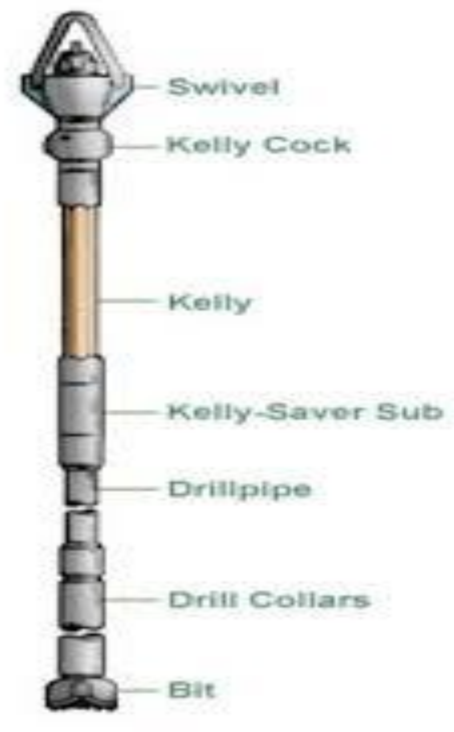


**Figure III.8:** Kelly.

### III.4.1.2.5 Kelly bushing:

The Kelly drive bushing is recommended to be fitted to the rotary table, through which the Kelly passes. it has an internal diameter profile that matches the Kelly, usually square or hexagonal.

Depth measurements are commonly referenced to the Kelly bushing.

The rotary motion from the rotary table is transmitted to the bushing through the pins, and then to the Kelly itself via the square or hexagonal flat surfaces between the Kelly and the Kelly bushing. The Kelly then turns the entire drill string because it is screwed into the top of the drill string.

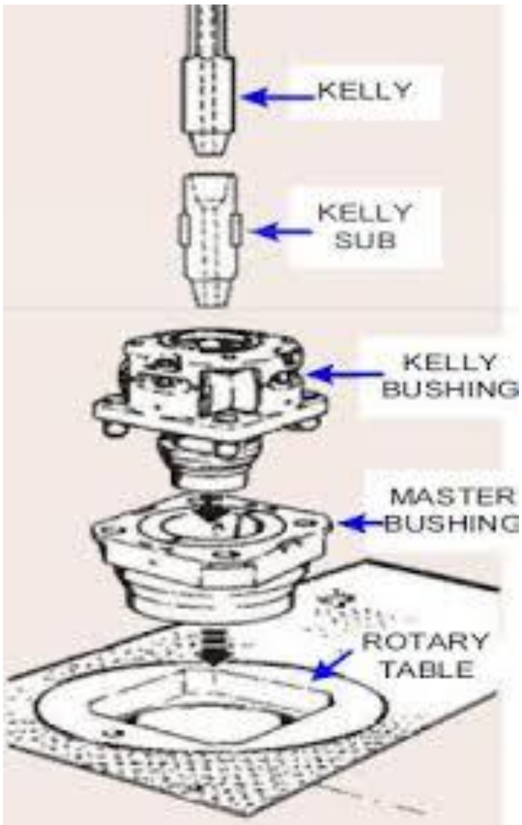


**Figure III.9:** Kelly bushing.

### III.4.1.2.6 Master bushing:

The master bushing is one of the most important parts of the drilling Rotary Table, also called the large rotor bushing. The master bushings are designed to work in conjunction with the roller liners of the drilling rotor under the Kelly pipe to control drill strings during oil and gas drilling. [17]

In this table we show three examples of technical parameters for master bushing:

**Table III.4:** Technical parameters for master bushing. [17]

| Model | Rotary table size (in) | Insert bowl | Tubular OD (in) |
|---|---|---|---|
| MDSP (Split) | 17 1/2 | - | 2 3/8 - 8 5/8 |
| | 20 1/2 | - | 2 3/8 - 8 5/8 |
| MSP (Split) | 27 1/2 | - | 2 3/8 - 8 5/8 |
| MSPC (Solid) | 20 1/2- 22 1/2 | Insert bowl 1809 | 2 3/8 - 8 5/8 |
| | | Insert bowl 1902 | 9 5/8 - 10 3/4 |
| | | Master bushing1805-1 | 11 ¾ - 13 3/8 |
| | | Master bushing19333 | 11 ¾ - 13 3/8 |
| | 23-27 1/2 | No.3 Insert bowl 1810 | 2 3/8 - 8 5/8 |
| | | No.2 Insert bowl 1904 | 9 5/8 - 10 3/4 |
| | | No.2 Insert bowl 1903 | 11 ¾ - 13 3/8 |

### III.4.1.3 Safety equipment:

#### III.4.1.3.1 Well head:

A wellhead is the structural and pressure-containing component installed at the surface of a well—whether oil, gas, or hydrogen. It provides the secure interface between the well's subsurface casing and tubing and the surface equipment used for drilling, production, and control.

Its function is:

- Supports the weight of the casing and tubing strings.
- Provides access for pressure testing, sampling, and well intervention.
- Controls and directs flow into surface facilities.
- Enables safe installation of blowout preventers (BOPs) during drilling.

Wellheads aren't a one-size-fits-all component. Every single one is custom-engineered to handle the specific depth, pressure, and temperature profile of its well.

**Pressure Ratings:** While a standard well might only need a 2,000 or 5,000 psi or 10,000 rating, extreme HPHT (high pressure, high temperature) applications can push equipment past 15,000 or even 20,000 psi.

**Temperature Classes:** The equipment has to hold up whether it's sitting in subzero Arctic environments or managing fluids that reach hundreds of degrees Celsius.

**Material Classes:** Defined by corrosion resistance, fluid compatibility, and strength.

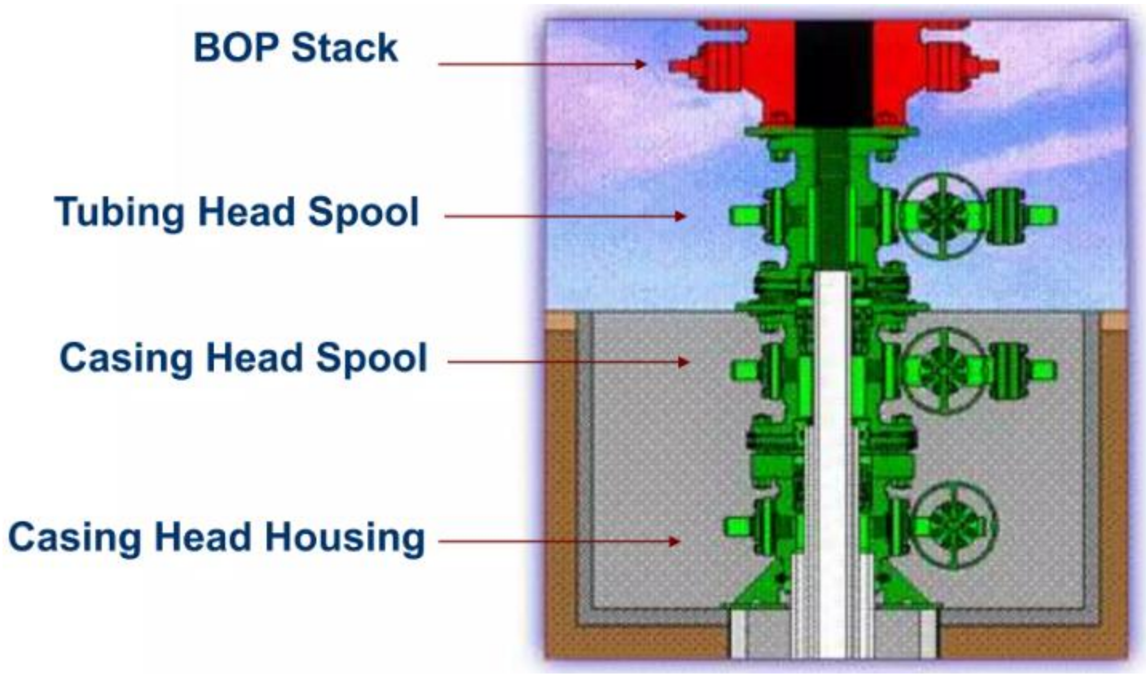


**Figure III.10:** Well-head.

#### III.4.1.3.2 Blowout preventer (BOP):

The BOP acts as the secondary barrier against a well blowout (the primary barrier is the heavy drilling mud inside the hole, which uses its weight to push down on the underground pressure). [23]

When a well experiences a "kick" meaning unexpected high-pressure fluid forces its way into the wellbore the crew uses the BOP to regain control:

- **Sealing:** The driller uses a remote-control panel to immediately actuate the BOP. This fires heavy-duty seals or steel blocks (rams) shut around the drill pipe, or seals the open hole entirely, trapping the pressure safely underground.
- **Killing the Well:** Once the well is sealed, the crew redirects the trapped fluids away from the rig floor through high-pressure lines.
- **Balancing the Pressure:** They then pump an ultra-dense, heavy fluid down into the wellbore. The weight of this new fluid creates enough

downward force to completely overpower and stop (or "kill") the incoming pressure from the underground formation. [23]

A full BOP system is typically stacked vertically and contains three main categories of equipment:

**The Stack:**

- **Annular Preventers:** Positioned at the top of the stack. They use a flexible, steel-reinforced rubber ring (like a giant donut) that squeezes tightly around whatever is in the well—whether it's a thick drill pipe, a thin tool, or even an empty hole. Because the seal is rubber, the crew can actually rotate or move the pipe up and down without breaking the seal.
- **Pipe Rams:** Heavy steel blocks faced with rubber that slide together from opposite sides of the wellbore to lock tightly around a specific size of drill pipe.
- **Blind / Shear Rams:** Blind rams type are used to seal over an open hole. They have a sealing surface that is pressed together when actuated. A special kind of blind ram is called a shear ram. Blind shear rams have cutting edges and can shear through drill pipe and seal over it. Because this option eliminates the possibility of circulating through the drill pipe, the shear ram is considered an option of last resort. [23]

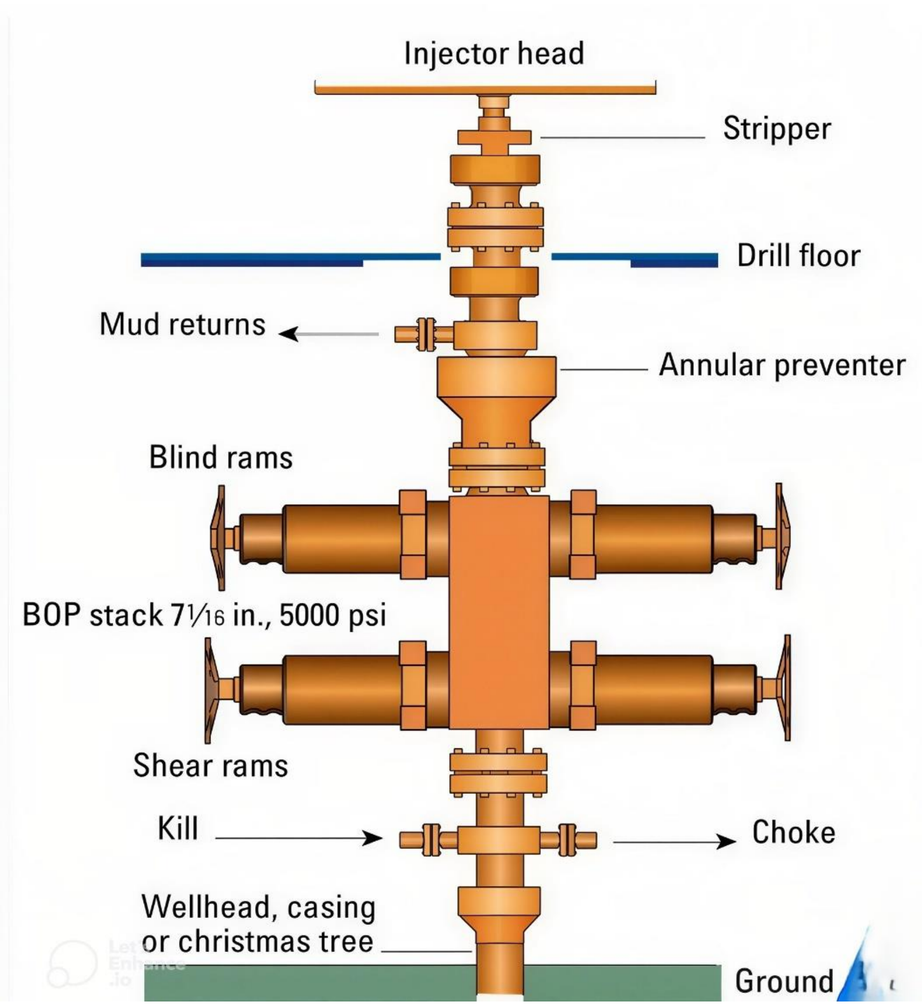

**Figure III.11:** Blowout preventer.

**The Power & Control System:**

- **Accumulators:** Sealing a well against thousands of pounds of pressure takes massive force. Accumulators are banks of cylinders that store pressurized hydraulic fluid, keeping it ready to slam the BOP rams shut instantly, even if the rig completely loses primary power. [23]

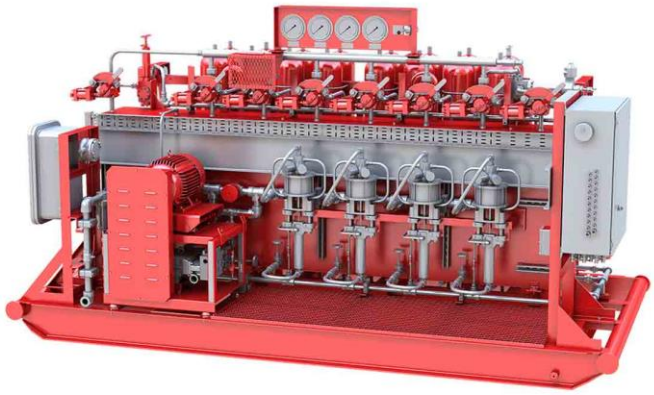

**Figure III.12:** Accumulator.

- **Control Panels:** Remote panels used by the driller to send electrical or hydraulic signals to trigger the stack. In deep subsea operations, they use high-speed multiplex (MUX) electrohydraulic systems to ensure the signal travels to the ocean floor instantly.

**The Flow Lines & Manifolds:**

- **Choke Line & Choke Manifold**: A high-pressure pipe running from beneath the BOP seals to a manifold of adjustable valves. This allows engineers to safely bleed off the trapped pressure and control the flow rate of the escaping fluids.

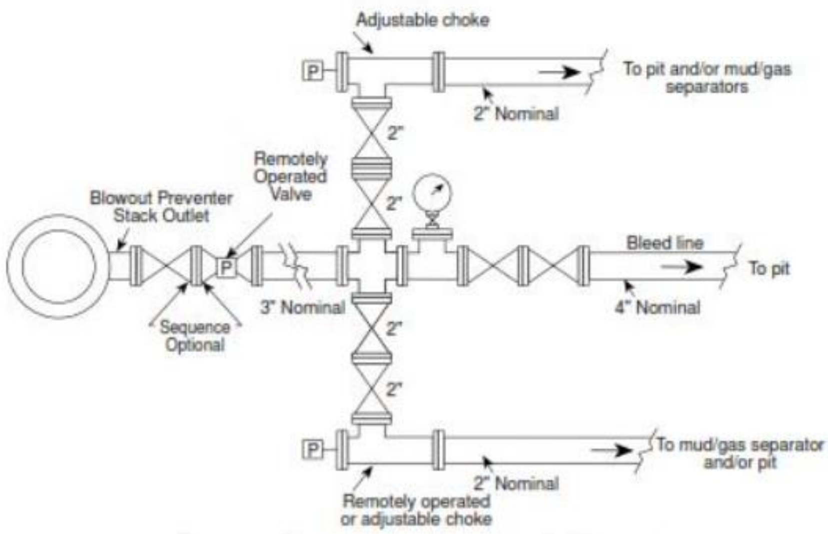


**Figure III.13:** Choke manifold.

- **Kill Line:** A backup high-pressure line connected to the mud pumps. If the crew can't pump heavy fluid down the inside of the drill pipe, they pump it through the kill line instead to flood the well and neutralize the pressure**.**

### III.4.1.4 Circulation equipment:

The term "circulation" refers to the drilling fluid used. The system circulates the drilling fluid in a closed loop, from the surface storage tanks down to the tool at the bottom of the well, and then back up to the surface. Among the objectives assigned to this mud circulation system are: lubrication of the drill bit, cooling of the tool, and cleaning of the hole.

To perform a drilling operation, the fluid must reach the bottom of the well by traveling through the inside of the drill pipes, circulate around the bit, and finally return up through the annular space between the drill string and the wellbore walls or the casing covering them. [18]

A circulation system uses the following equipment to circulate, clean, and recycle the drilling fluid:

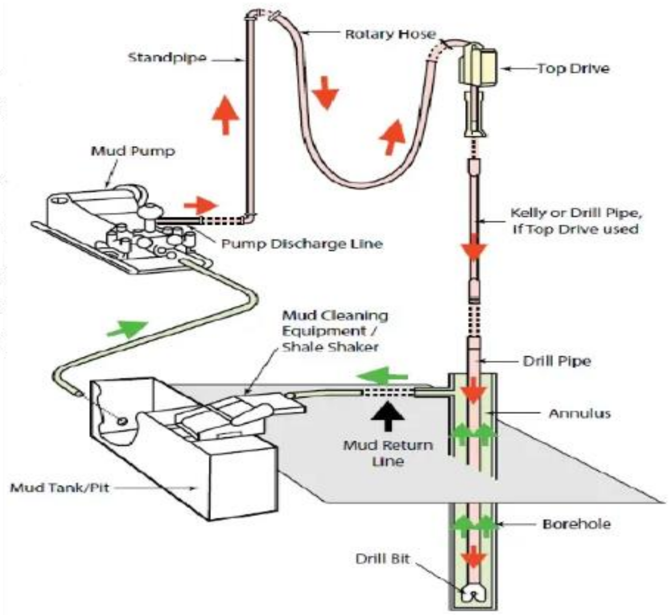


**Figure III.14:** Circulation operation.

- Mud pumps;

- Injection hose;

- Injection head (or swivel);

- Drill string;

- Drill bit;

- Mud return line;

- Mud tank (or mud pit).

**III.4.1.4.1 Drilling mud:**

Drilling mud (also called drilling fluid) is a weighted, viscous fluid mixture typically water, oil, or synthetic-based with clay and chemicals circulated through the wellbore during drilling to cool and lubricate the bit, carry rock cuttings to the surface, control formation pressure, and stabilize the wellbore walls. [18]

**III.4.1.4.1.1 Physical operating principles:**

The three main functions of drilling fluids are to:

- Control subsurface pressures:
- Controlled by Hydrostatic Pressure.
- HP is increase by increasing the density of the drilling fluid.
- Barite ($BaSO_4$), a high-density inert powder.
- Circulate drill cuttings from the well:
- Combination of fluid velocity, fluid viscosity, fluid density and drill string rotation.
- Maintain wellbore stability:
- Strength of the rocks being drilled, formation composition, filtration control, filter cake quality.

### III.4.1.4.1.2 The principal functions of the drilling fluid:

1. Subsurface pressure control.
2. Cuttings removal and transport.
3. Suspension of solid particles.
4. Sealing of permeable formations.
5. Stabilizing the wellbore.
6. Preventing formation damage.
7. Cooling and lubricating the bit and drill string.
8. Transmitting hydraulic horsepower to the bit.
9. Facilitating the collection of formation data.
10. Partial support of drill string and casing weights.
11. Controlling corrosion.
12. Assisting in cementing and completion.

### III.4.1.4.1.3 Mud Ingredients:

Various materials may be added at the surface to change or modify the characteristics of the mud. For example:

1. Weighting agents (usually barite) are added to increase the density of the mud, which helps to control subsurface pressures and build the wall cake.
2. Viscosifying agents (clays, polymers, and emulsified liquids) are added to thicken the mud and increase its hole-cleaning ability.
3. Dispersants or deflocculants may be added to thin the mud, which helps to reduce surge, swab, and circulating-pressure problems.

### III.4.1.4.2 Mud Pump:

A large, reciprocating pump used to circulate the mud on a drilling rig. A typical mud pump is a double- or triple-acting, two- or three-cylinder piston pump whose pistons travel in replaceable liners and are driven by a crankshaft actuated by an engine. A mud pump also is called a slush pump. [18]

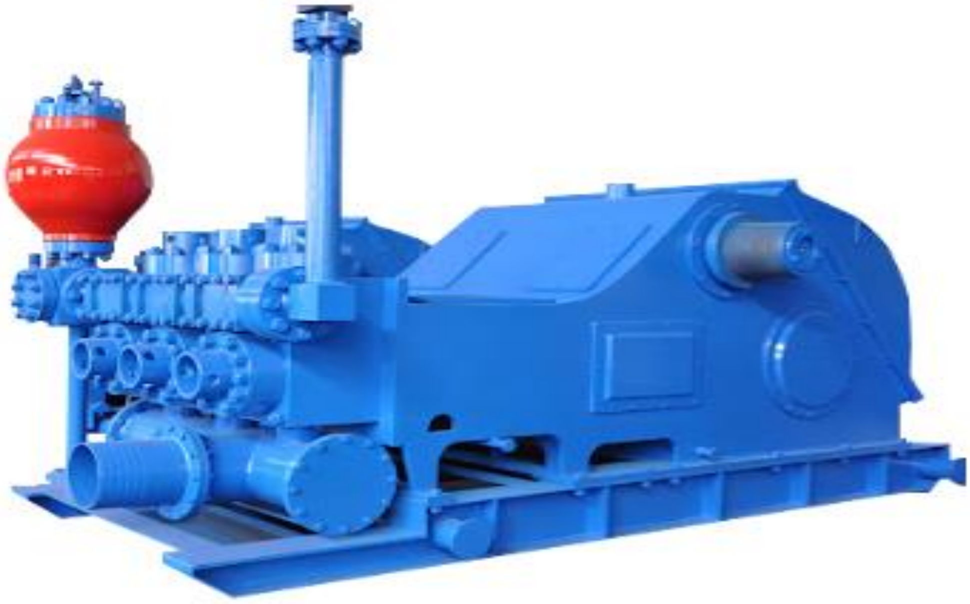

**Figure III.15:** Mud Pump.

**III.4.1.4.3 Desander:**

A hydrocyclone device that removes large drill solids from the whole mud system. The desander should be located downstream of the shale shakers and degassers, but before the desilters or mud cleaners. Various size desander and desilter cones are functionally identical, with the size of the cone determining the size of particles the device removes from the mud system. [18]

**Figure III.16:** Desander.

**III.4.1.4.4 Shale shaker:**

The primary and probably most important device on the rig for removing drilled solids from the mud. A wire-cloth screen vibrates while the drilling fluid flows on top of it. The liquid phase of the mud and solids smaller than the wire mesh pass through the screen, while larger solids are retained on the screen and eventually fall off the back of the device and are discarded. [18]

Where it was once common for drilling rigs to have only one or two shale shakers, modern high-efficiency rigs are often fitted with four or more shakers.

**Figure III.17:** Shale Shaker.

**III.4.1.4.5 Mud pit:**

A large tank that holds drilling fluid on the rig or at a mud-mixing plant. For land rigs, most mud pits are rectangular steel construction, with partitions that hold about 200 barrels each. They are set in series for the active mud system. On most offshore rigs, pits are constructed into the drilling vessel and are larger, holding up to 1000 barrels. Circular pits are used at mixing plants and on some drilling rigs to improve mixing efficiency and reduce dead spots that allow settling. Earthen mud pits were the earliest type of mud pit, but environmental protection concerns have led to less frequent use of open pits in the ground.

Today, earthen pits are used only to store used or waste mud and cuttings prior to disposal and remediation of the site of the pit. [18]

**Figure III.18:** Mud pit.

**III.4.1.4.6 Mud House:** The place where mud additives are kept at the rig, also known as the sack room.

**III.4.1.4.7 Reserve Pits:**

A mud pit in which a supply of drilling fluid has been stored. Also, a waste pit, usually an excavated, earthen-walled pit. It may be lined with plastic to prevent soil contamination. [18]

**Figure III.19:** Reserve Pits.

**III.4.1.4.8 Mud Gas Separator**:

- It captures and separates large volume of free gas within the drilling fluid.

- If there is a "KICK" situation, this vessel separates the mud and the gas by allowing it to flow over baffle plates.
- Gas will be vent to atmosphere via the vent line in derrick (offshore operation) or the line away from the rigs (land operation) and the mud will be returned back to the pit.

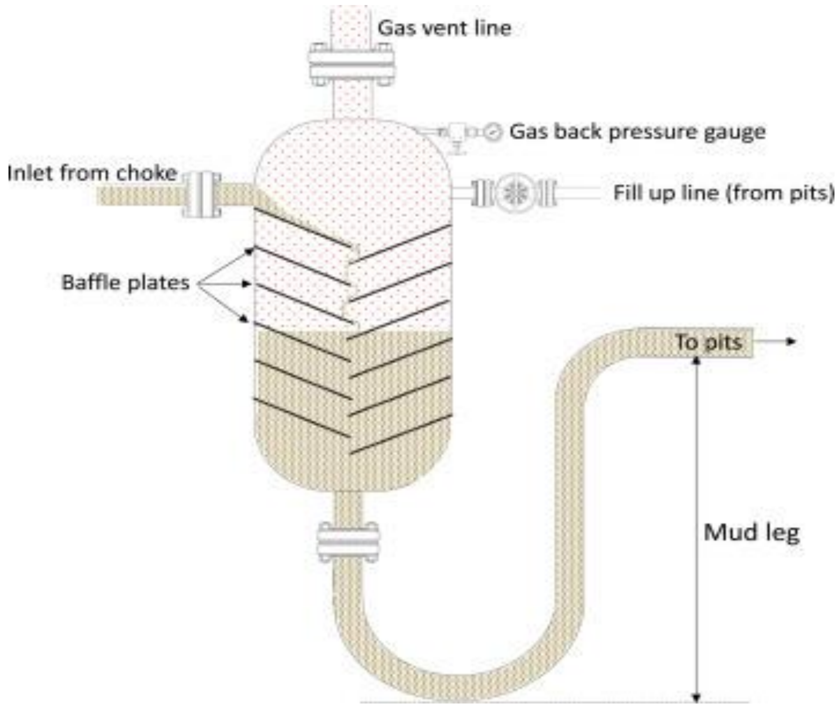


**Figure III.20:** Gas Separator.

**III.4.1.4.9 Desilter:**


**Figure III.21:** Desilter.

A hydro cyclone much like a desander except that its design incorporates a greater number of smaller cones. As with the desander, its purpose is to remove unwanted solids from the mud system. The smaller cones allow the desilter to efficiently remove smaller diameter drill solids than a desander does. For that reason, the desilter is located downstream from the desander in the surface mud system. [18]

### III.4.1.4.10 Centrifuge:

Drilling mud decanter centrifuge is the fourth stage equipment for a drilling mud system.
Drilling mud cleaning first stage uses drilling fluids shale shaker, then second stage uses desander, third desilter, (now drilling mud cleaner is widely used to replace desander, desilter).

The suspending fluids is pushed into the rotor drum through the inlet pipe and the fluid hole of the spiral feeder.

Under the influence of centrifugal force, solid phase particles are pushed to the internal wall of the drum, then to the mud export of the small end of the drum and excreted. [19]

**Figure III.22:** Centrifuge.

### III.4.1.4.11 Flowline (mud return line):

The large-diameter metal pipe that connects the bell nipple under the rotary table to the possum belly at the mud tanks. The flowline is simply an inclined, gravity-flow conduit to direct mud coming out the top of the wellbore to the mud surface-treating equipment. When drilling certain highly reactive clays, called "gumbo," the flowline may become plugged and require considerable effort by the rig crew to keep it open and flowing. In addition, the flowline is usually fitted with a crude paddle-type flow-measuring device commonly called a "flow show" that may give the driller the first indication that the well is flowing. [18]

### III.4.1.4.12 Stand pipe:

A rigid metal conduit that provides the high-pressure pathway for drilling mud to travel approximately one-third of the way up the derrick, where it connects to a flexible high-pressure hose (Kelly hose). Many large rigs are fitted with dual standpipes so that downtime is kept to a minimum if one standpipe requires repair.

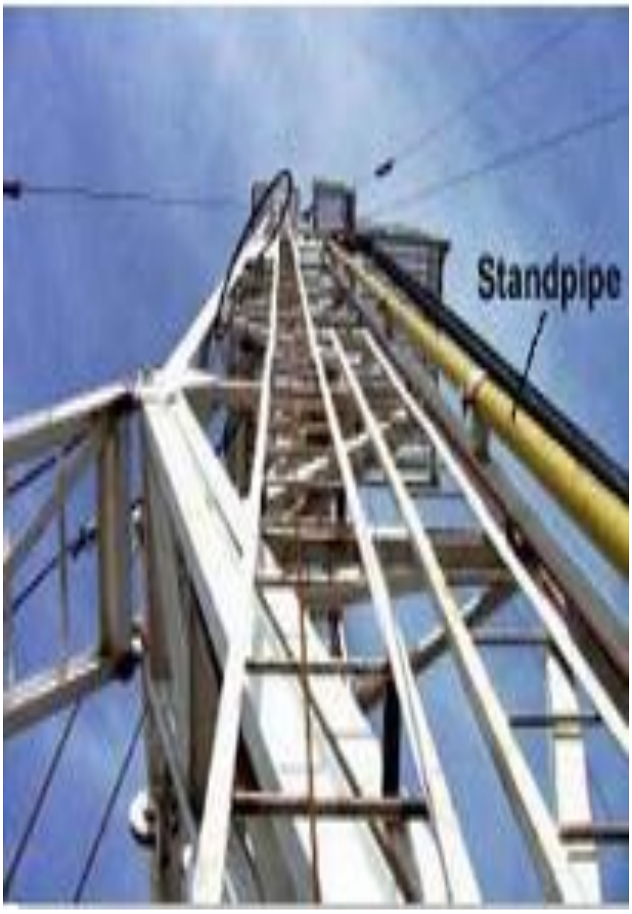


**Figure III.23:** Stand pipe.

### III.4.1.4.13 Annulus:

The space around a pipe in a well bore, the outer wall of which may be the wall of either the bore hole or the casing; sometimes termed the annular space.


**Figure III.24:** Annulus.

### III.4.1.5 Power system:

### III.4.1.5.1 Description of a Typical Drilling Installation:

The drilling installation is a complex system of equipment controlled by electrical energy. There are different types of drilling installations. The main characteristic for classifying them is the "drilling capacity" (maximum depth that can be reached by a drill string). The most classic installation consists of drilling the subsurface with specific perforating machines equipped with rotating drill bits mounted on platforms with pipe strings. Regardless of the power or drilling capacity, any rig includes two main sections that must work in coordination to achieve the objective [20]. The two sections are:

- Mud Section
- Drilling Section

The "mud" is a special fluid stored in tanks, composed mainly of water and various densifying substances. The "mud" allows controlling the hydrostatic pressure of the well and prevents the introduction of unwanted currents into the well. Using special pumps driven by electric motors, the mud is sent inside the drill string to lubricate and cool the tip of the rotary head and bring the drilling cuttings back to the surface from the annular space of the hole.

Drilling is carried out using a head equipped with cutting elements and mounted on a vertical tower, combining two simultaneous mechanical actions: weight and rotation. The rotational movement is imparted by a rotary table set in motion by high-power electric motors with adjustable speed. The vertical movement of the string is achieved by a winch that regulates the weight on the rotating head. [20]

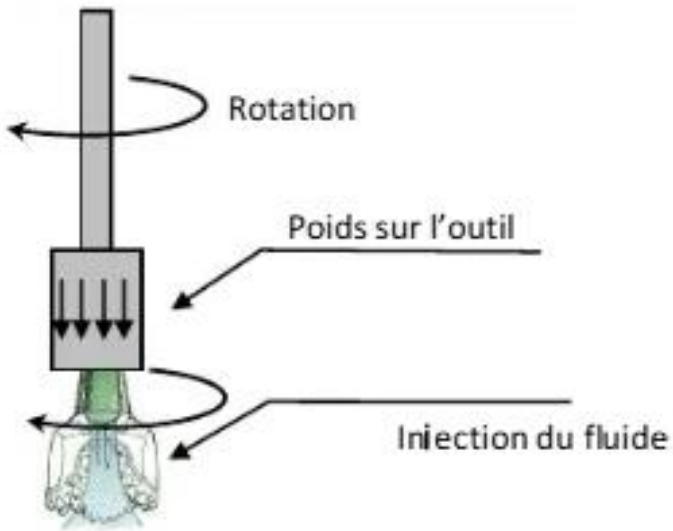


**Figure III.25:** Drilling Operation. [21]

The following figure shows the various devices on a drilling rig.

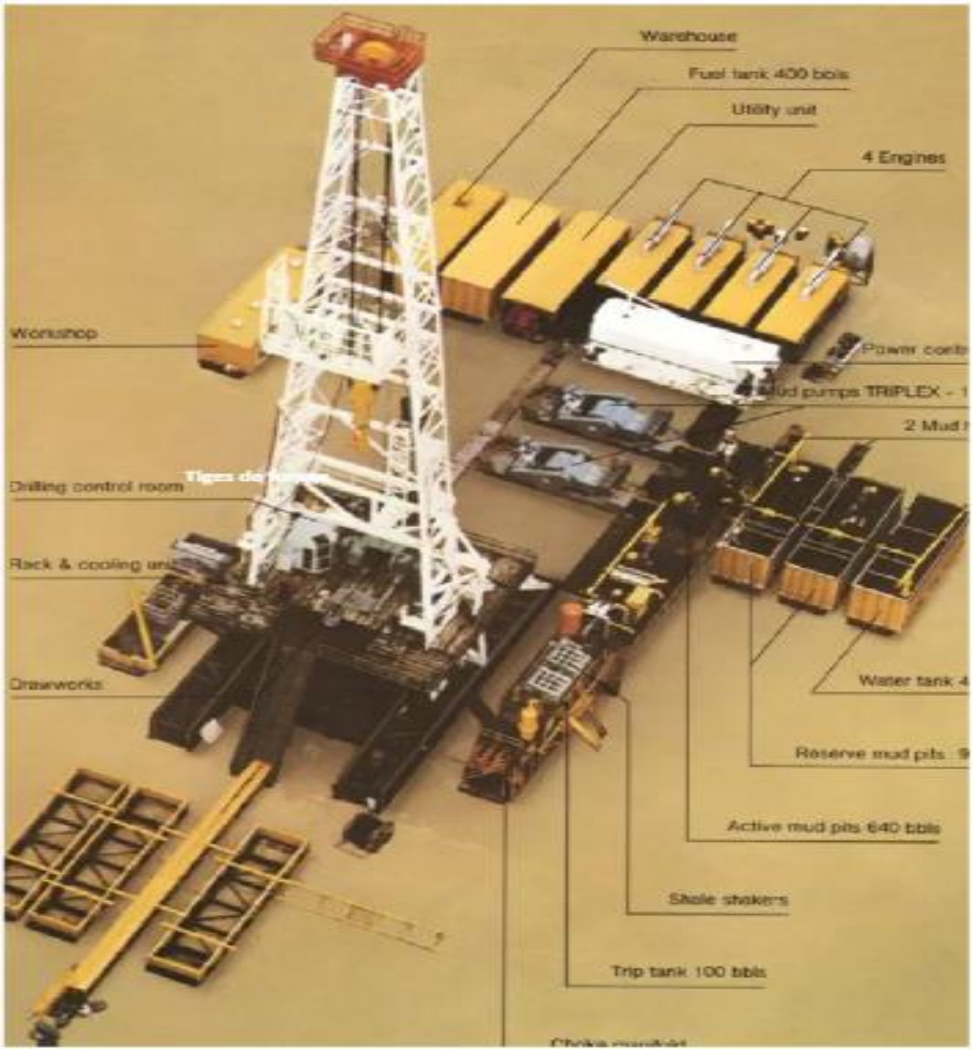


**Figure III.26:** Drilling rig.

### III.4.1.5.2 Electrical installations:

Here are some important concepts regarding oil drilling installations:

- All operations are carried out with electric motors;

- The energy for the machinery and drilling installations is electrical energy;

- The drilling installation is almost always independent; electrical energy is produced on site using generators driven by large diesel engines;

- To make the installation self-sufficient for several days, the fuel, lubricants, and water required for the drilling process are stored in large tanks located within the installation area. [20]

### III.4.1.5.3 Electrical energy generation:

- Electrical energy is generated by three-phase alternators, generally with a voltage of 3 x 600 VAC – 60 Hz; the power required for a standard medium-capacity installation is approximately 2400 kW; the energy produced by 3-4 generators is 600-800 kW.

- The prime mover driving each generator is a high-power diesel engine running at 1200 rpm.

- The generator is of the three-phase brushless type with a voltage of 3 x 600 VAC.

- The engine-generator sets are housed in containers, stored during transport or shutdowns to protect them from adverse weather conditions, and opened during operation to facilitate cooling if forced ventilation systems are not provided.

- All machine protections, measuring instruments, and paralleling devices are concentrated in a container called the "Control Cabin."

- Energy consumption varies according to the installation's operations; therefore, to optimize efficiency and prevent wear on the diesel engines, it is essential to activate and parallel several generators based on the electrical power demand, and to shut them down when demand decreases. [20]

**Figure III.27:** The Generator.

**III.4.1.5.4 Main electrical users in the drilling installation:**

- All generated and consumed energy is electrical in origin. The major consumers are the two mud pumps, the rotary table, and the drill string draw works (hoist).

- A standard medium-capacity installation for drilling on the order of 6000 m has two 600 kW motors for each of the mud pumps (MP1, MP2), two additional 600 kW motors for the draw works (DWK), and one motor – also 600 kW – for the rotary table (RT).

- Electrical consumption varies according to drilling operations; not all motors work simultaneously (see the following table). [20]

**Table III.5:** Electrical consumption.

| OPERATIONS | MP1 | MP2 | DWK | | RT | DWK brake |
|---|---|---|---|---|---|---|
| Lifting the drill string | | | * | | | * |
| Lowering the drill string | | | * | | | |
| Drilling | * | * | | | * | |

- The large electric motors used are of two types:

- DC motors, for traction applications, equipped with their SCR drives (BAY)

- Three-phase squirrel cage asynchronous motors designed to operate at variable frequency using a converter.

**III.4.1.5.5 Power drives:**

- A standard medium-capacity installation consists of 4 SCR power BAYS, associated respectively with the motors of each mud pump (MP1, MP2), the draw works motors (DWK), and the rotary table motor (RT).

- The association between the drive device and the motor can be modified to cope with breakdowns or maintenance cycles of the drive devices without stopping the drilling process (see the following table). [20]

**Table III.6:** The association between the drive device and the motor.

| DRIVE BAR | MP1 | MP2 | DWK | RT |
|---|---|---|---|---|
| 1 | * | * | | |
| 2 | * | * | * | |
| 3 | | | * | * |
| 4 | | | * | * |

### III.4.1.5.6 Other electrical services:

- A three-phase 600/400 V transformer supplies the platform's electrical services, such as fans, water pumps, degassers, etc., as well as personnel accommodations.

- Another three-phase 600/120 V transformer supplies the lighting circuits inside the platform's buildings and outside the work area.

**In summary:**

The motive power is produced by three generators (engine generator) (diesel-electric) which supply three three-phase voltages. These are then sent to the electrical control room (Control cabinet) where they are rectified and adapted to supply the direct current electric motors driving the mud pumps, the rotary table, and the draw works.

The electric motors are controlled by the shift supervisor through a control panel which has displays allowing the reading of: weight, pressure, speed ...

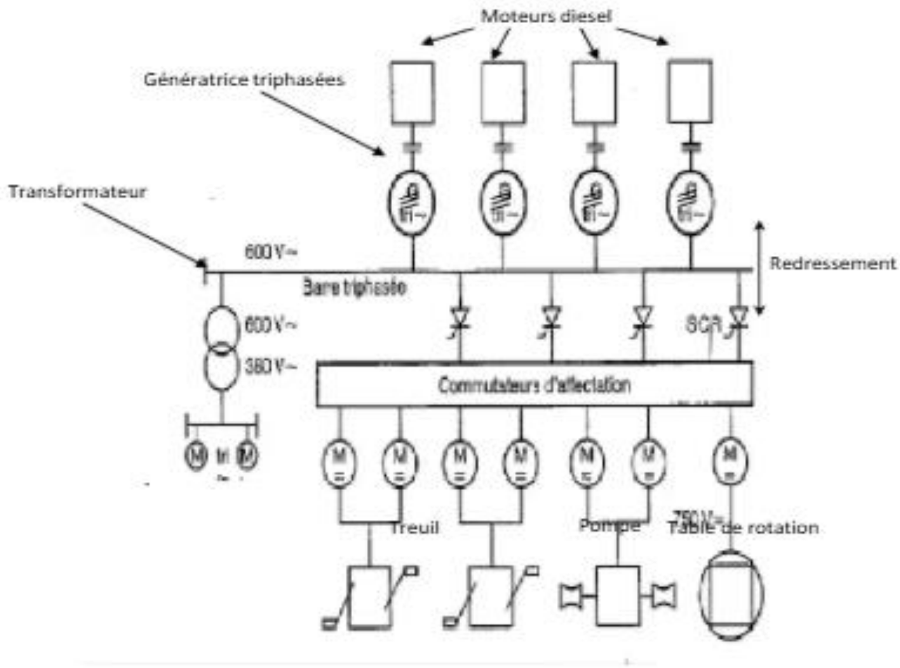


**Figure III.28:** Electrical power supply diagram of a drilling rig.

### III.4.1.5.7 Type of energy sources:

### III.4.1.5.7.1 Drilling rigs according to the type of energy source:

Drilling rigs are generally classified according to the type of energy source as:

- Mechanically driven rig.
- Diesel-electric rig. [22]

### III.4.1.5.7.1.1 Mechanically driven rig:

The motive power for the three main functions is provided by internal combustion engines (diesel engines) through transmission components (chains, cardan shafts, and other types of transmission).

### III.4.1.5.7.1.2 Diesel-electric rigs:

The electric motors for the three main functions operate on direct current (DC).

### III.4.1.5.7.1.2.1 Ordinary diesel-electric rig:

Motors with generators: the motive power consists of a set of generators driven by internal combustion engines; the current produced is direct current (DC).

### III.4.1.5.7.1.2.2 Diesel-electric rig equipped with an SCR:

Motors with alternators: the motive power consists of a set of alternators driven by internal combustion engines; the alternators produce alternating current (AC). Part of the energy produced is rectified into DC energy to supply the direct current motors.

The set of diesel engines and alternators is managed by a system called an SCR (Silicon Controlled Rectifier). [22]

**Figure III.29:** Direct current drive motor

### III.4.1.5.7.1.2.3 Advantages of diesel-electric rigs:

- Good efficiency, on the order of 85%.
- Reduced noise and vibrations, as well as elimination of exhaust fumes at the workplace (diesel engines and generators are located in an engine room away from the rig floor).
- Ability to obtain torque-speed characteristics adapted to each drilling machine.
- High power per unit mass of electric motors, thus reducing weight and space requirements.
- Fewer alignment problems.
- Quick disconnection and connection.

- Easy power transmission (via 1000 V cables).
- Suitable for automation techniques. [22]

### III.4.1.5.7.1.2.4 Silicon Controlled Rectifier (SCR) or Thyristor:

- A silicon rectifier converts alternating current (AC) into direct current (DC); the rectifier blocks the negative portion of the alternating current.
- The conversion can be done from 0% to 100% depending on the needs expressed by the drilling site. The SCR system operates with any number of alternators; voltage and frequency control are individual.
- The alternators work in parallel, and load sharing is achieved through electronic regulation. The leftmost alternator acts as the pilot (master).
- The four alternators are connected to a busbar; the amount of alternating current delivered at the busbar is converted into direct current by the thyristor bridge (P). [22]

### III.4.1.5.7.1.2.5 SCR system of a diesel-electric drilling rig:

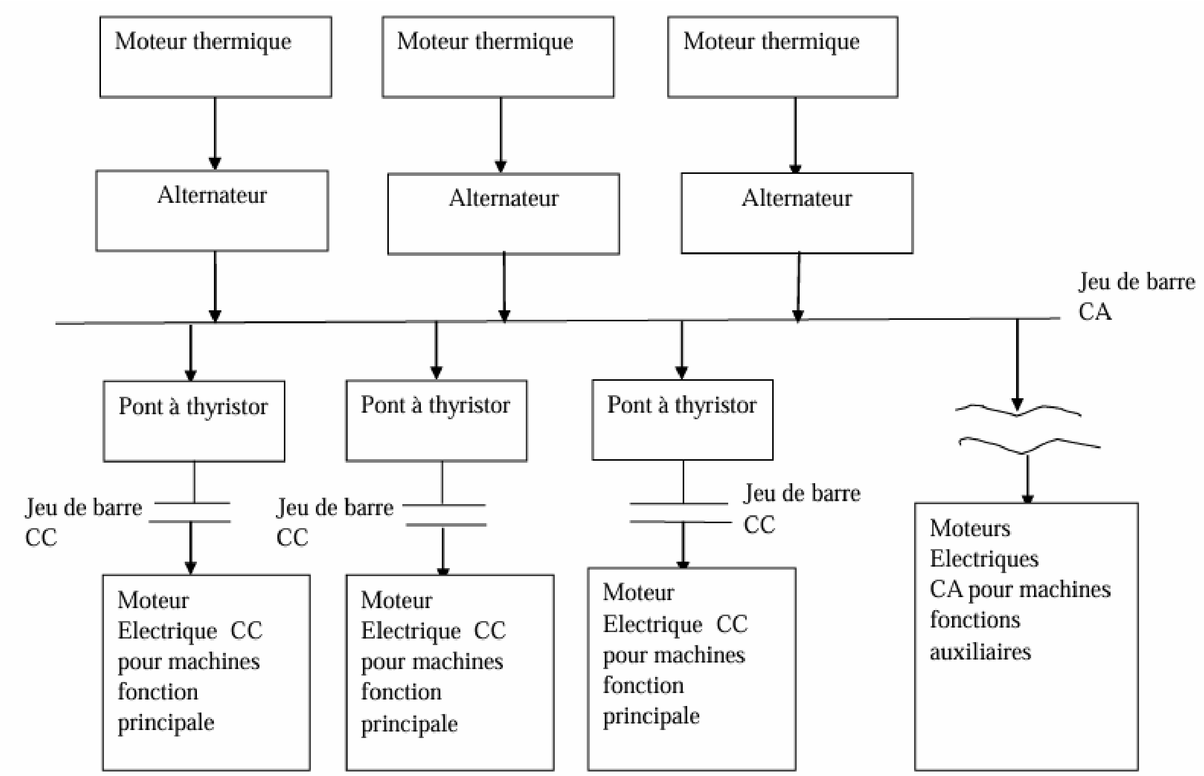


**Figure III.30:** SCR system on a diesel-electric drilling unit. [22]

### III.4.1.5.7.1.2.6 Advantages of the SCR:

- Conversion can be done from 0% to 100% according to demand.
- Use of fewer motors and generators.
- The loss of one motor does not affect the proper operation of drilling functions.
- The total available power (in HP) can be allocated to one function or distributed among different functions.
- Brushless alternators, making maintenance easier.
- No need for an auxiliary station.

### III.4.2 Bottom hole assembly (BHA):

- Drill bit.
- Drill collar (DC).
- Drill pipe (DP).
- Heavyweight drill pipe (HWDP).
- Stabilizers.
- Subs.

### III.4.2.1 BHA function:

• Used to apply weight on Bit.

• Used to build/ hold / drop angles.

• Used to make straighter hole.

• Used to cut / bore the formation.

• To protect the drill pipe from bending and torsional load..16.

### III.4.2.2 Drill bit:

Drill bit is a rotating tool attached to the bottom of the drill string. Its primary function is to penetrate subsurface rock formations by crushing, shearing, or grinding rock into small fragments (cuttings). Bits are classified by their cutting structure (e.g., roller-cone with tungsten carbide teeth or polycrystalline diamond compact (PDC) fixed blades) and are designed to withstand extreme pressures, temperatures, and abrasive conditions thousands of feet below the surface.

**Figure III.31:** Drill bit.

### III.4.2.3 Drill collar:

These are thick-walled pipes (tubulars) used in drilling to apply weight on bit, also help keeps the hole straight on the planned course and ensures the drill pipes are in tension to avoid buckling.


**Figure III.32:** Drill collar.

### III.4.2.4 Drill pipe:

Drill pipe is a seamless, high-strength steel tubular component that is connected end-to-end to form the drill string. It serves three critical functions:

- Torque Transmission: Transmits rotational force (torque) from the surface rig's rotary table or top drive down to the drill bit.
- Fluid Conduit: Provides a passageway for drilling fluid (mud) to be pumped downhole to cool the bit, lift rock cuttings to the surface, and maintain hydrostatic pressure.
- Axial Load Support: Supports the weight of the drill string components below it (including the drill collars and bit) while allowing for tension, compression, and bending stresses.

### III.4.2.5 Heavyweight drill pipe (HWDP):

These are special type of drill pipes which are stronger and have a smaller ID and acts as a transition from stiff drill collars to more flexible drill pipes, used to also apply weight on Bit and also to reduce fatigue on the drill pipes.

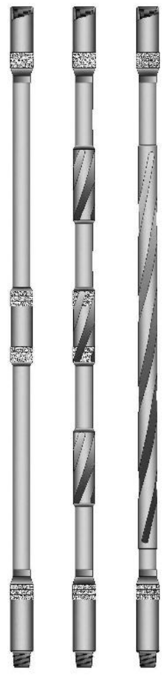

**Figure III.33:** HWDP.

### III.4.2.6 Stabilizers:

Are used to maintain a full gauge straight hole, also used to build, hold or drop the angle of the bit ensures that the drill string is centralized.

**Figure III.34:** Stabilizers.

### III.4.2.7 Subs:

Cross over sub - These are special subs used to adapt different sizes of equipment.

Bit sub / float sub - is used to attach the bit to the other part of the drill string, the float sub is used as a non-return valve to stop mud from flowing back into the string.

**Figure III.35:** Subs.

## III.5 Drill stem test (DST):

Drill stem tests (DSTs) are generally performed in exploration or delineation wells. They consist of temporarily bringing a reservoir potentially containing hydrocarbons into production to define its characteristics and those of the effluent it contains, in order to optimize drainage and improve performance. The test measures the pressure and flow rate of the effluent to assess the reservoir permeability and reserve, and takes a sample to reveal other characteristics (viscosity, salinity, API gravity, etc.). Exploration DSTs prioritize determining the nature of the fluids in place and the characteristics of the reservoir rock. [24]

The main parameters to get are:

- To detect the presence of hydrocarbons and their nature.
- To determine the production capacity.
- To determine the reservoir pressure.
- To determine the petrophysical parameters of the reservoir (k, Skin).
- Depending on the test time, to determine the reservoir model if necessary.
- Damage in the wellhead area.

This information can be obtained:

- During drilling.
- After drilling.
- After casing cementing.

### III.5.1 Drill stem test procedure:

The principle of a drill stem test is the installation of a temporary completion pack to bring the reservoir into production, thereby reducing the hydrostatic pressure of the mud at the reservoir for discharge. [24]

A packer is anchored above the reservoir to support the mud column. The pressure inside the test string is very low compared to that of the reservoir and is equal to the hydrostatic pressure of the buffer fluid. This allows the effluent to flow out as soon as the packer is anchored and the tester valve is opened, and then rise through the inside of the test string until it reaches the surface. There, it passes through a system of valves called the production head and a small manifold before being sent to the separation and storage or disposal facility.

### III.5.2 Drill stem test equipment:

**III.5.2.1 Gauge (Recorder) carrier:** It carries and protects downhole memory gauges. Gauge carriers can be run at multiple locations of the DST string. It contains two internal and two external recorder slots. The gauges are attached to the housing with metal seal connectors and are retained below the O.D. of the carrier to protect the gauges from damage while running the string. The carrier can be configured to provide outside and inside position electronic recorders. [24]

**III.5.2.2 Hydraulic jar:** Hydraulic jar is used to free the stuck section of drill string in case and open hole testing operations. The jar provides a temporary resistance that allows the drill pipe to be stretched. When the resistance is released, the jar body will fire rapidly upward to free the stuck string below. The impact force is dependent on the amount of over pull on the jar as it opens. It is easily reset for repeated use by putting setting down weight on the string.

**III.5.2.3 Safety joint:** The safety joint provides a means for releasing the tool string from above the packer in the event that packer cannot be released after jarring. This ensures recovery of DST tool and memory gauge data recorded during the well test. The safety joint is released with left hand rotation. The lower portion of the DST string can then be recovered with larger jars or fishing tools. [24]

**III.5.2.4 Packer:** A packer is used to isolate the formation from the rest of the bore hole, thereby forcing the fluid to enter the pipe. In Case hole DST, a retrievable product can packer is used and in open hole, an inflatable or compression set packer is used.

**III.5.2.5 Perforated anchor:** A perforated anchor is attached at the bottom of the tool string which allows the formation fluid or gas to enter the tool string pipes.

**III.5.2.6 Reverse circulating sub:** It is used to circulate fluid from the drill string after DST has been completed and drill string is ready to be removed. There are two types of these subs – Pump out sub and knock out (Bardrop) sub. In pump out sub, the port is opened by applying pressure to the inside of the drill string and shearing out the rapture disc. In knock out sub, a heavy bar is dropped to break the pin in the sub to open the port. [24]

**III.5.2.7 Rotating shut-in tool:** A rotating shut-in tool is used to obtain flow periods and shut in periods. Available in two flows and two shut-in periods or three flows and three shut in periods, it is run immediately above the hydraulic multiple shut-in tool and operated by right hand rotation of the pipe. The tool is run in open position, but the hydraulic multiple shut-in tool prevents any fluid from entering the test string. Once the testing depth is reached, the multiple shut-in tool is opened and the first flow period begins. Rotating right hand, the tool will shut off the flow for the first shut-in period and rotating again will start second flow period. [24]

**III.5.2.8 Hydraulic multiple shut-in tool:** It is a downhole valve that allows multiple opening and closing. This tool allows running into the hole with an empty test string. This eliminates the hydrostatic pressure on the formation at setting depth. Multiple shut-in tool is opened by slacking weight on it, and it is a time delayed tool (E.g.: 10,000 lbs. for 5 minutes). This delayed tool opening avoids accidental opening while running through tight spots in the hole. Picking up the tool string to the neutral weight will close the valve immediately. [24]

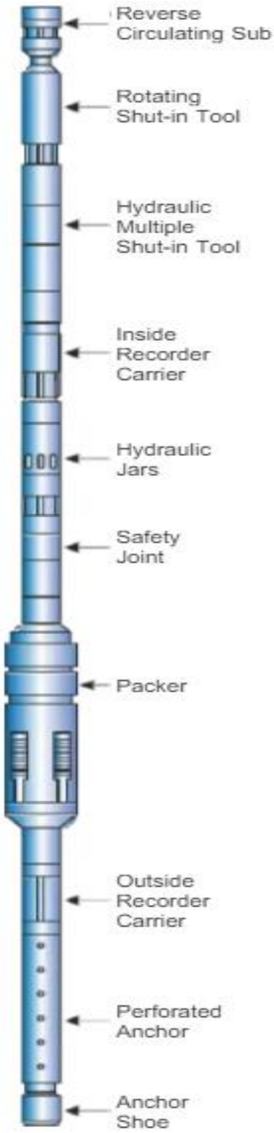


**Figure III.36:** DST tools.

### III.6 Well completion:

The term "completion" describes the assembly of Down hole tubulars and other safety equipment that is required to enable the safe and efficient production of oil or gas from the well after it has been drilled. [25]

### III.6.1 Completion Objectives:

- Provide optimum production/injection performance.
- Minimize the total costs per unit volume of fluid produced or injected.

- Minimize the cost of initial completion, maintaining production & any remedial measures.
- Ensure safety across the entire completion spectrum.
- Maximize the integrity and reliability of the completion over the envisaged completed well life. [25]

### III.6.2 Well completion types:

- Barefoot Completion.
- Open Hole Completion.
- Liner Completion.
- Perforated Liner.
- Perforated Casing.
- Cased Hole Completion.

### III.6.3 List of completion equipments used in well-1:

**Table III.7:** Surface equipments of well-1.

| A. Surface equipment | |
|---|---|
| Well head class "CC" (Metal to Metal); WP 5Kpsi | |
| 01 | Tubing Head: 11" x 7"1/16 - 5Kpsi |
| 01 | TH Adapter: 7"1/16 x 3"1/8 - 5Kpsi |
| 01 | X-Mas Tree: 3"1/8 x 3"1/8 - 5Kpsi |

**Table III.8:** Bottom hole equipments of well-1.

| | |
|---|---|
| B. Bottom hole equipment | |
| | 1. Bottom hole elements |
| 01 | Wireline Entry Guide / Mule Shoe, Top thread 3"1/2 N. Vam/HSC (Box) 13%Cr |
| 01 | Landing Nipple "X" Profile (Packing Bore: 2.750") 3"1/2 N. Vam/HSC (Box x Pin) 13% Cr. |
| 01 | Landing Nipple "XN" Profile (Packing Bore: 2.750”; NO-GO: 2.635") 3"1/2 N. Vam/HSC (Box x Pin) 13%Cr. |
| 01 | X-Over 4"1/2 N. Vam/HSC (Box) x 3"1/2 N. Vam/HSC (Pin) 13%Cr |
| 01 | Millout Extension "MOE" 4"1/2 N. Vam/HSC (Pin x Pin) 13%Cr |
| 01 | Permanent Hydraulic Production Packer (10000 or 7500psi), Casing 7" 29 - 32#, Bottom thread 4"1/2 N. Vam/HSC (Box) 13%Cr |
| 01 | Anchor Seal; Top thread 3"1/2 N. Vam/HSC (Box) 13%Cr |
| 04 | Flow coupling 3"1/2 N. Vam/HSC 13%Cr |
| | 2. Tubing |
| 281 | Joints (+/-2590m) de Tubing 3"1/2 9.20# (ID: 2.992”; Drift: 2.867") 110Ksi N.Vam/HSC (Box x Pin) 13%Cr, Range 2 |
| 04 | Pup Joints 3"1/2 9.20# 110Ksi N.Vam/HSC 13%Cr (02 PJ 1.5m et 02 PJ 2m) |

### III.6.4 List of completion equipments used in well-2:

**Table III.9:** Surface equipments of well-2.

| | |
|---|---|
| A. Surface equipments | |
| Well head Class "CC or BB”; WP 5Kpsi | |
| 01 | Tubing Head: 11" x 7"1/16 - 5Kpsi |
| 01 | TH Adapter: 7"1/16 x 3"1/8 - 5Kpsi |
| 01 | X-Mas Tree: 3"1/8 x 3"1/8 - 5Kpsi |

**Table III.10:** Bottom hole equipments of well-2.

| | |
|---|---|
| B. Bottom hole equipment | |
| 1- Bottom hole elements | |
| 01 | Wireline Entry Guide / Mule Shoe, Top thread 3"1/2 N. Vam/HSC (Box) 13%Cr |
| 02 | Landing Nipple "X" Profile 3"1/2 N. Vam/HSC (Box x Pin) 13%Cr. |
| 01 | X-Over 4"1/2 N. Vam/HSC (Box) x 3"1/2 N. Vam/HSC (Pin) 13%Cr |
| 01 | Millout Extension "MOE" 4"1/2 N. Vam/HSC (Pin x Pin) 13%Cr |
| 01 | Permanent Hydraulic Production Packer (7500psi), Casing 7" 32#, Bottom thread 4"1/2 N. Vam/HSC (Box) 13%Cr |
| 01 | Anchor Seal; Top thread 3"1/2 N. Vam/HSC (Box) 13%Cr |
| 04 | Flow coupling 3"1/2 N. Vam/HSC 13%Cr |
| 2- Tubing | |
| 200 | Joints (+/-1850m) de Tubing 3"1/2 9.20# 110ksi N. Vam/HSC (Box x Pin) Super 13%Cr, Range 2 |
| 04 | Pup Joints 3"1/2 9.20# 110ksi N. Vam/HSC Super 13%Cr (02 PJ 1.5m et 02 PJ 2m) |

## III.7 Conclusion:

In conclusion, the drilling rig and its main systems (lifting, power, rotary, circulation, and safety) are fundamental to ensuring safe and efficient drilling operations. Proper rig selection, based on technical and geological criteria, directly impacts performance. Beyond drilling, the drill stem test provides essential data on reservoir potential, while well completion prepares the well for safe and productive operation. Together, these stages from rig selection to well completion ensure the successful development of a well.

# Chapter IV: Results and discussion

## IV.1 Introduction:

This chapter presents the Drill Stem Test (DST) results and interpretation for two exploration wells located in the Illizi Basin, Algeria: Well-1 and Well-2. Both wells were completed as barefoot (open-hole) tests targeting different reservoir intervals — the deep Cambro-Ordovician formation for Well-1 and the shallower Devonian F2 formation for Well-2.

The primary objective of these tests was to evaluate reservoir productivity, fluid composition, pressure behavior, and overall energy sustainability. Over testing periods of four days (Well-1) and three days (Well-2), key parameters such as wellhead pressure, gas and liquid flow rates, fluid densities, bottom-hole pressures during build-up stages, and bottom-hole temperature were recorded. Crucially, both wells showed an absence of hydrogen sulfide ($H_2S$), which significantly reduces development costs and improves safety.

By comparing pressure trends, fluid quality (condensate API gravity, gas density, gas-oil ratio), and reservoir response, this chapter aims to identify which well offers better long-term production potential and what operational considerations should guide future development in the basin.

## IV.2 Well-1 identification:

Our study focuses on the exploration well-1, located in the Illizi Basin—a region well-known for its major gas reserves. To pinpoint its exact location, the well uses the following coordinates:

- **X Coordinate:** 466 131.584 m
- **Y Coordinate:** 3 149 248.433 m

Currently, Well-1 holds the status of an exploration well in the completion phase. This is the vital bridge between drilling the hole and turning it into a working producer. It is our best chance to check the well's safety barriers and isolate the target gas zones.

This table show to us all of the properties of this well:

**Table IV.1:** Well-1 properties

| **Well Acronym / Code** | Well-1 |
|---|---|
| **Basin** | Illizi |
| **Well Type** | Exploration Well |
| **Coordinates** | X: 466 131.584 m |
| | Y: 3 149 248.433 m |
| **Geographic** | Longitude: 08° 39' 14.51166" East |
| | Latitude: 28° 28' 17.89551" North |
| Gas Producer Well (PPG) | |

**IV.3 Well-1 localization:**

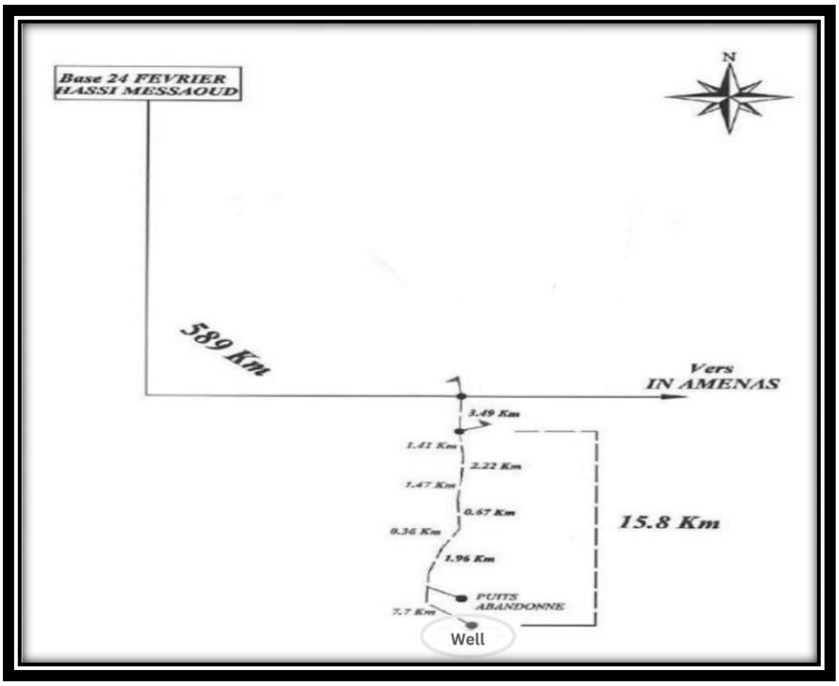


**Figure IV.1:** Well-1 localization

### IV.4 DST results of well-1:

#### IV.4.1 Test data:

**Test type:** Barefoot.

**Tested formation:** Cambro-Ordovician (units: IV – III – II).

**Intervals tested:** 2817 – 2641 m.

**Buffer height:** 150 m.

**Packer anchor elevation:** 2575 m.

This DST evaluates a barefoot (open-hole) completion within a deep reservoir (Cambro-Ordovician units IV, III, and II) across a substantial interval (2817 m – 2641 m).

The data strongly indicates a highly productive gas-condensate reservoir. Over the 4-day testing period, the well exhibits clean-up behavior followed by a late-stage stabilizing or shut-in period. Crucially, $H_2S$ is entirely absent, which is fantastic news for development economics and personnel safety, as it avoids the need for expensive sour-gas metallurgy or treatment facilities.

**Table IV.2:** DST results of well-1.

| **Date** | **1st day** | **2nd day** | **3rd day** | **4th day** |
|---|---|---|---|---|
| **WHP (psi)** | 1788 | 1595 | 1384 | 1750 |
| **Average Condensate Flow Rate ($m^3$/h)** | 3.33 | 8.83 | 4.012 | 3.554 |
| **Condensate density (15°C)** | 0.737 | 0.728 | 0.733 | 0.733 |
| **Average Gas Flow Rate ($m^3$/h)** | 4731 | 5709 | 6232 | 4484 |
| **Gas density (air = 1)** | 0.772 | 0.78 | 0.788 | 0.772 |
| **$H_2S$ (ppm)** | / | / | / | / |
| **Total volume of flared gas ($m^3$)** | 47310 | 62799 | 74784 | 35872 |

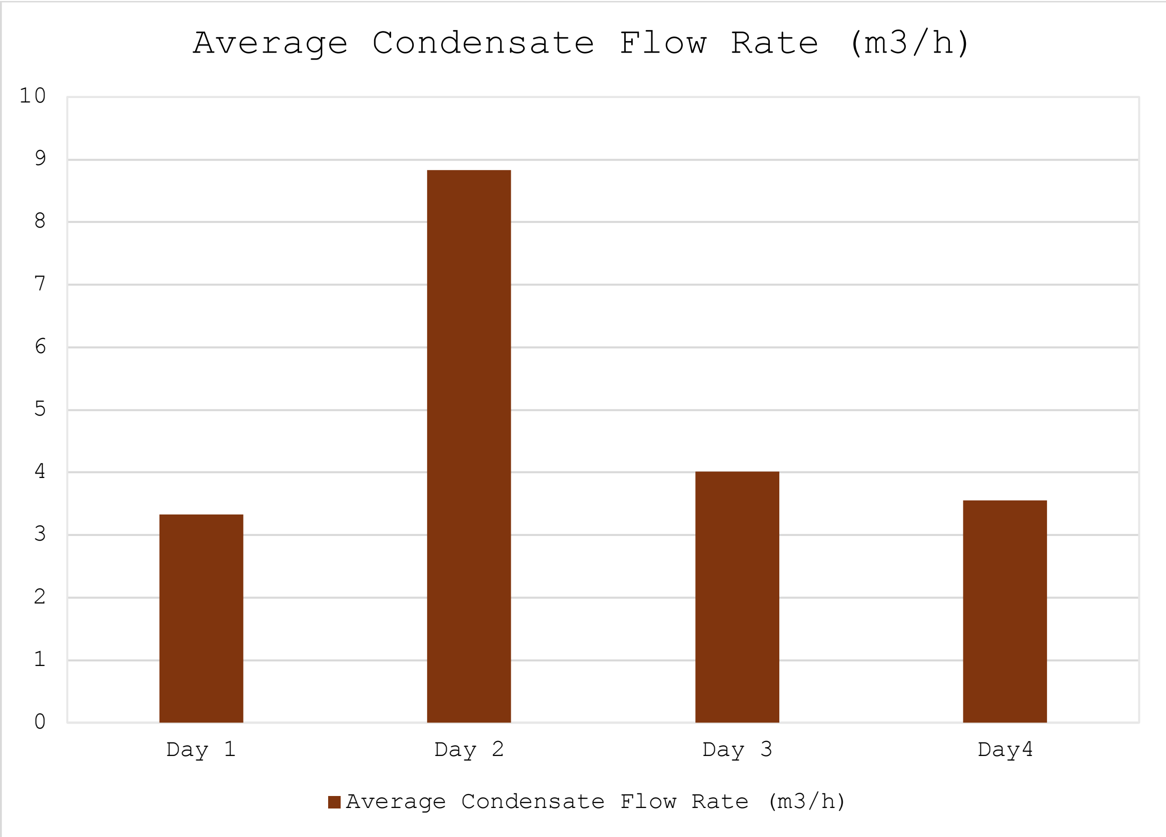


**Figure IV.2:** Average condensate flow rate of well-1.

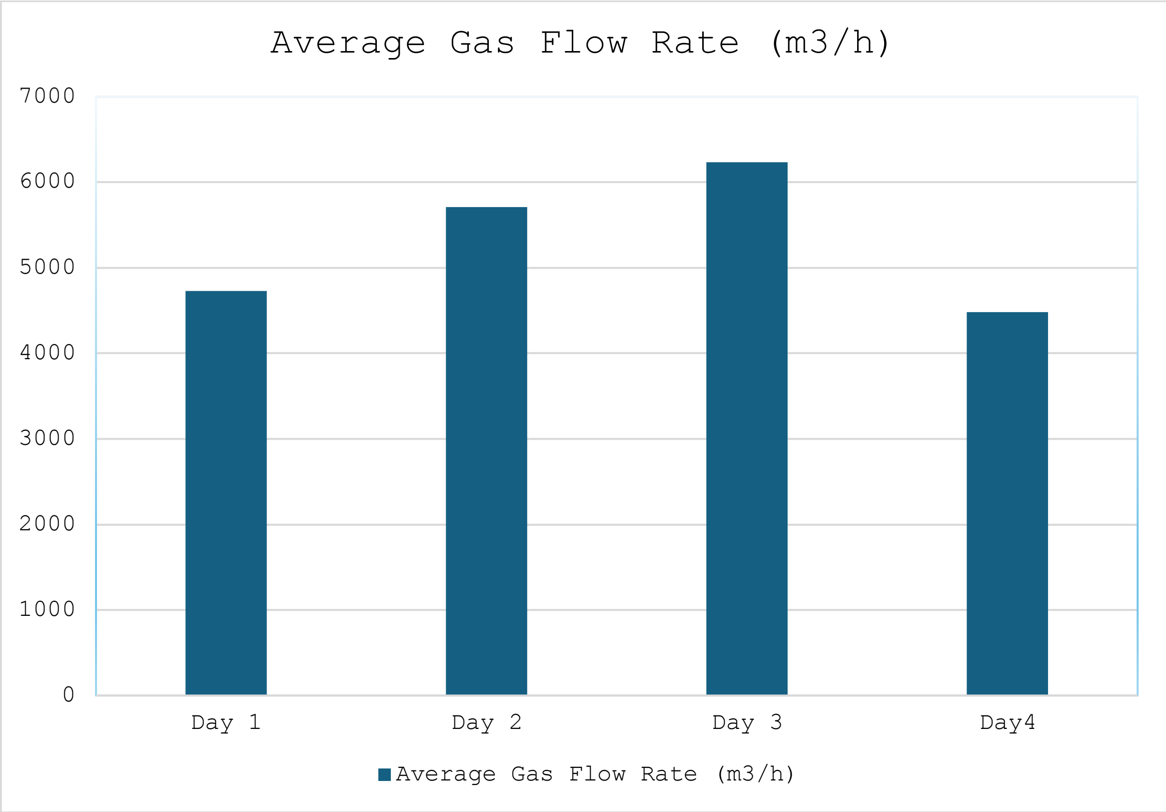


**Figure IV.3:** Average gas flow rate of well-1.

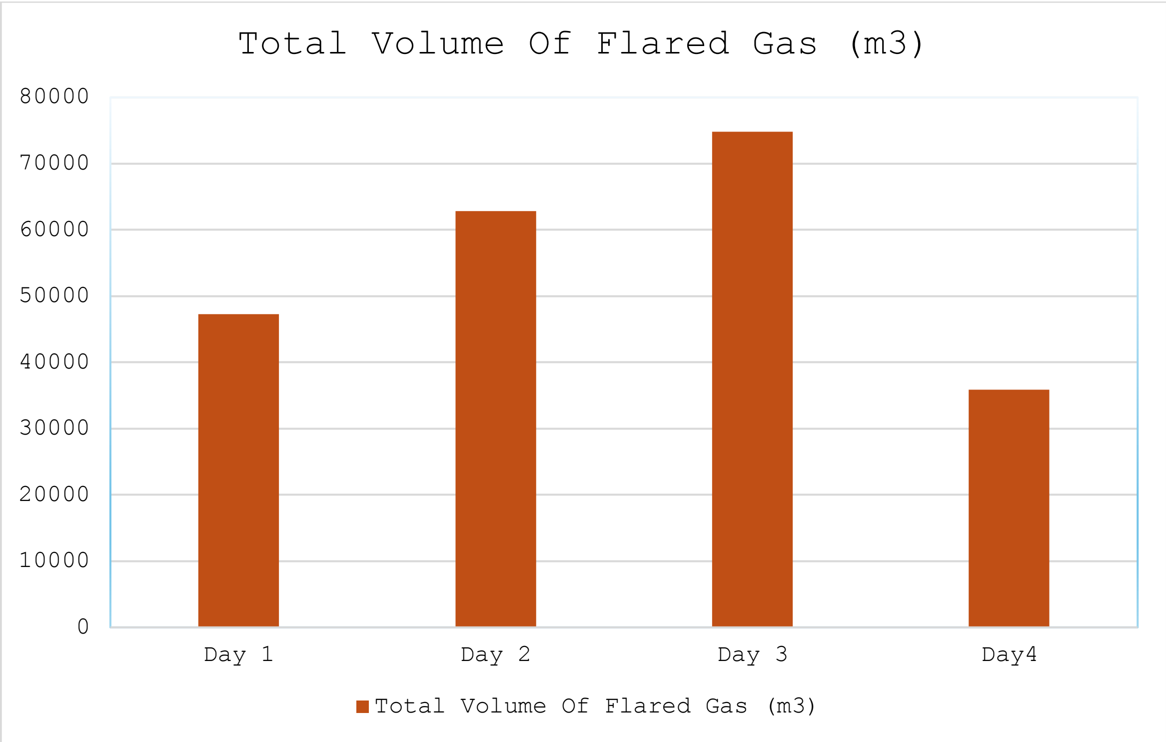


**Figure IV.4:** Total volume of flared gas of well-1.

**Bottom hole pressures of well-1:**

The well shows a generally stable pressure behavior with only moderate pressure depletion during the build-up stages. Although the pressure gradually declined during the early build-ups, the later partial recovery suggests that the reservoir still has active energy support and has not experienced severe damage or exhaustion.

The small difference between the initial and final hydrostatic pressures is encouraging because it means the reservoir is still maintaining most of its natural pressure. This usually points toward good reservoir continuity and potentially sustainable production performance.

**Table IV.3:** Bottom hole pressures of well-1.

| | |
|---|---|
| **Initial hydrostatic pressure (Psi)** | 3848 |
| **1$^{st}$ Build Up (Psi)** | 3488 |
| **2$^{nd}$ Build Up (Psi)** | 3436 |
| **3$^{rd}$ Build Up (Psi)** | 3410 |
| **4$^{th}$ Build Up (Psi)** | 3370 |
| **5$^{th}$ Build Up (Psi)** | 3418 |
| **6$^{th}$ Build Up (Psi)** | 3385 |
| **Final hydrostatic pressure (Psi)** | 3800 |
| **Bottom hole temperature (°C)** | 92 |

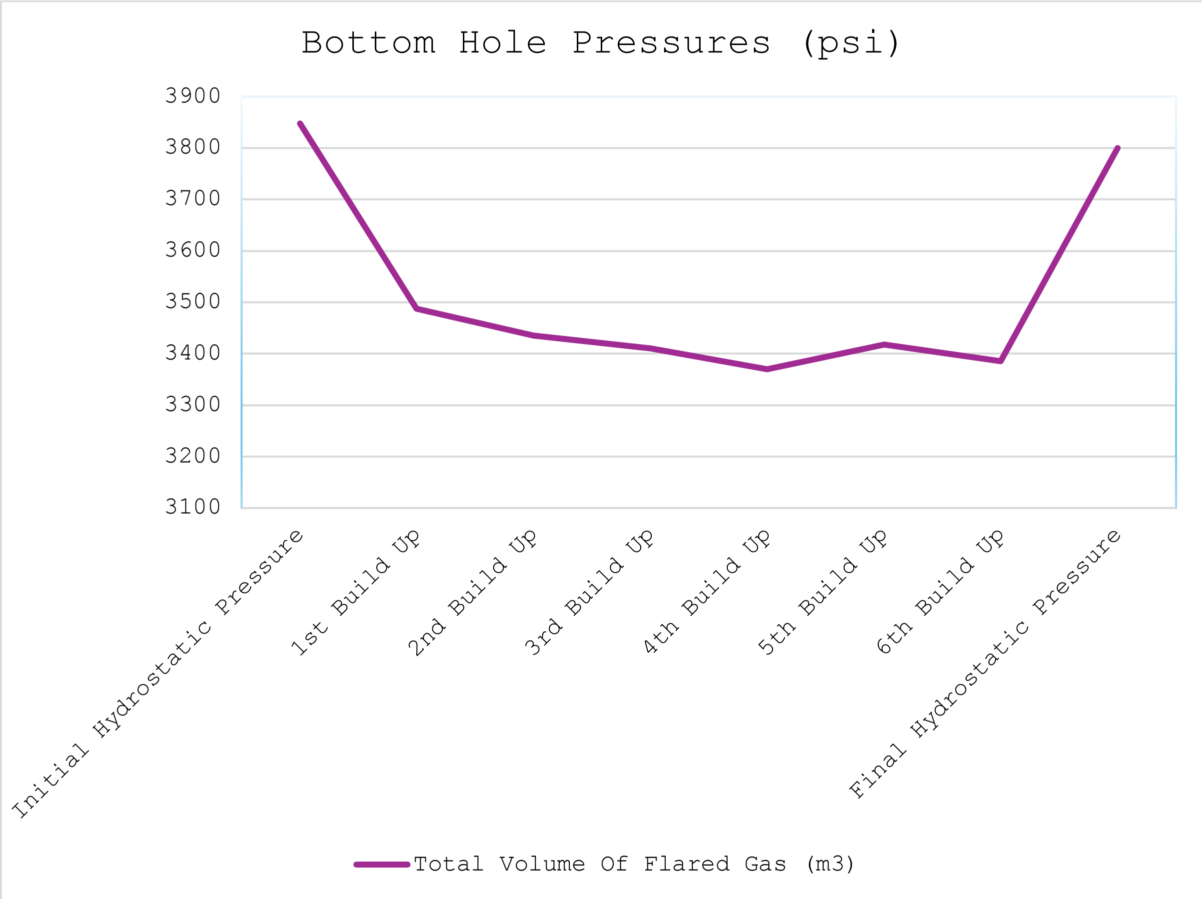


**Figure IV.5:** Bottom hole pressures of well-1.

**Observation:** Technically successful test, well producing gas and condensate.

### IV.4.2 Data analysis of well-1:

### Day 1: The Initial Flow & Clean-Up Phase

- WHP (Wellhead Pressure) is high at 1788 psi, while gas flow is at 4731 $m^3$/h and condensate is relatively low at 3.33 $m^3$/h.
- The well is opened to flow. This is the typical "clean-up" period. The high initial wellhead pressure is a great sign of reservoir energy, but the fluid rates are still adjusting as drilling mud filtrate and completion fluids are pushed out of the formation.

**Day 2: The Well Opens Up (Peak Production)**

- WHP drops slightly to 1595 psi, but fluid rates surge. Gas jumps to 5709 $m^3/h$ and condensate production nearly triples to 8.83 $m^3/h$. Condensate density drops to its lowest point 0.728.
- The well has cleared its throat. The "skin" or initial blockage from drilling has cleared, allowing the reservoir fluids to flow freely. The drop in WHP is a normal response to increasing the choke size or opening up the flow to maximize production rates. The drop in condensate density confirms lighter, cleaner hydrocarbons are making it to the surface.

**Day 3: Gas Maximum & Condensate Drop**

- WHP drops further to 1384 psi. Gas flow rate hits its peak at 6232 $m^3/h$}, but the condensate flow rate drops by more than half to 4.012 $m^3/h$.
- The field crew is pushing the gas limits. However, the drop in wellhead pressure likely caused a thermodynamic shift. When pressure drops below a certain point, heavier hydrocarbons can condense inside the reservoir rather than traveling to the surface. This explains why gas production peaked but liquid condensate dropped.

**Day 4: Pressure Build-Up or Optimization**

- WHP rebounds sharply to 1750 psi. Both gas 4484 $m^3/h$ and condensate 3.554 $m^3/h$ flow rates decrease. Gas density drops back to Day 1 levels 0.772.
- This looks like either a managed choke reduction to stabilize the well and prevent reservoir damage, or a partial shut-in period for a pressure build-up analysis. The sharp increase in WHP proves the reservoir has excellent "recharging" capability and has not depleted; the energy is still very much alive.

**Fluid & Engineering Key Metrics of well-1:**

**1. Gas-Oil Ratio (GOR) Tendency:**

The relationship between gas and condensate behaves dynamically over the test:

- **Day 1:** Gas-to-Condensate ratio is high (≈ 1420 $m^3$ of gas per $m^3$ of liquid).
- **Day 2:** The ratio narrows (≈ 646 $m^3/m^3$), showing heavy liquid contribution.
- **Day 3/4:** The ratio widens significantly again, confirming the volatile, gas-dominant nature of the Cambro-Ordovician reservoir.

**2. Hydrocarbon Fingerprint:**

- **Condensate Density (0.728 - 0.737):** Translates to an API gravity of roughly 60° to 63° API. This is highly valuable, crystal-clear light premium condensate (almost pure naphtha/gasoline fraction).
- **Gas Density (0.772 - 0.788 relative to air):** Indicates a "rich" or "wet" natural gas containing significant amounts of ethane, propane, and butane alongside methane, which aligns with the high condensate yield.

**Interpretation of the bottom hole results of well-1:**

**1. Initial Hydrostatic Pressure:**

The initial hydrostatic pressure was recorded at **3848 psi**, which represents the original pressure condition inside the well before the build-up sequence started. This indicates that the reservoir initially had relatively strong pressure support.

**2. Pressure Decline During Build-Up Stages:**

The build-up pressures generally decreased from:

- 3488 psi (1st build-up) to 3370 psi (4th build-up).

This gradual reduction suggests that the reservoir pressure was declining with time. In practical terms, this can mean:

- Fluid was being produced faster than pressure could recover.
- The reservoir may have limited natural energy support.
- There could be pressure depletion around the wellbore.

The pressure drops between the first and fourth build-up is approximately:

$$3488 - 3370 = 118$$

This is a moderate decline and may indicate normal reservoir drawdown behavior.

**3. Slight Pressure Recovery at the 5th Build-Up:**

An interesting observation is the increase from:

- 3370 psi (4th build-up) to 3418 psi (5th build-up).

This temporary recovery may suggest:

- Partial reservoir pressure stabilization,
- Improved fluid redistribution in the formation,
- Reduced production rate before the test,
- Or pressure support from nearby reservoir zones.

However, the pressure dropped again slightly to **3385 psi** during the 6th build-up, indicating the reservoir had not fully stabilized.

**4. Final Hydrostatic Pressure:**

The final hydrostatic pressure was measured at **3800 psi**, which is only:

$$3848 - 3800 = 48$$

below the initial hydrostatic pressure.

This is a very important result because it indicates:

- The well still retained most of its original pressure.
- The reservoir likely has good pressure support.
- Severe depletion has not yet occurred.
- The formation may still have productive potential.

Overall, the final pressure remaining close to the initial pressure is considered a positive sign for reservoir health.

**5. Bottom Hole Temperature:**

The bottom hole temperature was recorded at **92°C**, which indicates a relatively hot reservoir environment. This temperature can affect:

- Fluid viscosity,
- Gas solubility,
- Formation behavior,
- And pressure response during testing.

At this temperature, reservoir fluids may flow more easily compared to colder formations.

### IV.5 Well-2 identification:

Our study focuses on the exploration well-2, located in the Illizi Basin—a region well-known for its major gas reserves. To pinpoint its exact location, the well uses the following coordinates:

- X Coordinate: 580 873.600 m
- Y Coordinate: 3 094 446.600 m

Currently, Well-2 holds the status of an exploration well, specifically classified as a Gas Producer Well (PPG). This distinction marks it as a well capable of producing gas, making it a key asset for evaluating and developing the basin's gas potential.

**Table IV.4:** Well-2 properties.

| **Well Acronym / Code** | Well-2 |
|---|---|
| **Basin** | Illizi |
| **Well Type** | Exploration Well |
| **Coordinates** | X: 580 873.600 m |
| | Y: 3 094 446.600 m |
| **Geographic** | Longitude: 9° 49' 20.29072" East |
| | Latitude: 27° 58' 29.62596" North |
| Gas Producer Well (PPG) | |

### IV.6 Well-2 localization:

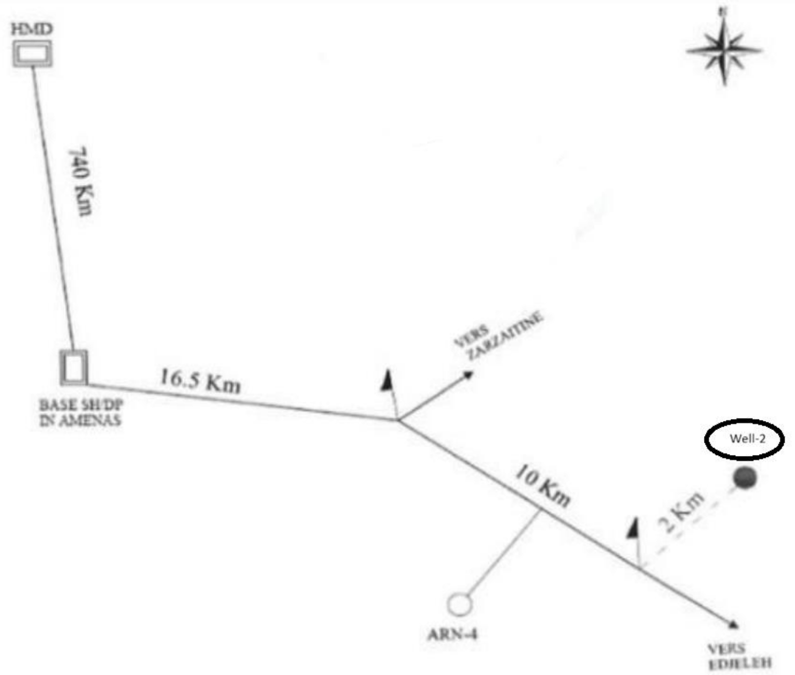


**Figure IV.6:** Well-2 localization.

### IV.7 DST results of well-2:

#### IV.7.1 Test data:

**Test type:** Barefoot.

**Tested formation:** Dévonien F2

**Intervals tested:** 1336 – 1418m.

**Buffer height:** 199 m.

**Packer anchor elevation:** 1295m (Cote sondeur).

This DST evaluates a barefoot (open-hole) completion within the Devonian F2 formation across a tested interval of 1336 – 1418 m (82 m gross interval). The packer is set at 1295 m, with a substantial buffer height of 199 m above the tested zone.

The data indicates a transition from a low-rate oil show to a progressively increasing gas flow with associated light oil. Over the 3-day testing period, the well exhibits a clear cleanup and increasing productivity trend. Crucially, $H_2S$ is absent (reported as "/" in all days), which is excellent for development economics and personnel safety, eliminating the need for sour-gas corrosion-resistant metallurgy and costly sulfur treatment facilities.

**Table IV.5:** DST results of well-2.

| **Date** | **1st day** | **2nd day** | **3rd day** |
|---|---|---|---|
| **WHP (psi)** | 1245 – 1223 | 810 | 490 – 485 |
| **Estimated light oil flow rate ($m^3/h$)** | / | 0.393 | 0.492 |
| **Light oil density (15°C)** | / | 0.787 | 0.794 |
| **Average Gas Flow Rate ($m^3/h$)** | 1681 | 2882 | 3726 |
| **Gas density (air = 1)** | 0.806 | 0.774 | 0.770 |
| **$H_2S$ (ppm)** | / | / | / |
| **Total volume of flared gas ($m^3$)** | 19331 | 28820 | 40986 |

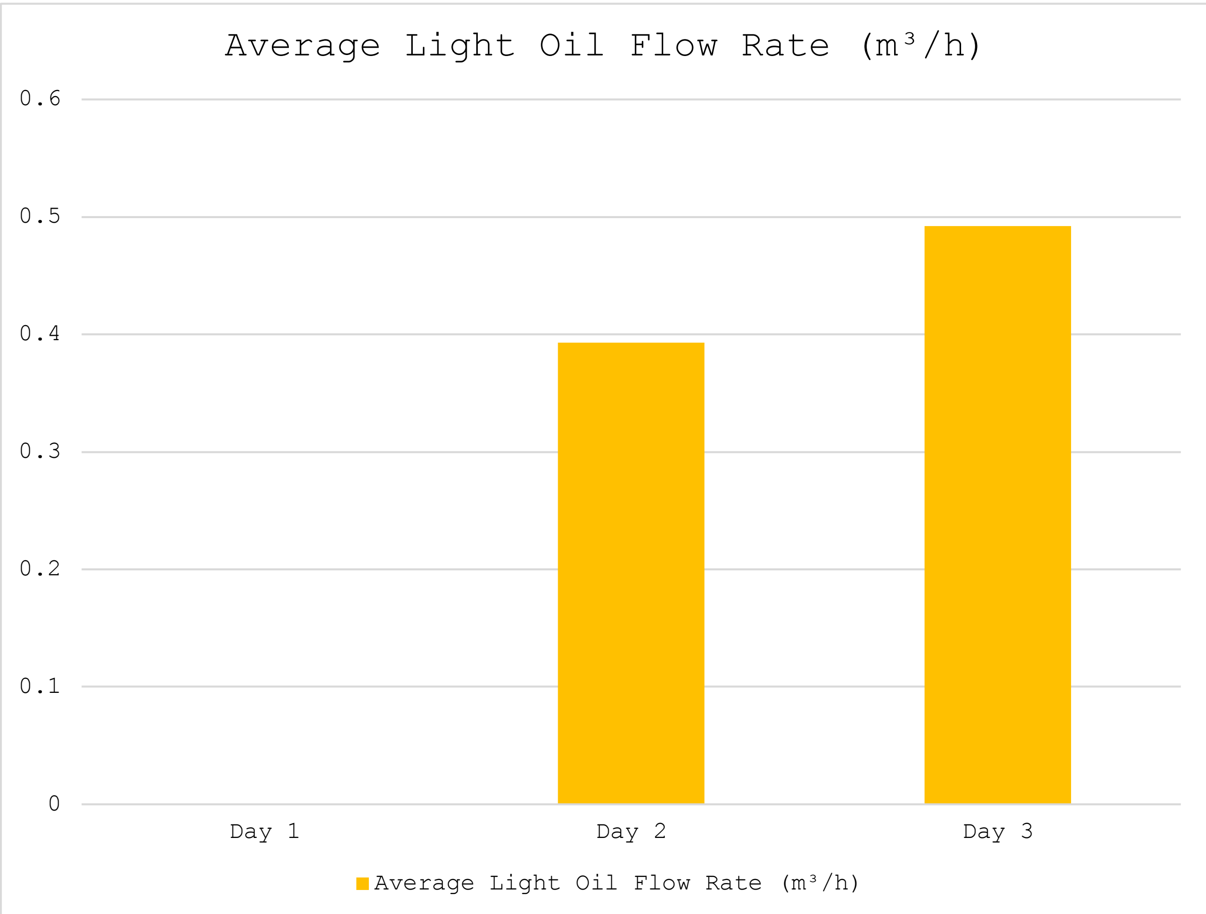


**Figure IV.7:** Average Light Oil Flow Rate of well-2.

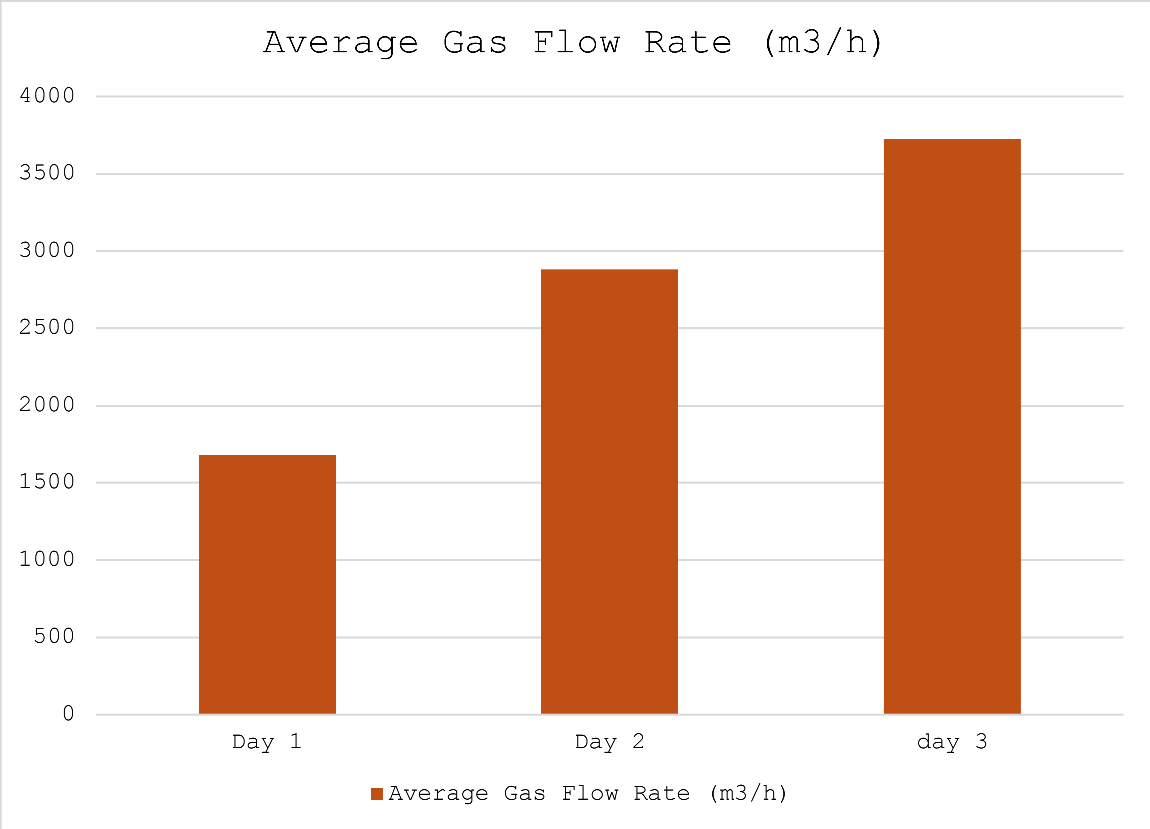


**Figure IV.8:** Average gas flow rate of well-2.

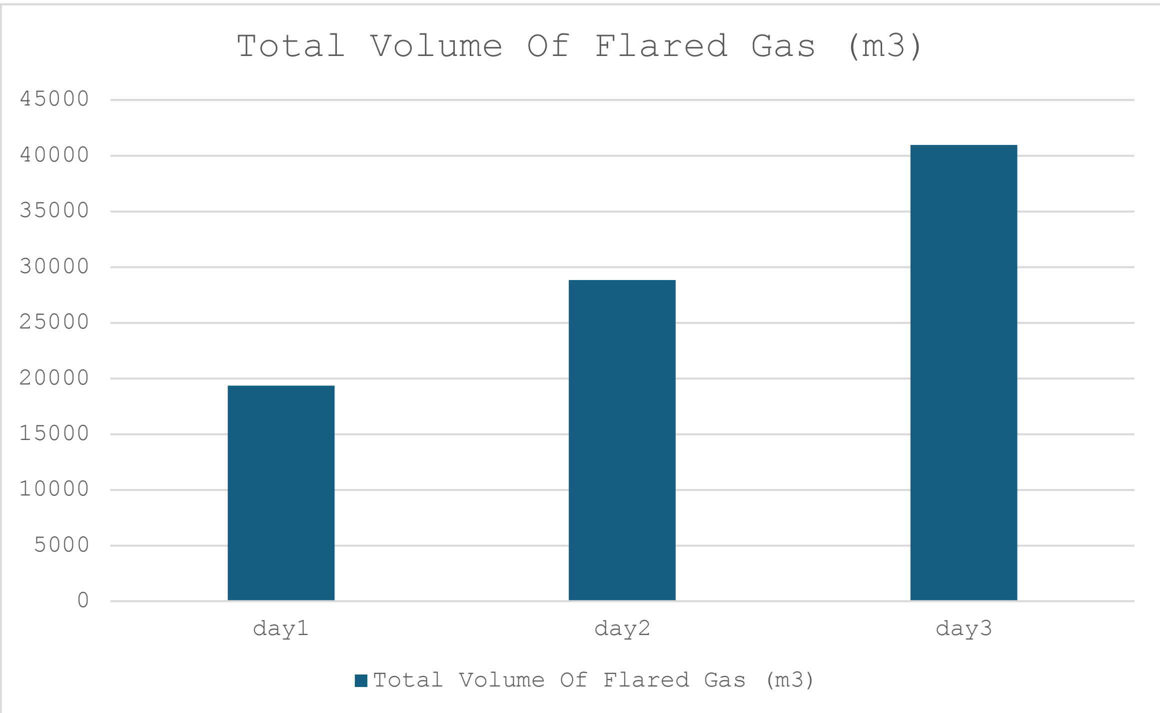


**Figure IV.9:** Total volume of flared gas of well-2.

**Bottom hole pressures of well-2:**

The well exhibits generally stable pressure behavior with only moderate depletion throughout the build-up stages. Although pressures gradually declined from the initial hydrostatic value of 2659 psi to a low of 2380 psi during the 4th build-up, later partial recovery (e.g., 2443 psi at the 5th build-up) indicates that the reservoir still has active energy support and has not suffered severe damage or exhaustion. Encouragingly, the small net pressure loss from the initial to the final hydrostatic pressure (2659 psi vs. 2439 psi, a difference of only 220 psi) means the reservoir is retaining most of its natural pressure. This points toward good reservoir continuity and potentially sustainable production performance.

**Table IV.6:** Bottom hole pressures of well-2.

| | |
|---|---|
| **Initial hydrostatic pressure (Psi)** | 2659 |
| **1st Build Up (Psi)** | 2471 |
| **2nd Build Up (Psi)** | 2408 |
| **3rd Build Up (Psi)** | 2421 |
| **4th Build Up (Psi)** | 2380 |
| **5th Build Up (Psi)** | 2443 |
| **6th Build Up (Psi)** | 2423 |
| **Final hydrostatic pressure (Psi)** | 2439 |
| **Bottom hole temperature (°C)** | 101 |

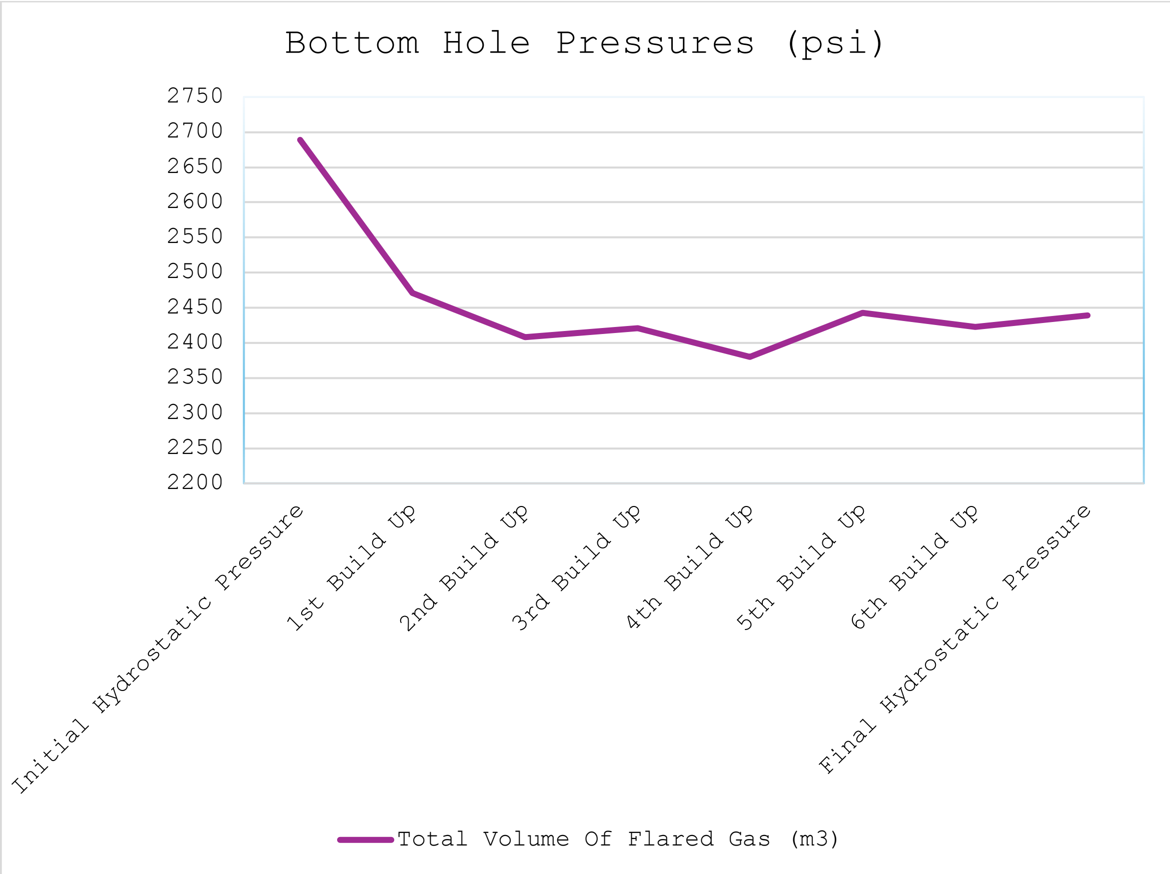


**Figure IV.10:** Bottom hole pressures of well-2.

**Observation:** Technically successful test, well producing gas and light oil.

### IV.7.2 Data analysis of well-2:

#### Day 1: The Initial Flow & Clean-Up Phase

- WHP (Wellhead Pressure) is high, ranging from 1245 – 1223 psi, while average gas flow is at 1681 $m^3/h$. No liquid oil rate is recorded on Day1.
- The well is opened to flow. This is the typical "clean-up" period. The high initial wellhead pressure indicates good reservoir energy, but the lack of measured oil rate suggests the flow is primarily gas and completion fluids. The total flared gas volume of 19,331 $m^3$ on Day 1 confirms significant gas breakthrough while liquids are still stabilizing.

**Day 2: The Well Opens Up (Liquids Appear)**

- WHP drops significantly to 810 psi, but light oil appears at 0.393 $m^3/h$ and gas flow surges to 2882 $m^3/h$. Light oil density is 0.787.
- The well has cleared its throat. The drop in WHP is a normal response to higher flow rates as the choke is likely increased. The emergence of measurable light oil indicates that formation liquids are finally reaching surface. Gas flow more than doubles from Day 1, showing excellent permeability. However, the oil rate remains modest, suggesting the fluid is very gas-rich.

**Day 3: Gas Maximum & Liquid Increase**

- WHP drops slightly to a stable range of 490 – 485 psi. Light oil flow rate increases to 0.492 $m^3/h$, and gas flow peaks at 3726 $m^3/h$. Oil density rises slightly to 0.794.
- The field crew is pushing the well toward maximum gas production. Despite lower WHP, both gas and oil rates increased compared to Day 2, indicating the well is responding positively. The higher oil density suggests slightly heavier hydrocarbon components are now being mobilized. Total flared gas reaches 40,986 $m^3$, showing sustained high gas deliverability.

**Build-Up Pressure Analysis (Reservoir Energy Assessment)**

- Initial hydrostatic pressure was 2659 psi. After multiple build-up sequences, pressures range from 2380 psi (4th Build Up) to 2471 psi (1st Build Up), with a final hydrostatic pressure of 2439 psi.
- This indicates the reservoir has experienced some pressure depletion during testing. The final pressure is 220 psi lower than the initial hydrostatic pressure (2659 → 2439 psi). Unlike the example where

pressure nearly fully recovered, here the final pressure remains significantly below the starting point, suggesting either limited reservoir volume, moderate permeability, or that the testing period has genuinely withdrawn fluid. The slight fluctuations (e.g., 5th Build Up at 2443 psi vs. 4th at 2380 psi) show intermittent recovery, but no return to original pressure.

**Fluid & Engineering Key Metrics of well-2:**

1. **Gas-Oil Ratio (GOR) Tendency:**

- Day 2: GOR = 2882 $m^3/h \div 0.393$ $m^3/h \approx 7{,}332$ $m^3/m^3$ (extremely gas-rich condensate).
- Day 3: GOR = $3726 \div 0.492 \approx 7{,}573$ $m^3/m^3$ (even higher).
- This is a very high-GOR, lean condensate system, not a rich condensate or volatile oil. The well is fundamentally a gas well with small liquid dropout.

2. **Hydrocarbon Fingerprint:**

- Light oil density (0.787 – 0.794): Converts to roughly 48° – 51° API. This is light condensate, but heavier than the example's 60°+ API. It is valuable but not ultra-premium.
- Gas density (0.770 – 0.806 relative to air): Indicates a moderately rich gas. The highest gas density (0.806 on Day 1) suggests heavier gas components early on, possibly from completion fluid vaporization. Later densities (0.770-0.774) are more typical of leaner natural gas.

**Interpretation of the Bottom Hole Results of well-2:**

1. **Initial Hydrostatic Pressure:**

- Recorded at 2659 psi. This represents the original undisturbed pressure before the build-up sequence, indicating a normally pressured to slightly under-pressured reservoir depending on depth (not provided).

2. **Pressure Decline During Build-Up Stages:**

- Build-up pressures decrease from 2471 psi (1st) to 2380 psi (4th). That is a decline of 91 psi across four measurements.
- This indicates progressive reservoir pressure depletion. Fluid is being produced faster than pressure can rebuild. The reservoir may have limited natural aquifer support or low permeability.

3. **Pressure Fluctuations (5th & 6th Build-Up):**

- 5th Build Up recovers to 2443 psi (up from 2380 psi), suggesting a temporary halt in production or improved local drainage. However, the 6th Build Up drops again to 2423 psi.
- This cycling behavior is typical of a heterogeneous reservoir or one where near-wellbore effects (skin, phase trapping) are causing pressure instability.

4. **Final Hydrostatic Pressure:**

- Final pressure = 2439 psi. Compared to initial 2659 psi, the net loss is:

$$2659 - 2439 = 220 \text{ psi.}$$

- Unlike the example where loss was only 48 psi, this well lost 8.3% of its initial pressure. This is a warning sign: the reservoir has limited energy support. Continued production without pressure maintenance could lead to rapid decline.

5. **Bottom Hole Temperature:**

Recorded at 101°C (slightly hotter than the example's 92°C). This high temperature will:

- Lower gas viscosity, improving flow.
- Increase vaporization of lighter ends.
- Keep heavier components in the gas phase longer, which explains why liquid oil rates are low despite significant gas production.

### IV.8 Comparison between well-1 and well-2:

#### IV.8.1 Reservoir and test setup:

**Table IV.7:** Reservoir & Test Setup.

| **Parameter** | Well-1 | Well-2 |
|---|---|---|
| **Formation** | Cambro-Ordovician (units IV, III, II) | Devonian F2 |
| **Tested interval** | 2817 – 2641 m (176 m gross) | 1336 – 1418 m (82 m gross) |
| **Test duration** | 4 days | 3 days |
| **Bottom hole temperature** | 92°C | 101°C |

#### IV.8.2 Pressure behavior:

- Well-1 shows excellent pressure maintenance – nearly full recovery, strong natural energy support.
- Well-2 shows moderate depletion with limited pressure rebound, suggesting smaller reservoir volume or weaker aquifer support.

**Table IV.8:** Pressure Behavior.

| **Pressure (psi)** | Well-1 | Well-2 |
|---|---|---|
| **Initial hydrostatic** | 3848 | 2659 |
| **Final hydrostatic** | 3800 | 2439 |
| **Net pressure loss** | 48 psi (≈1.2%) | 220 psi (≈8.3%) |
| **Lowest build-up** | 3370 (4th Build up) | 2380 (4th Build up) |

### IV.8.3 Fluid production and quality:

- Well-1 is a high-value gas-condensate well with premium light condensate and rich gas.
- Well-2 is a lean gas-condensate / gas-with-light-oil well – much lower liquid yield, though still commercially interesting.

**Table IV.9:** Fluid production and quality.

| **Parameter** | Well-1 | Well-2 |
|---|---|---|
| **Production** | Gas + Condensate | Gas + Light oil |
| **Peak gas rate ($m^3/h$)** | 6232 (Day 3) | 3726 (Day 3) |
| **Peak liquid rate** | 8.83 $m^3/h$ condensate (Day 2) | 0.492 $m^3/h$ light oil (Day 3) |
| **Condensate / oil density** | 0.728 – 0.737 → 60–63° API (ultra-light) | 0.787 – 0.794 → 48–51° API (light but heavier) |
| **Gas density (air=1)** | 0.772 – 0.788 (rich/wet gas) | 0.770 – 0.806 (moderately rich to lean) |
| **GOR range** | ~646 – 1420 $m^3/m^3$ | ~7,330 – 7,570 $m^3/m^3$ (much higher) |
| **$H_2S$** | / | / |

### IV.8.4 Wellhead pressure:

- Well-1 shows a strong rebound on Day 4, confirming excellent reservoir recharge.
- Well-2 shows continuous decline in WHP, consistent with limited energy support.

**Table IV.10:** Wellhead Pressure.

| Day | Well-1 (psi) | Well-1 (psi) |
|---|---|---|
| **1** | 1788 | 1245-1223 |
| **2** | 1595 | ~810 |
| **3** | 1384 | 490-485 |
| **4** | 1750 | / |

### IV.8.5 Overall reservoir energy and sustainability:

- Well-1 is the superior reservoir – it exhibits excellent pressure maintenance, very low net depletion (only 48 psi loss), high-value ultra-light condensate, and strong gas rates with a clear rebound in wellhead pressure. It is a highly sustainable gas-condensate producer.
- Well-2 is still a successful discovery but with clear limitations – it lost 220 psi (8.3%) during a short test, has much lower liquid yields, and shows pressure instability. It will likely produce gas commercially, but may require pressure support or careful production management to avoid rapid decline.

**Table IV.11:** Overall reservoir energy and sustainability.

| Aspect | Well-1 | Well-2 |
|---|---|---|
| **Natural pressure support** | Very strong (near-full recovery) | Moderate to weak (220 psi net loss) |
| **Depletion concern** | Low – sustainable production likely | Moderate – pressure maintenance may be needed |
| **Fluid value** | Very high (premium condensate) | Moderate (light oil but low rate) |
| **Flow stability** | Stable with cleanup and optimization | Increasing trend but pressure-sensitive |

## IV.9 Conclusion:

Well-1 is the superior reservoir and should be prioritized for development, offering strong pressure support, high-value condensate, and stable flow. Well-2 remains commercially viable as a gas producer but with moderate risk of depletion; it may benefit from reduced drawdown or future pressure support schemes. Both wells confirm the Illizi Basin's gas potential, and the complete absence of $H_2S$ across both tests is an exceptionally positive outcome for safe and economical field development.

## Conclusion:

This study set out to evaluate and compare two exploration wells in the Illizi Basin Well-1 and Well-2 based on their geological context, drilling test data, pressure behavior, fluid properties, and overall reservoir performance. The analysis leads to several clear and actionable conclusions.

From a geological perspective, the Illizi Basin presents a thick, varied sedimentary cover ranging from Cambrian to Paleogene, with multiple potential reservoir intervals. The Cambro-Ordovician units (targeted by Well-1) and the Devonian F2 formation (targeted by Well-2) both contain hydrocarbons, confirming the basin's rich petroleum system.

From a drilling and equipment standpoint, both wells were completed as barefoot (open-hole) tests under technically sound conditions. The drilling rig systems hoisting, rotary, circulation, power, and safety functioned adequately to allow successful DST operations. The use of modern drill stem test tools (packers, gauges, shut-in tools, etc.) provided reliable downhole pressure and fluid data. Well completion equipment was properly selected for both wells, with appropriate tubing, packers, and wellhead assemblies.

Well-1 should be prioritized for full-field development due to its strong pressure maintenance, high-value condensate, stable flow behavior, and low depletion concern. Well-2 remains commercially viable as a gas producer, but it will require careful production management likely reduced drawdown or future pressure support to avoid rapid decline.

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