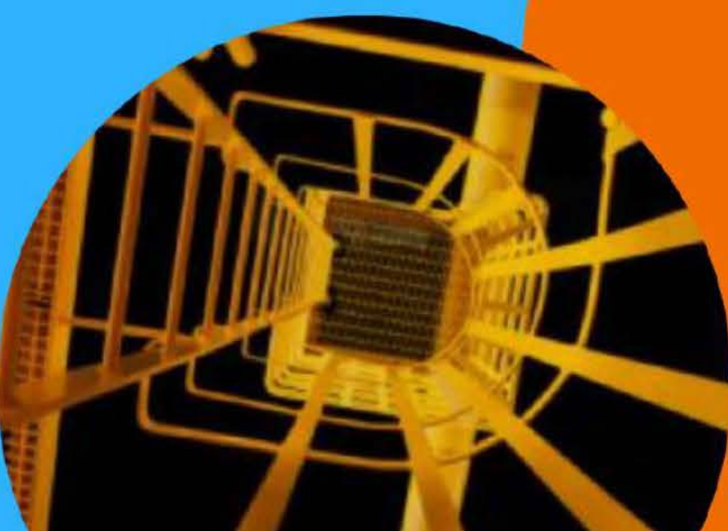
THE FIRST STEP FOR SUCCESS

STUDENT'S BOOK OF PETROCHEMICAL TECHNOLOGY

VOLUME 1



POLITEKNIK MALAYSIA

KEMENTERIAN PENGAJIAN TINGGI

KOLEJ KOMUNITI MALAYSIA

SHARIFFAH NUR JANNAH SYED ZAINOL ABIDIN
ROSNI YUSOFF

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to a new student who is keen
to make money through oil and gas

Thank you

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Introduction to Petroleum Chemistry

2.0

Petroleum production

Glossary

Absorbed heat - transferred heat- Effect include increase in volume and temperature, change of state, electrical transfer, and chemical change.

Aromatics - Include benzene, toluene, and xylenes, which also are a source of plastics (polyurethane, polystyrene, acrylates, nylon), as well as synthetic detergents and dyes.

Blowout preventers - A series of hydraulic actuated steel rams that close quickly around the drill string or casing to seal off a well. It is called BOPs.

Borehole- Is the wellbore itself, including the open-hole or uncased portion of the well. Borehole may refer to the inside diameter of the wellbore wall, the rock face that bounds the drilled hole.

Casing - Large-diameter pipe lowered into an open hole and cemented in place. The well designer must design casing to withstand a variety of forces, such as collapse, burst, and tensile failure, as well as chemically aggressive brines.

Christmas tree - The set of valves, spools, and fittings connected to the top of a well to direct and control the flow of formation fluids from the well.

Drilling Rig - The machine used to drill a wellbore. Major components of the rig include the mud tanks, the mud pumps, the derrick or mast, the draw works, the rotary table or top drive, the drill string, the power generation equipment, and auxiliary equipment.

Drilling fluid - Any of a number of liquid and gaseous fluids and mixtures of fluids and solids (as solid suspensions, mixtures and emulsions of liquids, gases and solids) used in operations to drill boreholes into the earth. Synonymous with "drilling mud" in general usage, although some prefer to reserve the term "drilling fluid" for more sophisticated and well-defined "muds."

Fault trap - Is formed by fracture and slippage of rock along a fault line may bring an impermeable stratum in contact with a layer of permeable reservoir rock and thus forms a barrier to petroleum migration.

High permeability - Is the formation implies greater oil and gas production rates and more economically attractive production wells.

Paraffin - Saturated hydrocarbon without ring structure

Naphthenes - Saturated hydrocarbon contain ring structure

Nomenclature - Rules to generate systematic names for chemical compound

Oxidation - Process in which electron are eliminate from the molecule during the chemical reaction

Olefins - Include ethylene, propylene, and butadiene. These are the main sources of plastics (polyethylene, polyester, PVC), industrial chemicals and synthetic rubber.

Permeability - Is defined as the ease in which fluids flow through porous media.

Reservoir - A subsurface rock formation containing one or more individual and separate natural accumulations of moveable petroleum that is confined by impermeable rock and is characterized by a single-pressure system.

Substituent - One or group of atom that replaces hydrogen atom on the parent chain

Synthesis gas (syngas) - Is formed by steam reforming between methane and steam to create a mixture of carbon monoxide and hydrogen. It is used to make ammonia, e.g., for fertilizer urea, and methanol as a solvent and chemical intermediary. Syngas is also feedstock for other processes such as the Fischer–Tropsch process that produces synthetic diesel.

Structural traps - Is a structure with a concave roof caused by the local deformation of the reservoir rock and the impermeable cap rock, formed by an anticline.

Stratigraphic trap - Is the variations within the rock strata themselves, such as a change in the local porosity and permeability of the reservoir rock, rocks laid down, or a termination of the reservoir rock. These variations may influence the areal extent of the reservoirs in the traps.

Solution gas drive - A type of reservoir-drive mechanism in which the energy for the transport and production of reservoir fluids is provided by the gas dissolved in the liquid. As reservoir fluids enter the wellbore, changing pressure conditions cause the gas to break from solution to create a commingled flow of gas and liquid that aids production.

Rotating System - It allows the rotation of the drill string, and it consists of the rotary table, the kelly and the swivel; In modern rigs, a top drive groups together the functions of the above three items of equipment.

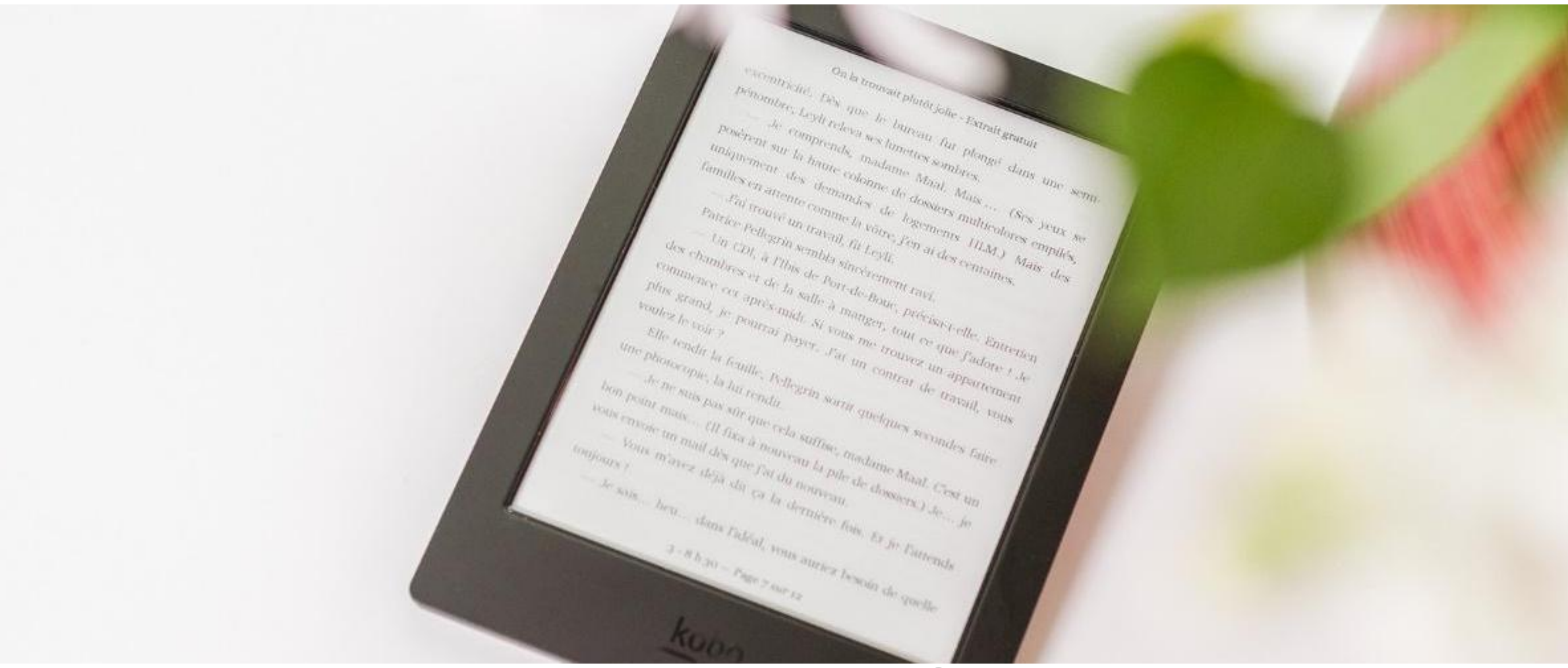
Platform - A relatively flat, nearly level area of sedimentary rocks in a continent that

System lifter - It is for responsible for supporting the rotating system in borehole drilling operations by providing ideal equipment for lifting, lowering and suspend rotating system

Tubing - It can be a variety of tubing, one is a tubular used to produce reservoir fluids which is production tubing. The production tubing selected for any completion should be compatible with the wellbore geometry, reservoir production characteristics and the reservoir fluids.

Wellhead - The system of spools, valves and assorted adapters that provide pressure control of a production well.

Separation system - An operation in which the well stream is passed through two or more separators that are arranged in series. The first separator is called first-stage separator, the second separator is called second-stage separator and additional separators are named according to their position in the series. The operating pressures are sequentially reduced, so the highest pressure is found at the first separator and the lowest pressure at the final separator



PREFACE

This Student's Book of Petrochemical Technology is intended for students who seek to understand the basic petroleum and petrochemical study related to oil and gas as the world's largest production. It is illustrated based on the course structure of the Diploma in Mechanical (Petrochemical) Engineering Program. This ebook comes with Volume 1 and Volume 2, and the terms Petrochemical Technology was used to classify both terms of petroleum and petrochemical as a first step to view this technology. This ebook is designed to provide the apprentice technician with the foundation of the petroleum and petrochemical field. This ebook devotes the chapters to each of these courses and provides a glance at ideas with review activities at end of the chapters.

This ebook is divided into Two (2) chapters, a broad spectrum of petroleum origin and related production are include in both chapters. Chapter 1 describes petroleum chemistry, explaining more on chemical substances used in petrochemical industries. Chapter 2 gives a brief introduction of petroleum exploration and production, revealing a geology formation of crude oil, working activities in drilling and its installation are discussed as well. In addition, this e-book would give a smooth foundation for the student who wishes to make money through this career!

The authors would like to express their utmost gratitude to those who have been involved in proving and building the course contents of this e-book.

Thank you.

Shariffah Nur Jannah Syed Zainol Abidin
Rosni Yusoff
2021

Introduction to Petroleum Chemistry

1.0

1.0 Introduction to Petroleum Chemistry

1.1 Introduction to Petroleum Chemistry

Hydrocarbons are organic compounds made up of two elements (carbon and hydrogen). The main source of hydrocarbons is crude oil. Hydrocarbons are the most abundant compounds in crude oils, however in crude oil they also contain others atom such as nitrogen, sulfur, oxygen and trace element such as nickel and vanadium. Table 1.1 shows the proportion of the element in petroleum. The distribution and characteristics of these molecular species account for the rich variety of crude oil. The quantity and percentage of the specific types of hydrocarbon in raw crude oil can be determined by testing in a laboratory.

Table 1.1: Proportion of Element in Petroleum (Speight, 2014)

Element	Percentage (%)
Carbon	83 % - 87 %
Hydrogen	10 % - 14 %
Nitrogen	0.1 %- 2.0%
Oxygen	0.05%- 1.5 %
Sulphur	0.05%- 6.0 %
Metal (Ni and V)	< 1000ppm

1.2 Classification of Hydrocarbons (Crude Oil)

Nineteenth-century chemists classified hydrocarbons as either aliphatic or aromatic on the basis of their sources and properties. Aliphatic (from Greek *aleiphar*, “fat”) described hydrocarbons derived by chemical degradation of fats or oils. Aromatic hydrocarbons constituted a group of related substances obtained by chemical degradation of certain pleasant-smelling plant extracts. The terms *aliphatic* and *aromatic* are retained in modern terminology, but the compounds they describe are distinguished on the basis of structure rather than origin.

Figure 1.1 shows a structure of hydrocarbons in petroleum or crude oil. It has been well established that the hydrocarbon compounds of petroleum are composed of paraffinic, naphthenic and aromatic groups. Olefin groups are not usually found in crude oils and alkynes and very rare indeed due to their high reactivity (Robinson, 2006). It is therefore convenient to divide the hydrocarbon component of petroleum into the following three classes.

i. Paraffin: Which are saturated hydrocarbon with straight or branched chains, but without any ring structure (Alkane series)
ii. Naphthenes: Which are saturated hydrocarbon containing one or more rings, each of which may have one or more paraffinic side chains (known as alicylic hydrocarbon)
iii. Aromatic: Organic compound that contain benzene ring or in others words the ring structure in which electron are shared by many atoms

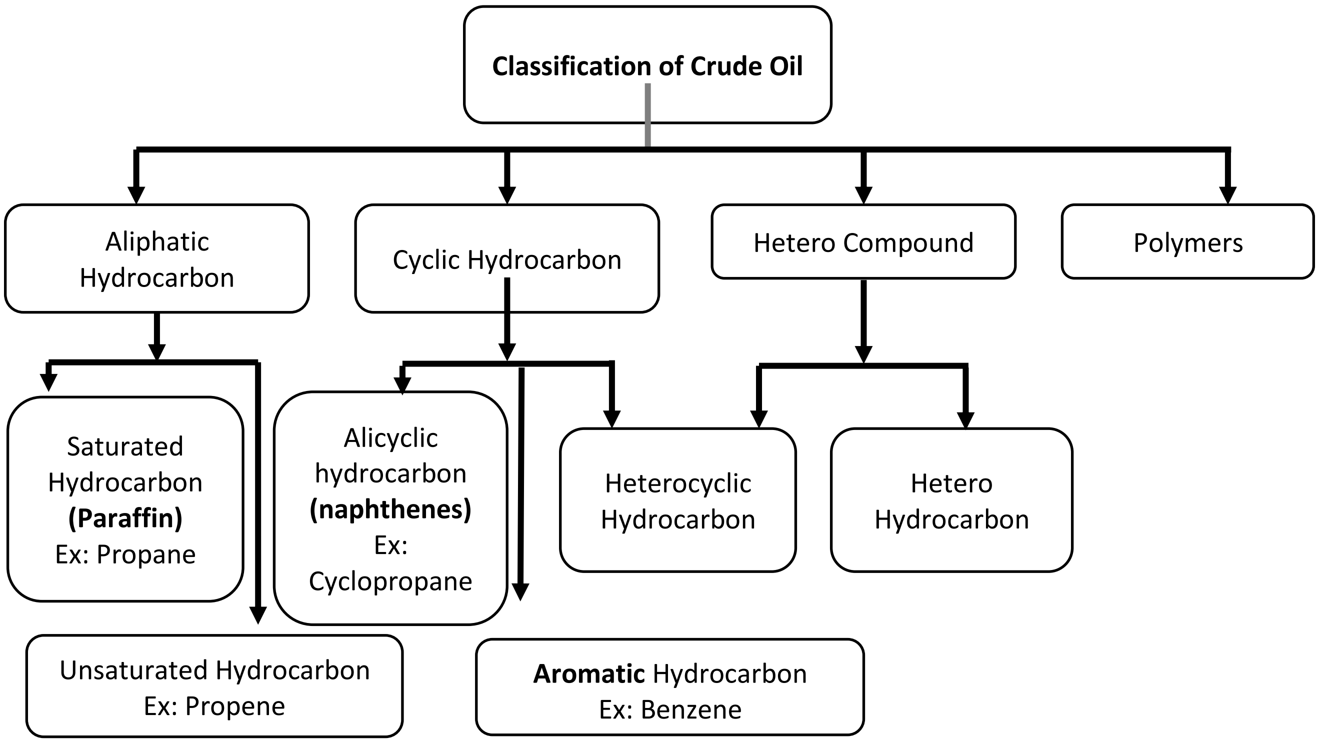


Figure 1.1: Classification of Hydrocarbon in Crude Oil

1.2.1 Aliphatic and Aromatic Hydrocarbon

Aliphatic hydrocarbon is hydrocarbon based on a chain of carbon atoms. There are two types of aliphatic which are saturated hydrocarbon (alkane) and unsaturated hydrocarbon (alkene and alkynes). Alkane, others used the word paraffin are the simplest of hydrocarbon species. They contain entirely single bond between carbon atoms. In alkane, C bonded in a straight chain are called normal alkane, whereas alkane that contains at least one ring of C atoms is called cycloalkane (naphthenes). Alkene is hydrocarbon that contains at least one double bond (C=C) and alkynes are hydrocarbons that contain at least one triple bond.

In nineteen century, the term aromatic was used because many benzene-related compounds were found in pleasant smelling of fruits, plant and spices parts [2]. As compared to naphthenes, hydrocarbon that have at least one benzene ring as part of structure called aromatic ring. Difference in their constituents display significant difference in physical and chemical properties. Compared to paraffin and naphthenes with the same carbon number, aromatics are denser and have high octane numbers (Robinson, 2006). Hydrocarbons can exist in the form of gas, liquid and solid. At room temperature the atoms C1 – C4 are gases, C5 – C20 is fluid and C20+ is solid.

In organic compound, atoms other than carbon and hydrogen are called hetero-atoms. As mentioned above sulfur, nitrogen, oxygen and metals are minor constituents of crude oil, however as we go through the petrochemical process, their impact on processing costs can be major. For instance, the emission of high- sulfur used in vehicles or power plants causes' acid rain. For many refining processes, sulfur, nitrogen and metals are catalyst poison. Thus, refiners consign large amount of time and money to eliminate hetero-atoms from intermediate streams and finished products.

1.3 Nomenclature and Structure Of Alkane, Alkene, Cyclic Hydrocarbon (Alkane, Alkene and Aromatic)

In chemical nomenclature, the IUPAC Nomenclature of organic chemistry is the method of naming the organic chemical compound as recommended by the International Union of Pure and Applied Chemistry (**IUPAC**).

I. Nomenclature and structure of Alkane

Alkane and cycloalkane are referring to hydrocarbons having no double bond or triple bond depending on whether the carbon atoms of the molecule are arranged in chains or in rings. Both of these are also the members of a large class of compounds referred to as aliphatic. In order to name the organic compounds, we must first memorize a few basic names. The following Table 1.2 lists the IUPAC names assigned to simple continuous- chain alkanes (n-alkane) from C-1 to C-10. The common **"ane"** suffix identifies these compounds as alk**ane**s.

** The suffix reflects the type of functional group present on the parent chain. Other groups attached to the parent chain are called substituents.

✓ Step naming straight chain alkane

i. Determine the longest carbon

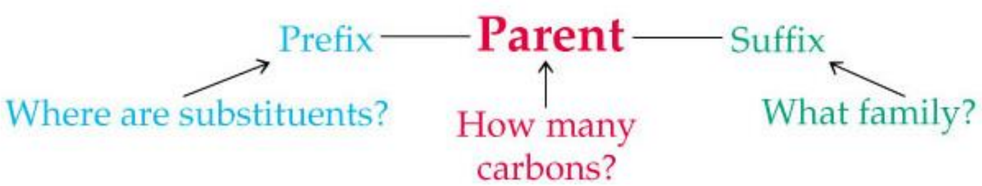
ii. Select correct prefix

iii. Add the suffix 'ane' at the end of the prefix

Table 1.2: Simple Unbranched (Straight chain) Alkanes

Number of C	Name	Molecular Formula
1C- Meth	Meth**ane**	CH_4
2C- Eth	Eth**ane**	C_2H_6
3C- Prop	Prop**ane**	C_3H_8
4C- But	But**ane**	C_4H_{10}
5C- Pent	Pent**ane**	C_5H_{12}
6C- Hex	Hex**ane**	C_6H_{14}
7C- Hept	Hept**ane**	C_7H_{16}
8C- Oct	Oct**ane**	C_8H_{18}
9C- Non	Non**ane**	C_9H_{20}

Based on the trend of alkane the formula and structure are increased uniformly by CH_2 increment and the formula fits the **CnH2n+2** rule.

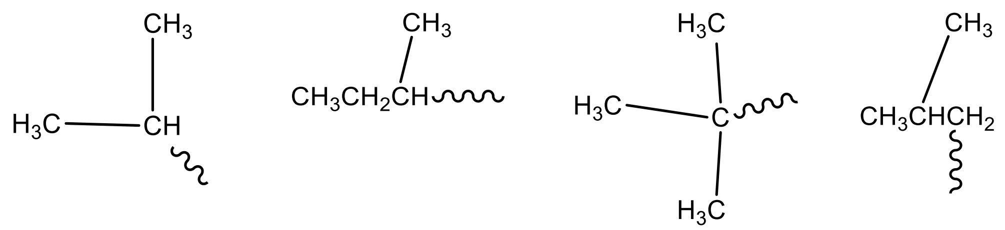


There are few branched substituents which commonly seen and formed by removal one hydrogen from the end of chain result change from **–ane** to **–yl** such as;

$$CH_4 \longrightarrow CH_3^-$$
Methane → Methyl

$$CH_3CH_2CH_3 \longrightarrow CH_3CH_2CH_2^-$$
Propane → Propyl

There are also others few branch substituents (Figure 1.2) which you should memorize



Isopropy Sec-butyl Tert-butyl Iso-butyl

Figure 1.2: Branch Substituent

✓ <u>Step naming branched chain alkane</u>

i. Identify the longest carbon chain (Parent chain)
ii. Identify all of the substituents
iii. Number the carbons of the parent chain from the end that gives the substituents the lowest numbers
iv. If the same substituent occurs more than once, the location of each point on which the substituent occurs is given (di, tri, tetra, ect.)
v. If there are two or more different substituents they are listed in alphabetical order
vi. If chains of equal length are competing for selection as the parent chain, then the choice goes in series to:

a. The chain which has the greatest number of side chains.
b. The chain whose substituents have the lowest- numbers.
c. The chain having the greatest number of carbon atoms in the smaller side chain.
d. The chain having the least branched side chains.

vii. A cyclic (ring) hydrocarbon is designated by the prefix cyclo- which appears directly in front of the base name

Note: Commas are used between numbers and dashes are used between letters and numbers. There are **no** spaces in the name.

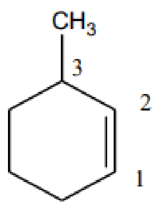
Note: Normal Butane (n-butane) motor gasoline in general has 'low octane number' but Isobutane has high octane number. Thus, i-butane over desired as a component in gasoline products.

II. Nomenclature and Structure of Alkene

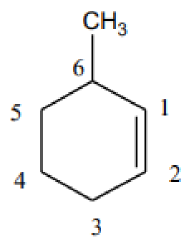
As mentioned early alkene are hydrocarbons which respectively have **Carbon-carbon double bond.** The presence of a double bond in hydrocarbons is named by changing the suffix "-ane" to "-ene". Its **formula CnH2n**. It is more reactive than paraffin due to the presence of the double bond. In other words, the unsaturated compound is less stable and easy to change shape when applicable in a chemical reaction. Olefin hydrocarbons exist a little bit in a petroleum in a natural state, but it arises from the reaction thermal or catalytic cracking in the petroleum refining process in the refinery.

✓ Step naming branched chain alkene

i. The parent chain is numbered so that the double bond has the lowest number.
ii. If the double bond is in the center of the chain, the nearest substituent is used to determine the end where numbering starts.
iii. If more than one double bond is present, indicate their position by using the number of the first carbon of each double bond and use the suffix -diene (for 2 double bonds), -triene (for 3 double bonds), -tetraene (for 4 double bonds)
iv. Cycloalkenes are named in a similar way. Number the cycloalkene so the double bond carbons get numbers 1 and 2, and the first substituent is the lowest possible number.

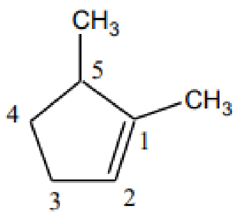


3-methylcyclohexene

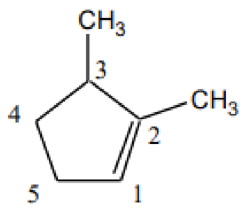


NOT
6-methylcyclohexene

viii. If there is a substituent on one of the double bond carbons, it gets number 1.

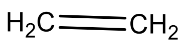


1,5-dimethylcyclopentene

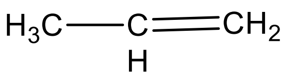


NOT
2,3-dimethylcyclopentene

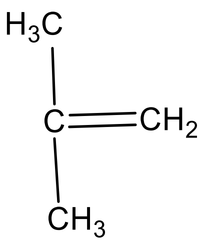
ix. Non-IUPAC Alkenes:



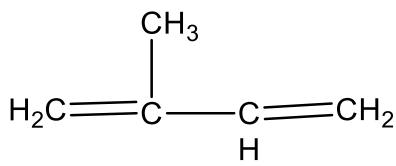
Ethylene



Propylene



Isobutylene



Isopropene

III. Nomenclature and Structure of Aromatic

Aromatics are cyclic but unsaturated hydrocarbons with alternating double bonds. Group of petrochemicals known as ‘aromatics’ which includes benzene, toluene and xylene **(BTX)** (Figure 1.3). Generally, aromatics are produced in refineries. The most popular processes in refineries to produce them is in the "reformer". Aromatic is used as a "blending component" to produce gasoline with a high octane number. The simplest aromatic hydrocarbon is benzene (C_6H_6). Although benzene has three carbon-carbon double bonds, it has a unique arrangement of electrons with resonance structures of the double bonds (aromaticity) that allow benzene to be relatively stable and chemically reactive.

The reactivity due to the presence of double bond on the aromatic ring may be represented by the various petrochemicals derived from them such as polystyrene, epoxy, and polyester such as polyethylene terephthalate (PET), the water bottle material. Others, such as clothing, packaging, paints, adhesives, computers, compact discs, snowboards and tennis racquets are among the many products that rely on aromatics.

However, benzene is known to be a cancer-inducing compound. For this reason, the amount of benzene allowed in petroleum products such as gasoline or fuel oil is limited by government regulations in many countries.

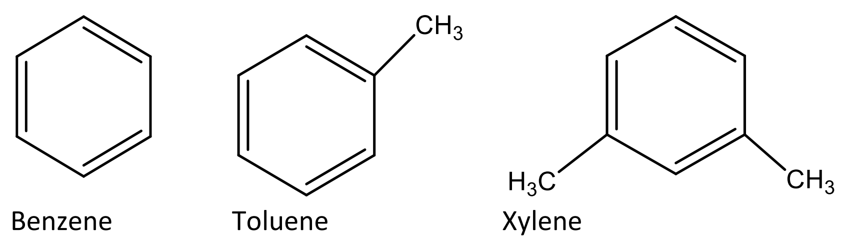
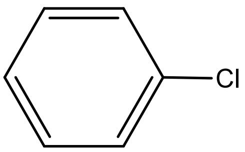


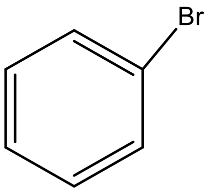
Figure 1.3: The Structure of Aromatic

1.4 Benzene Structure, Its Derivatives and Reactions

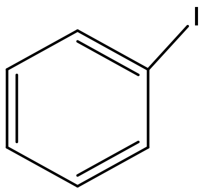
1.4.1 In the International Union of Pure and Applied Chemistry (IUPAC) system, aromatic hydrocarbons are named as derivatives of benzene (Figure 1.4). Five examples are shown below. In these structures, it is immaterial whether the single substituent is written at the top, side, or bottom of the ring: a hexagon is symmetrical, and therefore all positions are equivalent.



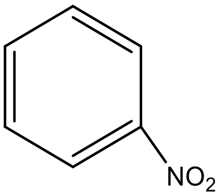
Chlorobenzene



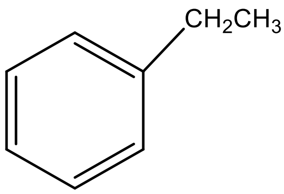
Bromobenzene



Iodobenzene



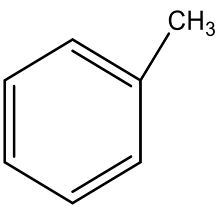
Nitrobenzene



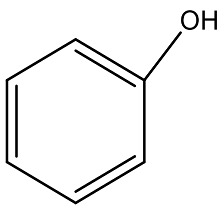
Ethylbenzene

Figure 1.4: Example of Benzene Derivative

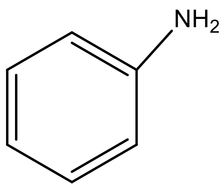
Although some compounds are referred to exclusively by IUPAC names, some are frequently denoted by common names, as indicated below.



Toluene



Phenol



Aniline

Figure 1.5: Common Name Used for Benzene Derivatives

1.4.2 Reaction Involve in Benzene Structure

Benzene is a volatile, colorless and flammable liquid aromatic hydrocarbon possessing a characteristic odor. Benzene is a simple molecule with six carbon ring, a hydrogen atom attached to each carbon but it is a start of many reactions (Figure 1.7). Below is the chemical reaction takes place for benzene molecules.

i. Electrophilic substitution reaction (Figure 1.6)
   a. Nitration (*)
   b. Sulphonation (*)
   c. Friedel - craft alkylation (*)
   d. Friedel- craft acylation (*)

ii. Addition reaction of Benzene
   a. Halogenation
   b. Hydrogenation (*)

iii. Oxidation of benzene

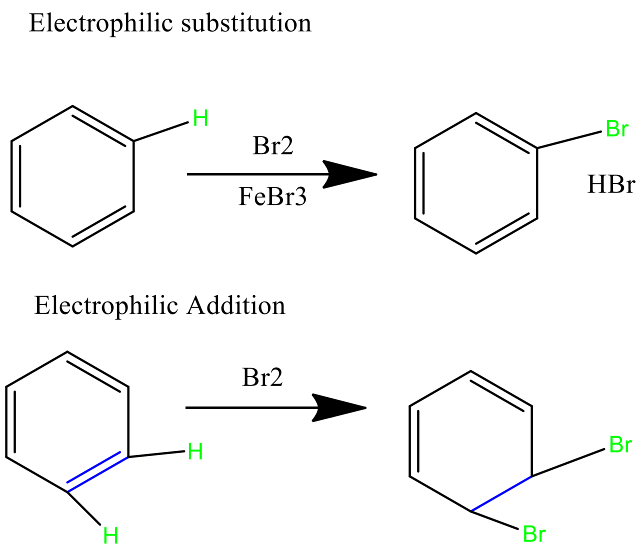


Figure 1.6: The Simple Difference between Substitution and Additional Reaction in Benzene

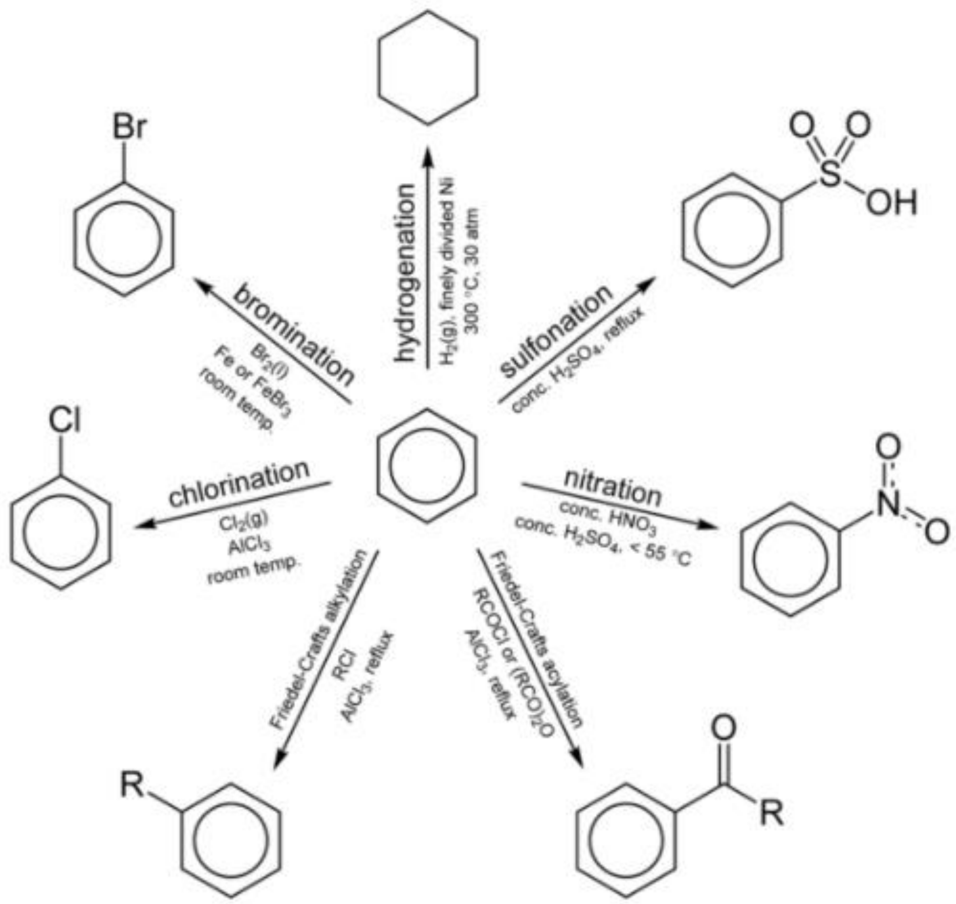


Figure 1.7: Chemical Reaction Involved in Benzene

1.5 Formation of Alcohol, Ketone and Aldehydes from Alkene.

Two most important and most abundant organic chemicals produced from crude oil are alkene and propylene. They are used as a starting materials to synthesize numerous compounds.

i. Alkene to alcohol

Ethylene → Ethanol (Example use as a solvent)

Propylene → isopropyl alcohol (Cosmetic)

Ethanol can be manufactured by the **hydration** of ethylene. In this reaction, ethylene is heated with steam in the presence of a catalyst of phosphoric acid (to speed up the reaction). This reaction typically uses a temperature of around 300°C and a pressure of around 60–70 atm.

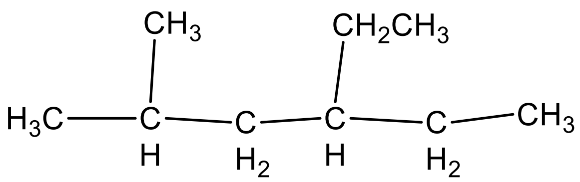
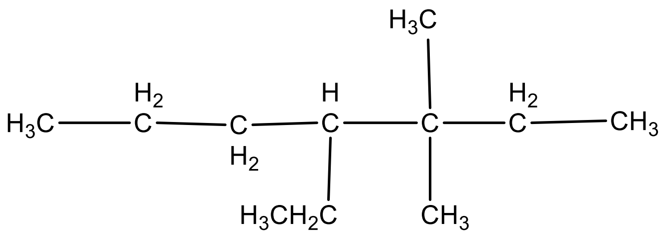
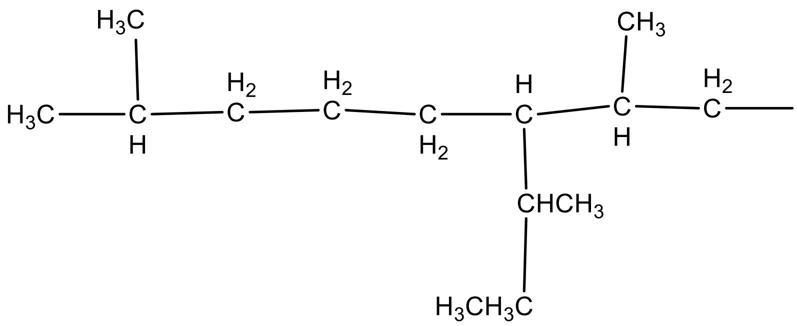
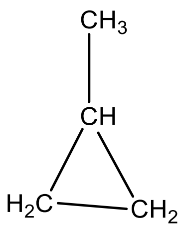
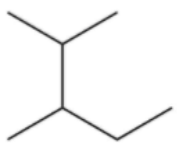
ii. Alkene to Ketone

Acetone is an important chemical intermediate used in the production of acrylic plastics, polycarbonates and epoxy resins. Acetone is also used in its own right as a solvent. Acetone is manufactured from the basic raw materials of benzene and propylene. These materials are first used to produce cumene, which is then **oxidized** to become cumene hydroperoxide, before being split into phenol and its co-product, acetone.

iii. Alkene to Aldehyde (Oxidation)

Ethylene →Acetaldehyde (Example use as a preservatives, flavoring agents)

Activity 1.1 Review Question

No	Molecular Structure	Name
1		
2.		
3.		
4.		
5.		

Activity 1.2 Review Question

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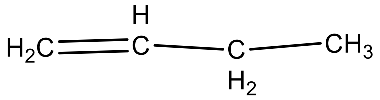
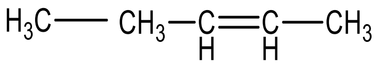
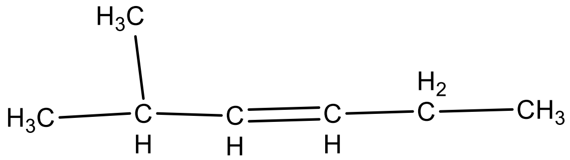
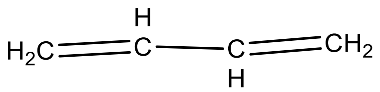
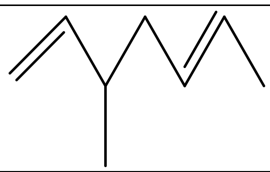
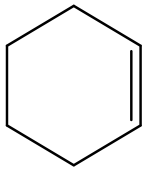
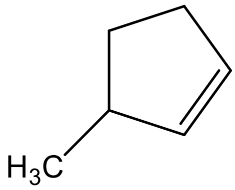
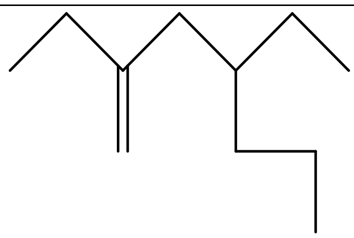
1		
2		
3		
4		
5		
6		
7		
8		

Petroleum Production

2.0

2.0 Petroleum Production

2.1 Basic of Petroleum Geology

The study of the geological processes that create crude oil and natural gas reservoirs is referred to as Petroleum Geology. Specialized areas of geologic study including Stratigraphy and Structural geology.

Stratigraphy is the study of the layers (or strata) within rock formations; while Structural Geology is the study of the deformation of rock under tectonic forces. Figure 2.1 shows layering (stratigraphy) and deformation (structure) of road-cut of Route 322 of State College (King, 2020).

Figure 2.1: Layering (stratigraphy) and deformation (structure)
[Source: Pennsylvania State University, 2020]

Hydrocarbon reservoirs are typically associated with sedimentary rock formations. Over geologic time, weathered and eroded rock materials are carried downstream from elevated regions to lower regions in rivers and streams to oceans, seas, or lakes.

At the point in the rivers, oceans, seas, or lakes where the energy in the water can no longer suspend or transport the rock material, it begins to settle in the water and is deposited onto the bottom of the water body. This is called the depositional process. During the depositional process, the environment can change over the geologic time scale: mountain tops and hilltops erode, sea-levels rise or lower, etc. With these changes, the types of sediments that are deposited change and the locations where they are deposited also change.

There are two (2) commonalities that exist during the depositional process, even over the geologic time scale which are:

1. The sediments and, consequently, the sedentary rocks that are lower in the stratigraphic column were deposited earlier than sediments higher in the stratigraphic column and,
2. The layers of sediment are initially deposited horizontally. From this discussion, we can see that sediments lower in the stratigraphic column must be older than those higher in the stratigraphic column.

Noticing that the stratigraphic column is a written, pictorial, or schematic record of the local rock strata showing the order of the rock deposition (older rocks at the bottom and younger rocks at the top), along with notes concerning the age of the rocks, occurrence of any fossils, any rocks which may be absent from the local geological record due to erosion, or any notes of use to a geologist.

2.1.1 Definition of Petroleum

Petroleum is a complex mixture of hydrocarbons that occur beneath the Earth in liquid, gaseous, or solid forms. The word petroleum comes from the Greek old word 'petra "meaning rock and the Latin word" oleum "means oil. Thus the word petroleum is defined as rock oil because most of the oil is found in the rocks.

In terms of terminology, consists of crude petroleum (crude oil) and natural gas (natural gas). Oil and gas is also known as compound "hydrocarbons" because it consists of two elements, namely hydrogen and carbon. Besides hydrocarbons, usually there is unwanted substance in the oil and gas content such as nitrogen, carbon dioxide, hydrogen sulfide, water and so on.

2.1.2 Raw Material, Side Product and Products of the Industries Involved

The word petroleum is often restricted to liquid form, but it also includes natural gas and the solid bitumen. The ancient Sumerian, Assyrians, and Babylonians used crude oil and asphalt more than 5000 years ago. Crude oils were used as a weapon of war during, The Arabs and Persian distilled crude oil to obtain flammable products (Gary et al., 2007). With the discovery of kerosine in 1846, the oil became a commercial commodity.

The discovery of a process making liquid fuel out of coal, called kerosine (coal oil) is marketed for street lighting in Halifa, Nova Scotia. Boiling and distillation at different temperatures were found to produce high quality illuminating oil (one fraction of distillation process is kerosine). The first refinery to process crude used existing coal refineries or were built where oil was found.

Over subsequent decades, the development of electricity and the creation of combustion engine significantly impacted the demand for refined products, such as gasoline and diesel fuels in place of kerosine. Air transportation and World War 2 created the need for high octane, aviation gasoline, and later jet fuel. Today, petroleum refining is a mature and well established industry infrastructures and technology base, employing a complex array of chemical and physical processing facilities to transform crude oil into products that consumer’s value.

Petrochemicals

Petrochemical derived from petroleum or natural gas are an essential part of the current chemical industry. Petrochemicals refers to all those compounds that can be derived from petroleum refinery products. In a petrochemical plant, it produces thousands of chemical compounds.

Petrochemical plants are divided into three (3) primary product groups according to their feed stock and primary product:

a. Olefins
b. Aromatics
c. Synthesis gas

The typical feedstock to petrochemical processes include

a. C1 Compounds: Methane & Synthesis gas
b. C2 Compounds: Ethylene and Acetylene
c. C3 Compounds: Propylene
d. C4 Compounds: Butanes and Butenes
e. Aromatic Compounds: Benzene

Therefore, petrochemicals are produced from simple compounds such as methane, ethylene and acetylene but not multicomponent products such as naphtha, gas oil etc.

2.1.3 Petroleum Reservoirs

A reservoir is defined as the portion of a geological trap which contains oil and/or gas as a single hydraulically connected system. Due to their petro-physical characteristics, oil and gas accumulation occurs mainly in sedimentary rocks such as limestone, dolomite, and sandstone, where fluids are stored and distributed according to their densities. Although petroleum reservoirs exist mainly in sedimentary rock systems, occasionally petroleum reservoirs are also found in igneous and metamorphic rocks.

Petroleum reservoir is a subsurface pool of hydrocarbons. There are five geological requirements for the formation of a conventional hydrocarbon reservoir:

1. Source Rock
2. Migration Path
3. Cap Rock
4. Reservoir Rock
5. Trap

The reservoir formation is illustrated in Figure 2.2 which color bands represent either porous or non-porous rocks.

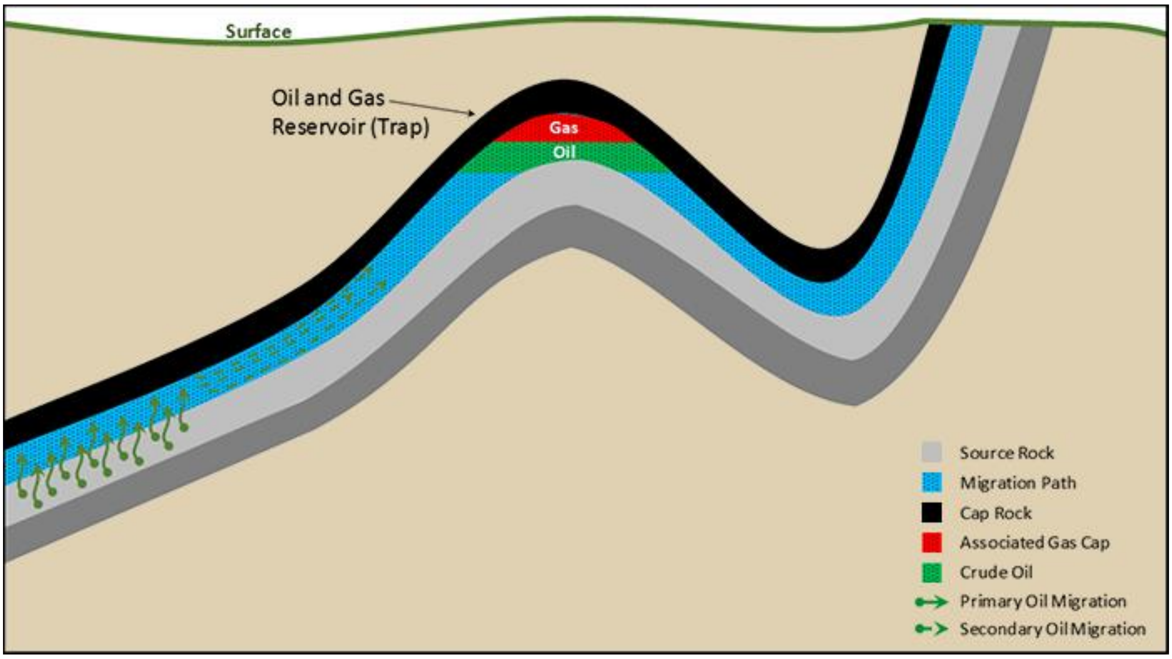


Figure 2.2: Typical Oil and Gas Reservoir requirement for Conventional Crude Oil and Natural Gas Reservoir [Source: Pennsylvania State University, 2020]

Source Rock

Source rock, represented in grey colour, is original organic material converted into hydrocarbons. Hydrocarbons do not necessarily originate in the hydrocarbon reservoir itself, but are generated away from the reservoir in rocks that are conducive to hydrocarbon generation. These source rocks are typically organic-rich shales, siltstones, or coals.

Migration Path

There must be a pathway for hydrocarbons to migrate from the source to the reservoir, called Migration Path (blue). Migration Path is a water-filled rock layer (aquifer).

Solid green arrows represent primary migration of hydrocarbons which refers to the initial expulsion of the hydrocarbons from the source rock. The dashed green arrows represent the secondary migration of the hydrocarbon which is the remainder of migration to the reservoir.

Cap Rock

According to Figure 2.2, all fluid migration is upward. This is because the main driving mechanism in hydrocarbon migration is buoyancy, which occurs because the oil and gas are less dense (lighter) than the resident water. In order to prevent this buoyant flow from occurring all of the way to the surface, a vertical flow barrier, or Cap Rock, is required along the migration path and at the reservoir itself. A cap rock (black) is simply an overlying rock layer that is impermeable to flow. Permeability is a property of the rock that is a measure of the ease in which fluids can flow through a porous medium (in our case, a rock formation).

Reservoir Rock

The fourth requirement for a hydrocarbon accumulation is the presence of a Reservoir Rock. Reservoir rock is the same rock formation as the migration path. The most common reservoir rocks are sedimentary rocks; however, naturally fractured igneous and metamorphic rocks can also form hydrocarbon reservoirs.

A high porosity and high permeability are two requirements for a commercial crude oil or natural gas reservoir which exist in the pore-space between the grains of the sedimentary rocks. Permeability is defined as the ease in which fluids flow through porous media. A high permeability formation implies greater oil and gas production rates and more economically attractive production wells.

Trap

The last component of a hydrocarbon reservoir system is the Trap. A trap or trapping mechanism is a change in the stratigraphy or a structural deformation that is capable of stopping the migration process and keeping the oil and gas in place over geologic time. The oil is always accompanied by water and natural gas which are confined in porous and permeable reservoir rocks such as limestone.

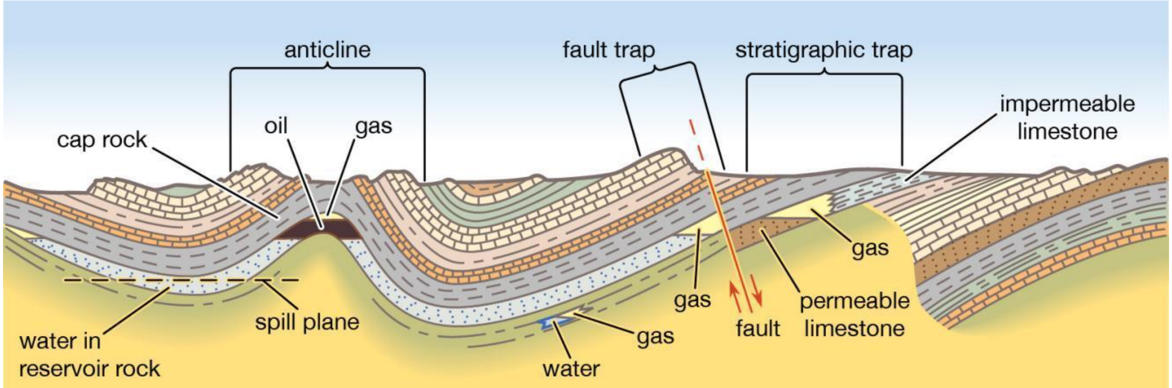


Figure 2.3: Petroleum Trap [Source: Encyclopædia Britannica, 2021]

Hydrocarbons are normally in a lower density than water formation. Thus, if no mechanism is in place to stop their upward migration they will eventually seep to the surface. There are three basic forms of trap as shown. There are

a. Stratigraphic traps

b. Structural traps

Stratigraphic traps

In a stratigraphic trap, variations due to a change in the local porosity and permeability, rocks laid down, or a termination of the reservoir rocks play the important role to form kinds of reservoirs. These stratigraphic changes are the influence on the areal extent of the reservoirs in these traps. Traps may show as pinch-out trap and uniformity trap as seen in Figure 2.4 (a) is pinch-out trap and Figure 2.4 (b) is an uniformity trap.

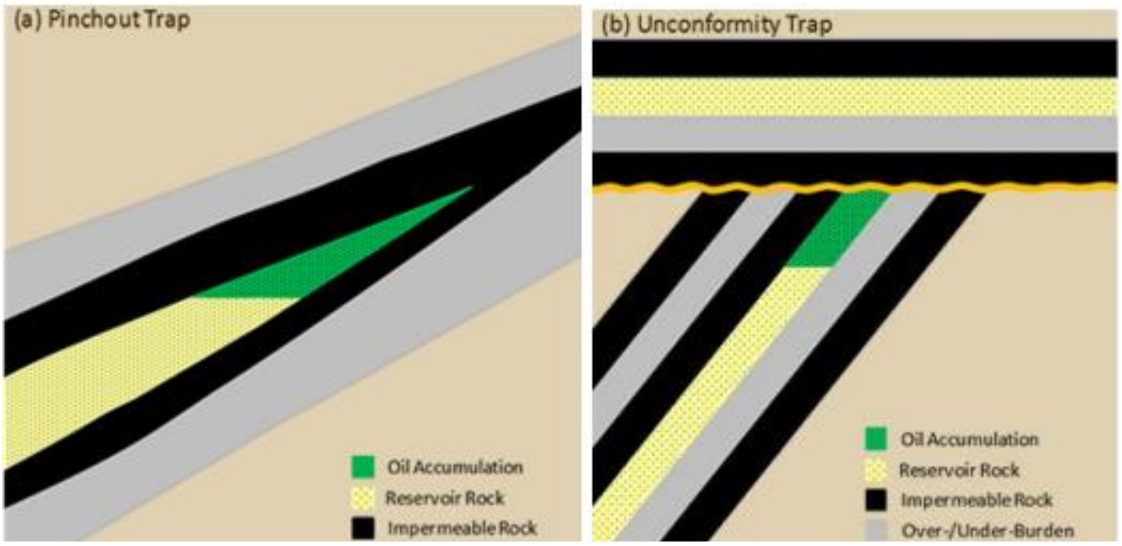


Figure 2.4: Stratigraphic Traps Resulting in Crude Oil and Natural Gas Accumulations of (a) Pinchout Trap and, (b) Unconformity Trap
[Source:Pennsylvania State University, 2020]

Pinchout Trap

A pinchout trap is formed due to the relative rise and fall of a water body in relation to the local land mass. A relative rise or fall may be due to either a true rise or fall of the sea level, or a subsidence or uplift of the land mass. Figure 2.4 (a) represents the crude oil reservoir by the green area encased in the black, impermeable layer. The size and weight of the sediments that form sedimentary rocks deposited in water are dependent on the energy of the water suspending the particles.

Coarse materials can only be suspended in a high energy environment, near the shore where water and tidal action keep these materials mixed with water. Finer sediments can be suspended in a low energy environment away from the shore in more calm waters and, consequently are deposited further from shoreline.

As the relative position of the sea level changes over the geologic time scale, the positions of the coarser and finer sediments change. The coarser materials with the larger pore spaces between the sediment grains often make good quality rock, while the finer materials, particularly clays and silts, with smaller pore spaces make good impermeable seals (cap rocks). Under the proper sequence of events, as the geographical locations of the sediments change over the geologic time scale, the changes in the size of the sediments can create pinchout, or stratigraphic traps.

Unconformity Trap

A geological unconformity is a boundary between two rock sequences of different ages that are missing some transitory rock over intermediate ages. The depositional history of an unconformity trap is slightly more complicated than that of a pinchout trap. In this trap system, an early depositional period caused sedimentary rocks to be deposited horizontally. These rocks were then tilted due to local tectonic forces and formed the lower tilted layers as in Figure 2.4 (b). The higher, uplifted portions of the tilted layers were then eroded over geological time. The orange wavy line represents an unconformity surface where rocks are missing from the geological record.

Geologists recognize these unconformity surfaces when they see rocks of one age sitting on top of rocks of a different age with no intermediary age rocks between them. In contrast, palaeontologists recognize unconformities by rocks containing fossils from one age sitting directly on top of rocks containing fossils from a different, much older age. After subsidence, a second depositional period occurs where additional sedimentary rocks are again deposited horizontally over the erosional surface.

In order for an unconformity trap to develop, the first layer deposited during the second depositional period must be an impermeable rock which can act as the cap rock for the reservoir. After the second depositional period, the trap can be charged with crude oil to form the oil reservoir - the green area of the figure. The horizontal yellow layer representing good quality reservoir rock above the unconformity surface, does not contain crude oil or natural gas. This is because it is missing a trapping mechanism at this location.

These histories illustrate the critical nature of the timing in the development of hydrocarbon reservoirs. For a hydrocarbon reservoir to develop, all five elements of the reservoir system must be in place prior to the formation and migration of the hydrocarbons. If one element is missing from the system, then a crude oil or natural gas reservoir cannot develop.

Structural Traps

The second category of hydrocarbon reservoir trap is structural trap, illustrated in Figure 2.4. Structural traps related to mechanical deformations and failures of the reservoir rock. Figure 2.5 (a) shows an anticlinal structure, or anticline which is statistically the most common reservoir trap. This anticlinal trap simply requires the reservoir rock and cap rock be folded in a manner that can trap the lighter hydrocarbons.

Figure 2.5 (b) shows fault traps. A fault trap is created when a rock formation undergoes mechanical failures during an earthquake and the resulting fault causes a porous and permeable rock formation (reservoir rock) to be positioned adjacent to an impermeable rock formation. Thus, closure to the trap is formed by the cross-fault impermeable layer.

Figure 2.5 (c) shows traps along a salt dome. These traps are common in areas where salt formations exist, such as in the Gulf of Mexico. Since large volumes of salt behave in a plastic manner over geologic time, the weight of the overburden creates great pressures within the salt causing it to flow through any local weak spots in the overburden. These salt intrusions can create hydrocarbon traps above and to the flanks of the intrusion called Salt Dome Traps.

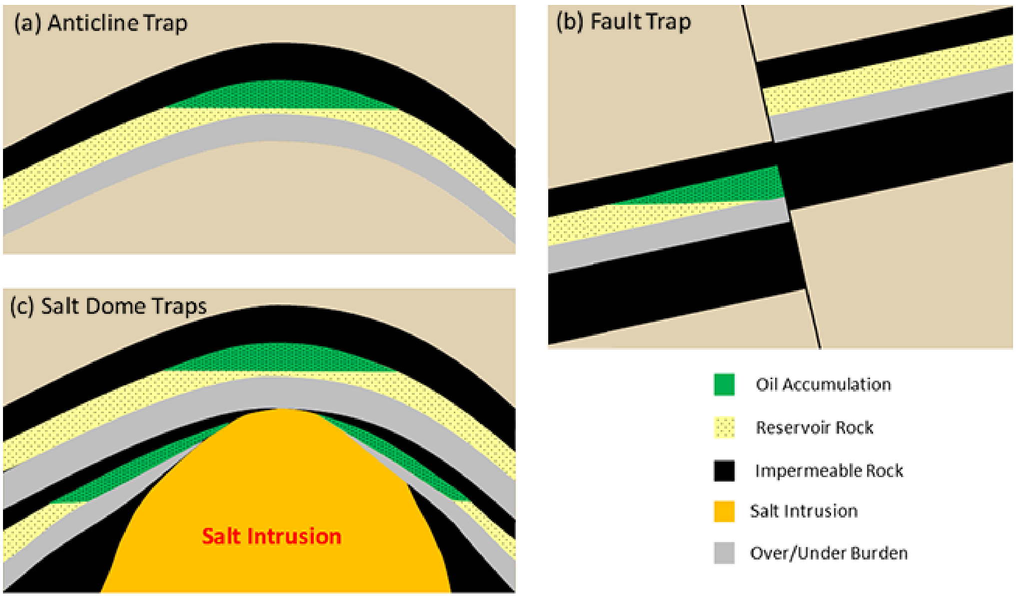


Figure 2.5: Structural Traps Resulting in Crude Oil and Natural Gas Accumulation
[Source:Pennsylvania State University, 2020]

2.1.4 Reservoir drive mechanisms

In nature, as gases and liquid, crude oil in the reservoir flows from the location of high (internal reservoir) to a low pressure (production well). This pressure differential is driving the fluid flow and production from wells. Drive mechanisms are the physical phenomena that occur in the reservoir that help to keep the reservoir pressures high. Reservoir drive mechanism is natural forces in the reservoir that displace hydrocarbons out of the reservoir into the wellbore and up to surface. It is also called natural drives.

Reservoir drive mechanisms include gas drive (gas cap or solution gas drive), water drive (bottom water drive or edge water drive), combination drive, and gravity drainage. Water drive is the most efficient drive mechanism, followed by gas drive and gravity drainage.

Primary Production

The reservoir drive mechanism supplies the energy that moves the hydrocarbon located in a reservoir container toward the wellbore as fluid is removed near the wellbore. There are five drive mechanisms that are associated with the Primary Production. Primary Production occurs without any pressure maintenance supplied by fluid injection or by use of chemical, miscible, or thermal enhanced recovery methods during production of a crude oil from reservoirs.

During primary recovery the natural energy of the reservoir is used to transport hydrocarbons towards and out of the production wells. There are several different energy sources, and each gives rise to a drive mechanism. It is determined by analysis of production data such as reservoir pressure and fluid production ratios.

Possible determination of the drive mechanism is a primary goal in the early life of the reservoir, as its knowledge can greatly improve the management and recovery of reserves from the reservoir in its middle and later life. There are five important drive mechanisms (or combinations).

These are:

a. Solution gas drive

b. Gas cap drive

c. Water drive

d. Gravity drainage

e. Combination or mixed drive

One type usually dominates, but drive types can occur in combination. Depending on the drive mechanism, characteristic recovery efficiencies can be expected for a given reservoir

Solution Gas Drive

Solution gas drive is caused by the solubility of natural gases in crude oils. As wells are drilled and put into production, the reservoir pressure declines (but supported by rock and fluid expansion) until it reaches the bubble-point pressure. At this time, gas comes out of solution and also begins to expand. It is the expansion of the gas that was originally in solution in the oil phase that we refer to as solution gas drive. Typically, solution gas drive accounts for between **15 – 20 percent recoveries** of the Stock Tank Original Oil in Place (STOOIP) in normal oil reservoirs. An analogy that we can use for solution gas drive is a bottle full of a carbonated beverage. Figure 2.6 illustrates the solution gas drive reservoirs.

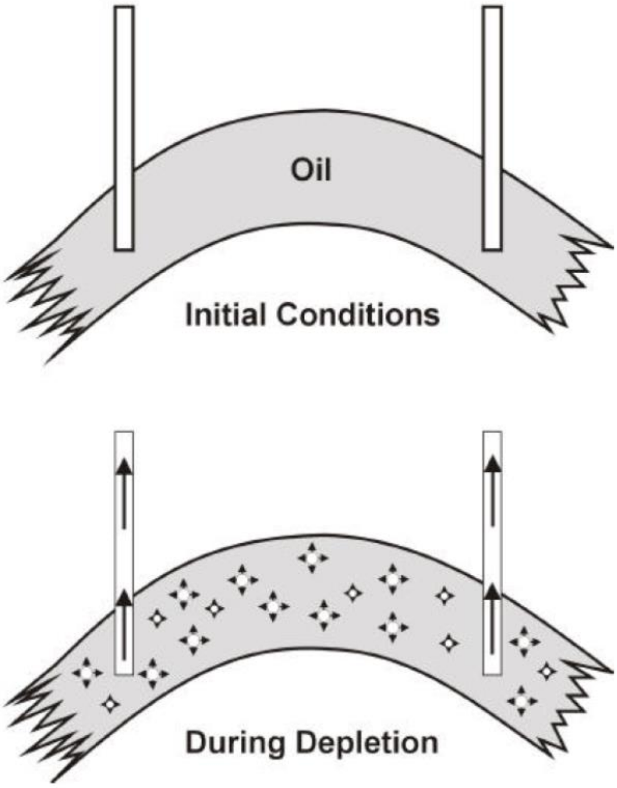


Figure 2.6: Solution Gas Drive

Gas Cap Drive

Gas cap drive is similar to solution gas drive; however, it only occurs in saturated oil reservoirs (oil reservoirs discovered below the bubble-point pressure of the crude oil). In saturated oil reservoirs, the free gas forms a Gas Cap (portion of the reservoir overlain by free gas due to gravity segregation). As wells are drilled and put into production, the pressure declines (again, other drive mechanisms may provide support to partially maintain the reservoir pressure), and the gas cap begins to expand. It is the expansion of the gas that was originally free in the reservoir that we refer to as gas cap drive. Gas cap drive can account for up to 30 percent recovery of the STOOIP depending on the size of the original gas cap. Figure 2.7 illustrates the gas cap drive reservoir.

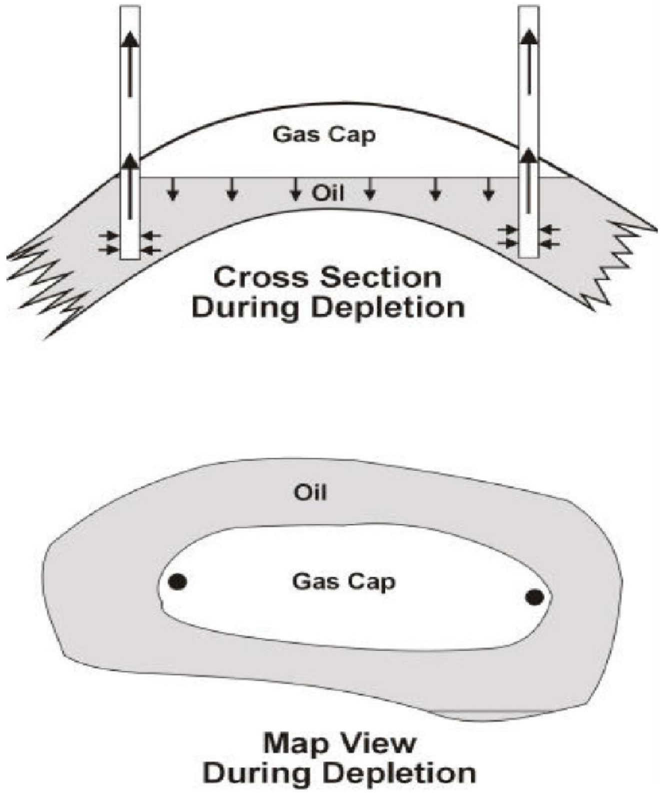


Figure 2.7: Gas Cap drive

Please note that during pressure decline, gas will also come out of solution. The expansion of this liberated gas is still referred to as solution gas drive. Thus, in this situation, we would have combined drives occurring simultaneously in the reservoir including gas cap drive and solution gas drive, and, to a lesser extent, rock and fluid expansion.

Water Drive

If a reservoir is in contact with a water-bearing aquifer, then as the reservoir pressure declines, the rock and water in the aquifer expand and water is expelled from the aquifer and into the reservoir. This encroachment of water into the reservoir provides pressure support and helps to displace oil from the regions of the reservoir in contact with the aquifer to production wells. Aquifer drive may account for 35 – 45 percent recovery of the STOOIP depending on the size of the aquifer. Figure 2.8 illustrates the water drive reservoir.

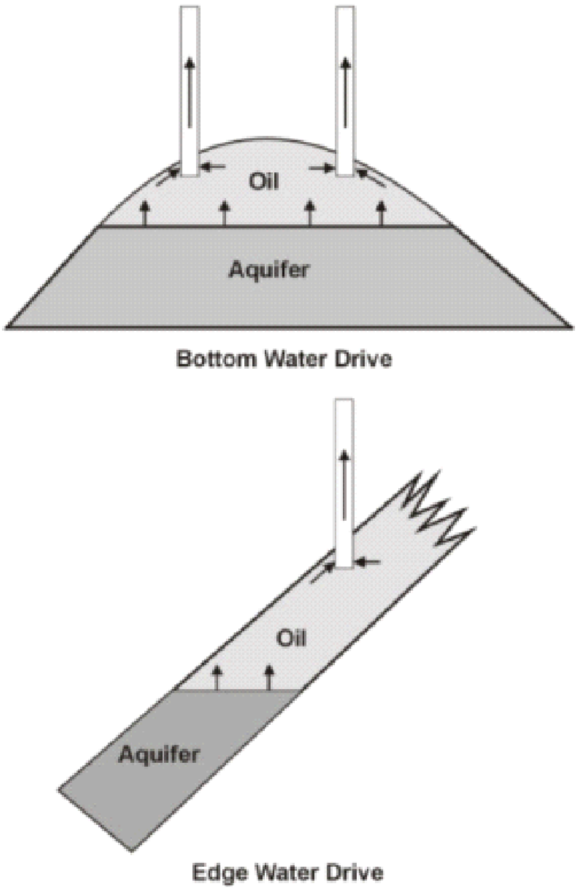


Figure 2.8: Water Drive

Gravity Drainage

Gravity drainage is another drive mechanism that can occur in both saturated and under-saturated oil reservoirs. In very thick reservoirs or in highly dipping reservoirs, gravity drainage can be a very effective drive mechanism and may account for up to 40 percent recovery of the STOOIP. In order to be effective, wells must be completed deep in the reservoir and must have a large Oil Column (reservoir depth containing oil) above the completion. Figure 2.9 illustrates the gravity drainage drive reservoir.

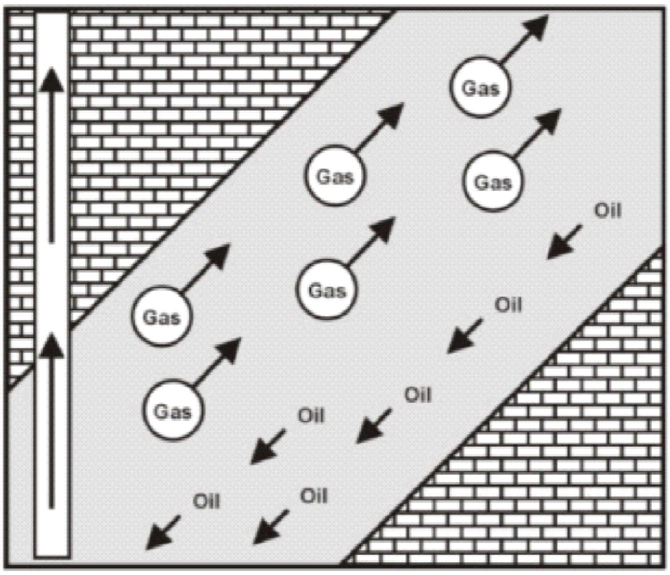


Figure 2.9: Gravity Drainage

Combination or Mixed Drive

In practice a reservoir usually incorporates at least two main drive mechanisms. We have seen that the management of the reservoir for different drive mechanisms can be diametrically opposed (e.g. low perforation for gas cap reservoirs compared with high perforation for water drive reservoirs). If both occur as in Figure 2.10, a compromise must be sought, and this compromise must take into account the strength of each drive present, the size of the gas cap, and the size/permeability of the aquifer. Figure 2.10 illustrates the combination or mixed drive reservoir.

It is the job of the reservoir manager to identify the strengths of the drives as early as possible in the life of the reservoir to optimize the reservoir performance.

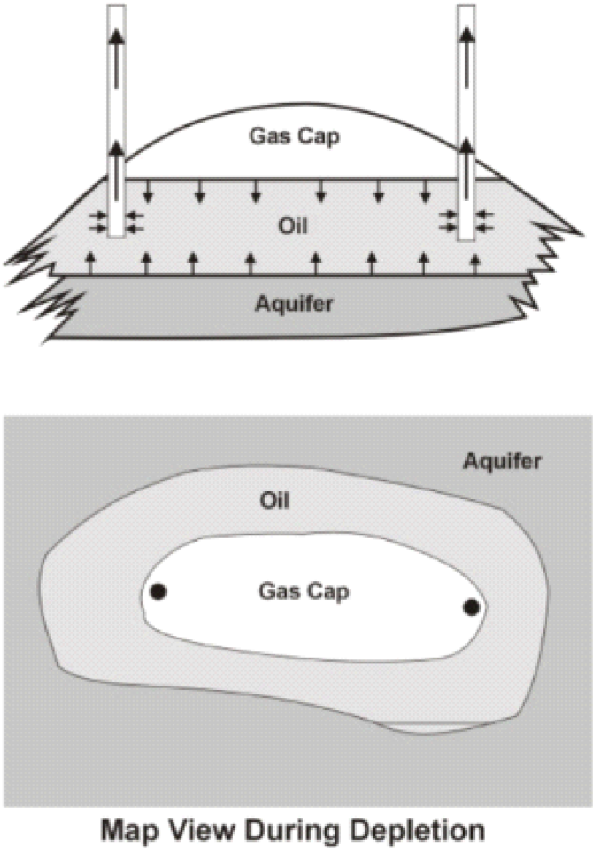


Figure 2.10: Mixed Drive Reservoir

All these drive mechanisms commonly act simultaneously. When this occurs, we refer to the reservoir as a reservoir undergoing combined drive. Table 2.0 shows the drive mechanisms typically found in crude oil reservoirs and the maximum Recovery Factors (percentage of STOOIP recovered) typically observed in the field.

Table 2.0: Recovery Ranges for Each Drive Mechanism

Drive mechanism	Energy sources	Recovery %
Solution gas drive Evolved gas Gas expansion	Evolved solution gas and expansion	20-30 18-25 2-5
Gas cap drive	Gas cap expansion	20-40
Water drive Bottom Edge	Aquifer expansion	20-60 20-40 35-60
Gravity drainage	Gravity	50-70

2.2 Introduction to Drilling Operation

Once a promising geological structure is identified by seismic and advanced 3D visualization techniques, exploration, or commonly known as wildcats are planned. The only way to to confirm the presence of hydrocarbon and the thickness and the internal pressure of reservoir is to drill the land-based.

The term drilling describes the whole complex of operation necessary to construct wells of circular section applying digging techniques. Before drilling it is necessary to carry out simultaneously the following action during drilling process;

- to overcome the resistance of the rock, crushing it into small particles measuring just a few mm;
- to remove the rock particles, while still acting on fresh material;
- to maintain the stability of the walls of the hole;
- to prevent the fluids contained in the drilled formations from entering the well.

Therefore, on the land-based, rig and self-contained drilling rig modules for both hydrocarbon exploration and production are assembled (Figure 2.11). Specification of hole and casing size and the final depth are requirements of the drilling rig. Figure 2.11 shows the drilling equipment of Rig.

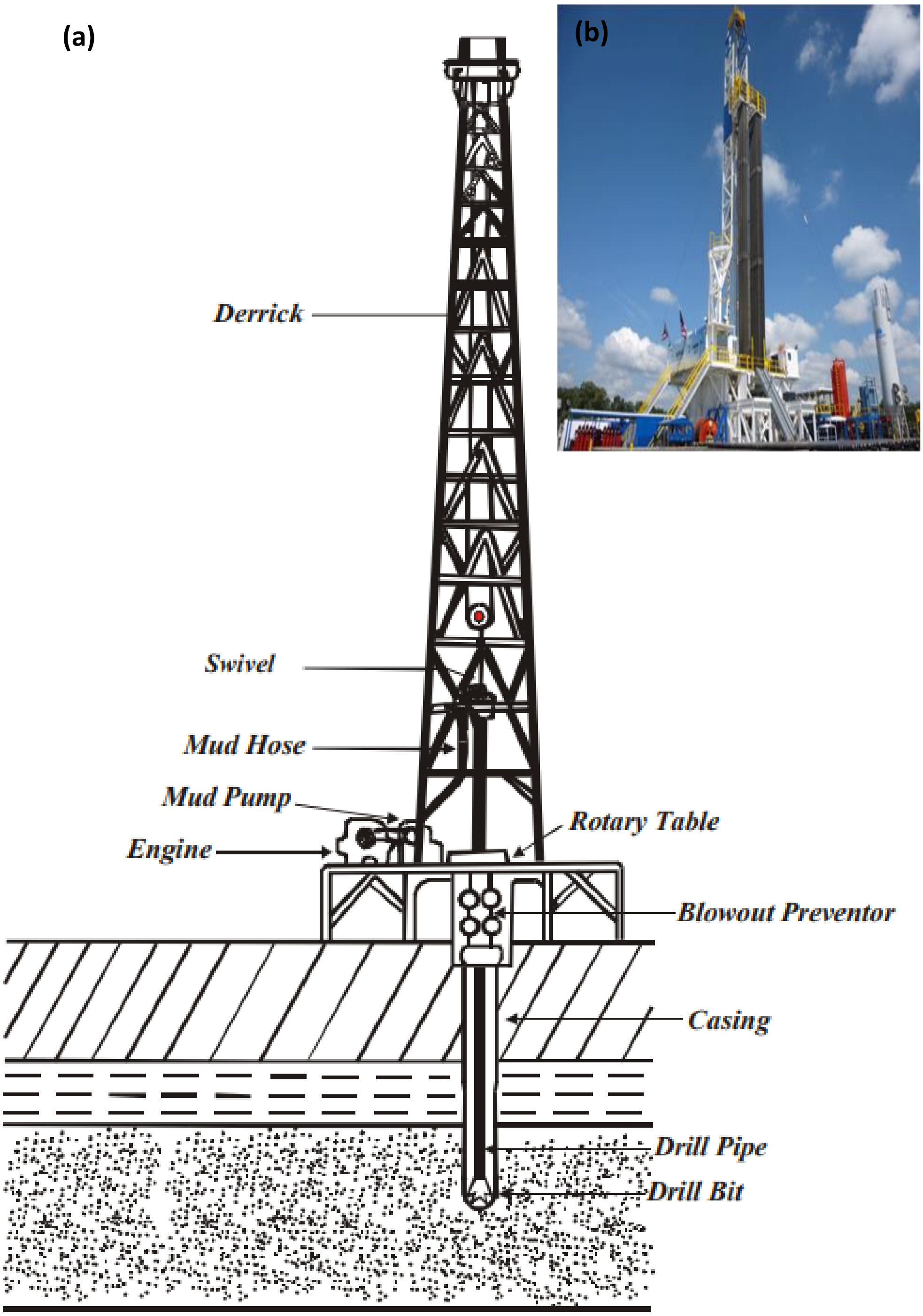


Figure 2.11: Drilling Operation (a) Sections of Drilling Rig (b) Land Drilling Rig Module
[Source: Srintel, 2021]

Basic drilling operation

The drilling rigs are mobile and complex equipment which can be moved from one drill site to another (onshore and offshore), drilling a series of wells. In rotary drilling the rock is bored using a cutting tool called the bit, which is rotated and simultaneously forced against the rock at the bottom of the hole by a drill string consisting of hollow steel pipes of circular section and screwed together. The cuttings produced by the bit are transported up to the surface by a drilling fluid, usually a liquid (mud or water), or else a gas or foam, circulated in the pipes down to the bit and thence to the surface.

The rotation is transmitted to the bit from the surface by a device called the rotary table or, in the modern rigs, by a top drive motor with the rotary table as backup; additional rotation can be added by down-hole motors located directly above the bit. After having drilled a certain length of hole, in order to guarantee its stability it has to be cased with steel pipes, called casings, joined together by threaded sleeves. The space between the casing and the hole is then filled with cement slurry to ensure a hydraulic and mechanical seal.

The final depth of the well is accomplished by drilling holes of decreasing diameter, successively protected by casings, likewise of decreasing diameter, producing a structure made up of concentric tubular elements.

Basic of drilling equipment

Rotary drilling equipment currently consists of five main systems. This equipment is a main requirement of an oil rig as shown in Figure. Five systems are:

a. System Lifter
b. Rotating System
c. Circulating System

d. Explosion prevention system

e. Power System

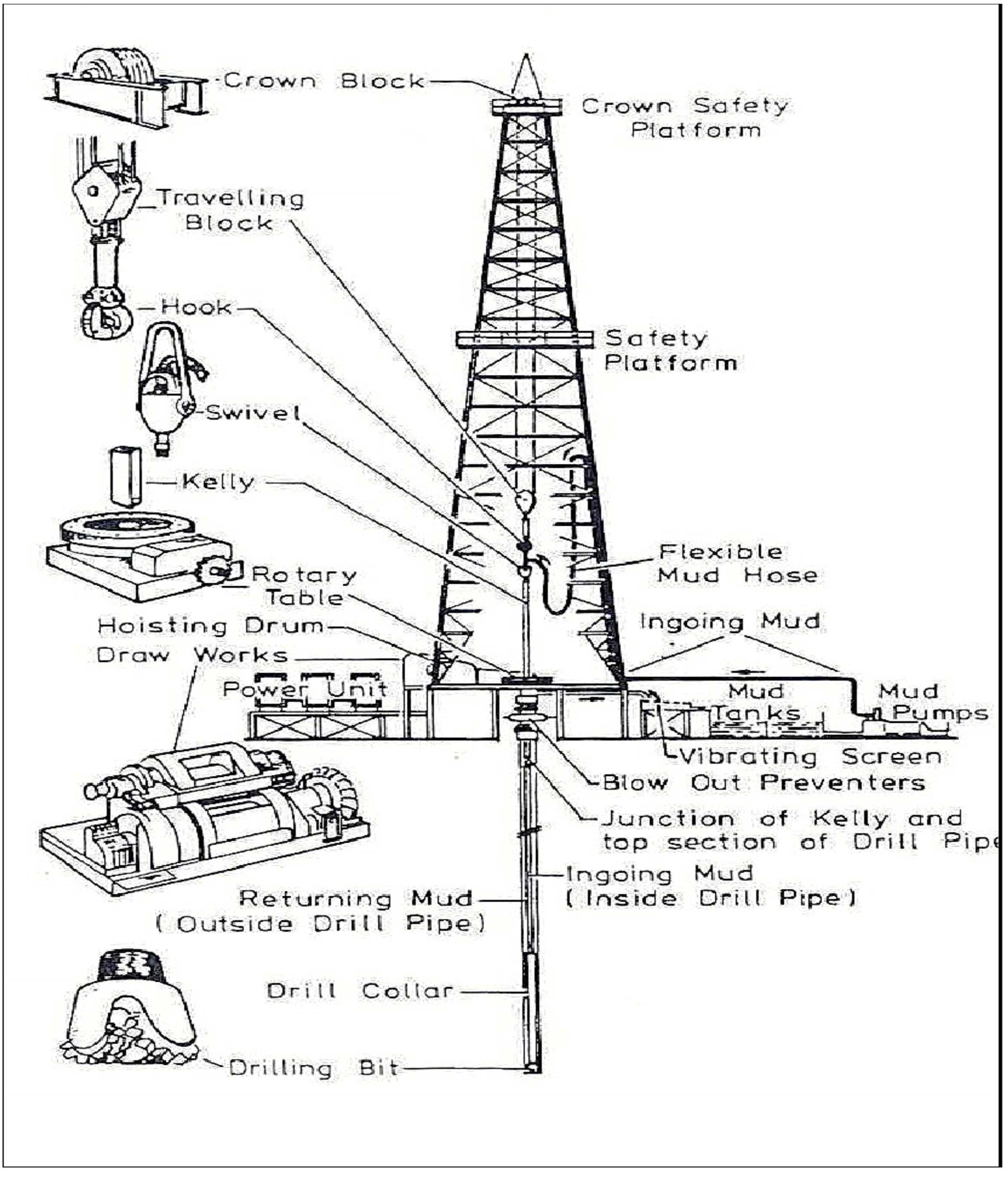


Figure 2.12: Basic Drilling Equipment (INTI, INSTEP)

A. System Lifter

This system is responsible for supporting the rotating system in borehole drilling operations by providing ideal equipment for lifting, lowering and suspend rotating system which is very large. It consists of two main components:

i. Supporting Structure

ii. Lifter Equipment

Supporting Structure

Consists of a supporting frame drilling equipment such as tower blocks, drill string and others. Figure 2.13 shows the main parts of System Lifter. Its main components are substructure, rig floor and drilling tower.

i. Substructure

A large metal frame mounted on the drill. It has space for equipment and workers between rig floors.

ii. Rig Floor

Platform floor provides an area for drilling work. It is also a closed area at each stage of the framework.

iii. Drilling Tower

Providing a metal frame to support the lifting system. It consists of Mast and derricks. Mast usually found in prefabricated condition while the derrick is usually installed one by one in the drilling area. Derick and mast able to withstand a vertical load of 0.25 million pounds to 1.5 million pounds. It is also able to withstand wind speeds of 100 to 130 mph sederas.

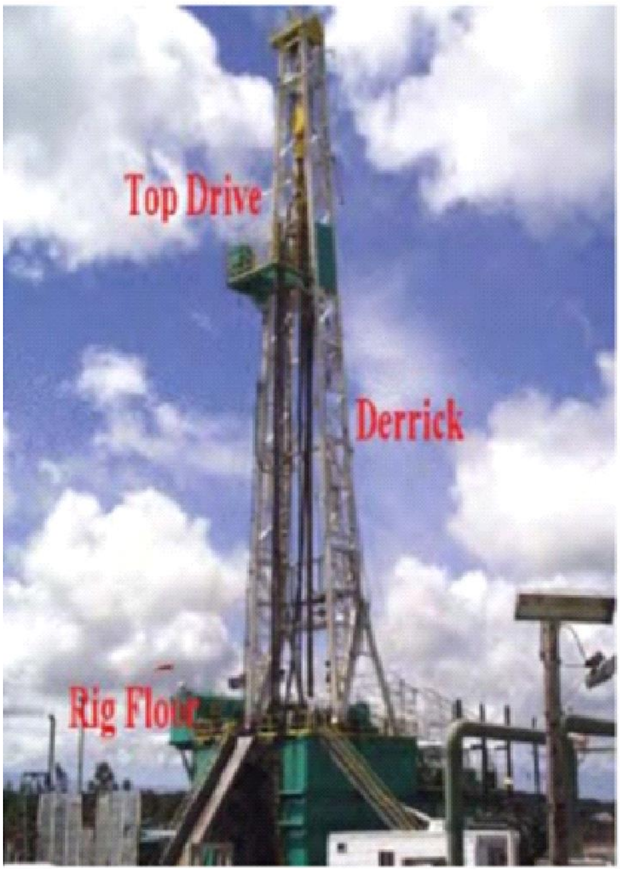


Figure 2.13: Part of Supporting Structure of System Lifter

Lifter Equipment

i. Drawwork

Act like a "winch" that acts upward and downward a big rod and heavy drill during drilling operations. It’s close to the rotary table on the platform floor.

ii. Upper equipment

Where it joins a chain bracelet in a conveying system. It consists of the crown block, traveling block, hook and elevators. It works just like a pulley system where he raised and lowered the heavy pipe and casing.

iii. Drilling Cable

It is strong cable and high quality in which they join all components in the lifting system.

B. Rotating system

Rotating system is a system that is important in oil well drilling operations. This system serves to rotate the drill string and allow drill bit or bits drilling a hole from the surface until it penetrates the potential areas in the earth layer.

The system is divided into three main components, namely:

i. Rotor,

ii. Drill stem and

iii. Bit.

Rotor

Components of this system lies in the middle of the floor platform. It consists of the main bushing (bushing master), kelly bushing, rotary table, slip screwdriver, and rotary table

i. Main Bushing

ii. Kelly Bushing

iii. Rotary Table

iv. Slip Screwdriver

v. Rotary Slip

Main Bushings

Bushings can be installed and removed easily on the rotary table. When attached to the Kelly bushing, it will rotate the drill stem and when the rotor slip attached to it, it will suspend the drill string while adding or removing parts of the drill.

Kelly Bushings

It is a device that is connected to the main bushing that allows Kelly moved down during the drilling progress.

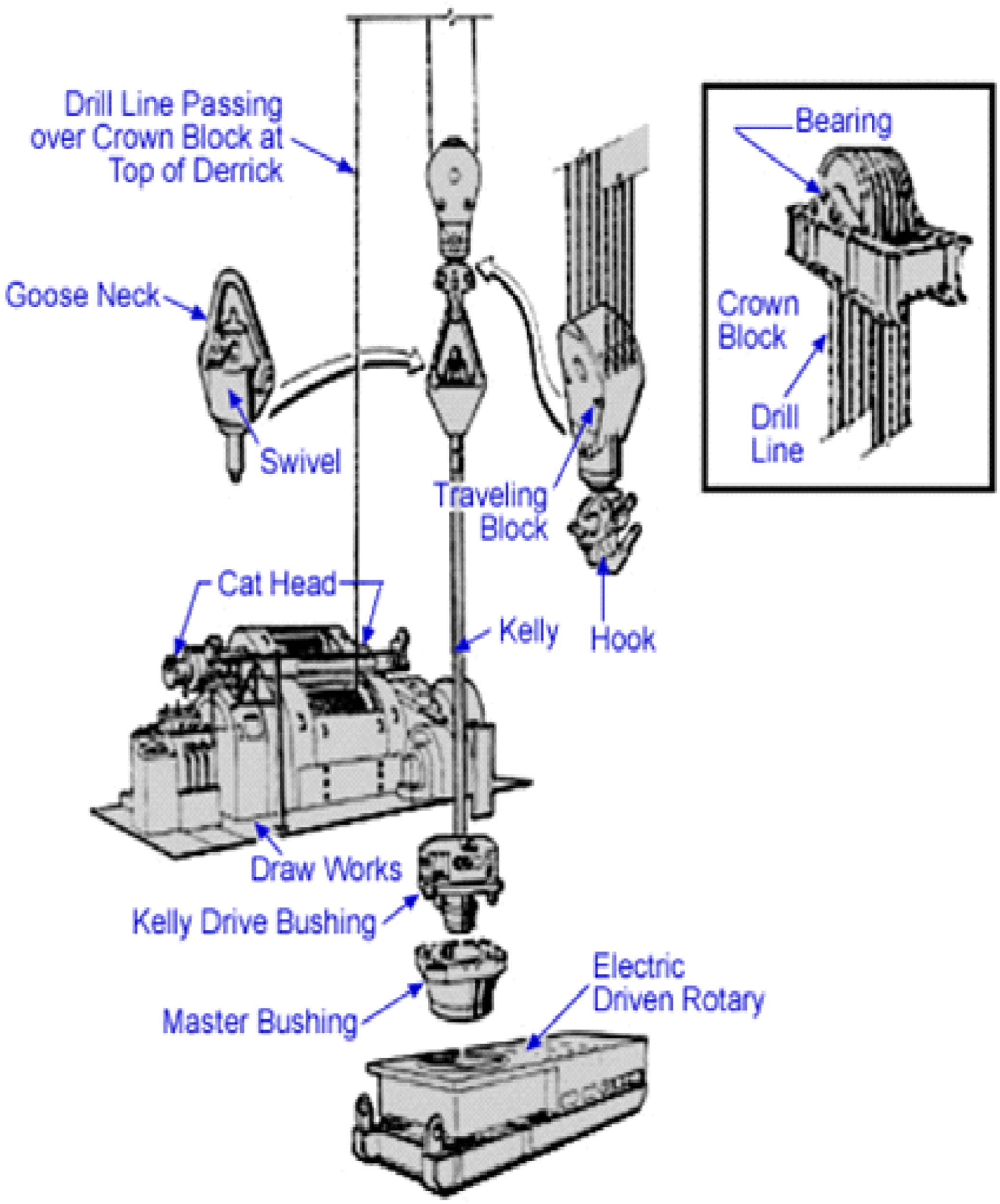


Figure 2.14: Lifting Equipment

Rotary Table

It one ada1ah rough device and is a very strong player device that is placed in the floor of the platform (rig floor). Its location is right under the crown block. Used with master bushing and other equipment. It transfers the rotational motion to suspend the drill stem or drill holes.

Slip Screwdriver

Consists of grabbing tool set (gripping) tapered metal placed in the master bushing around the drill and is used to suspend the drill string in the hole when the connection is made or broken drill stem.

Rotary Slip

Consists of gripping tool set tapered metal placed in the master bushing surround the drill and is used to suspend the drill string in the hole when the connection is made or broken drill stem.

Drill Stem

It hangs and elongated from hooks to the rotary table and it acts as a connecting chain between the rotary at the top of the wellholes. It may consist of:

i. Swivel
ii. Kelly,
iii. Drill pipe joints
iv. Drill collars.

Swivel

It suspended by a hook on the traveling block (traveling block) installed on the top of kelly valve and it fully supports the weight of the drill string during rotation. Swivel located at the top of the drill and allow the kelly and the drill to freely rotate during drilling operations occur. It also provides a connection to the mud enters through a hose cuff and also as a way for drilling fluid (mud) flows down the kelly and to stem below. It is half-coil shaped and situated at the top of swivel.

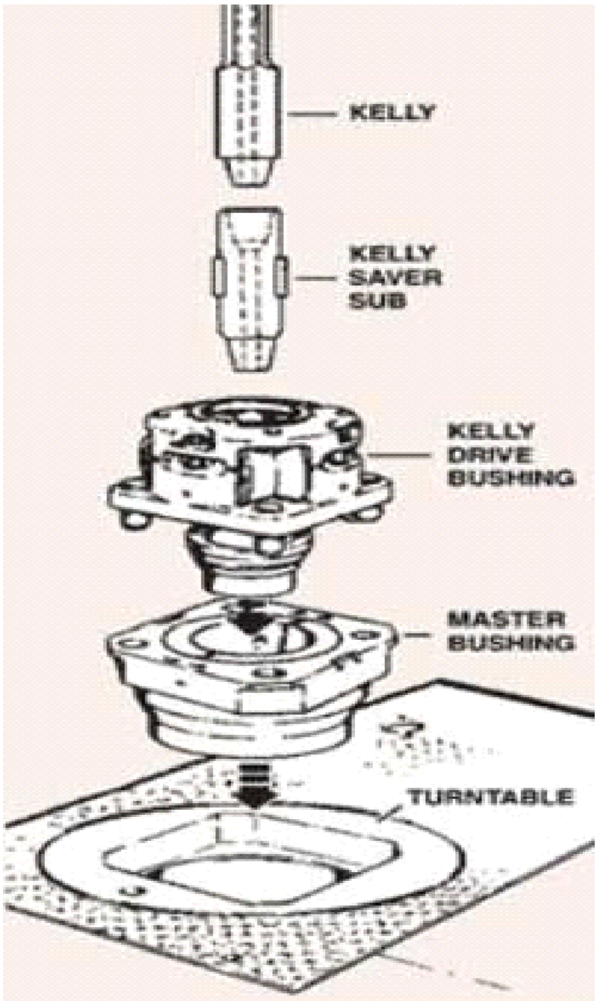


Figure 2.15: Rotating System

Kelly

Is a heavy metal rod pipe and it hangs on the swivel through the rotary table and directly connected to the drill string. It is available in the form of squares, rectangles and hexagons. It transfers the rotation of the kelly bushing and rotate the drill stem. Kelly is the longest part and can be found in various sizes (40 ', 43', 46 'and 56' long). 1a is longer than a connection of a single pipe (30 ').

Drill Pipe

Is a large hollow tube stick to "tool joint". It is located in the top and middle of the drill. This pipe is used to extend the drill stem and acting as a connector for the collar and bits. Drill pipe is available in 4, 4 ½ and 5 inches. But normal size is 4 ½ inches. The pipe length is usually 30 feet (9 meters) to the weight of 226 kg.

Drilled collar

It is thick, tubular and made of heavy steel. It is located at the lower end of the drill string to maintain a constant weight on bit. The length is 30 'and the outside diameter is 7 ". Drill collars usually weigh 2 tons or more.

Bit

A device that is located under the drill string where it works to cut or dig up the wellbore during the drilling process. All bits have a gateway or nozzle to allow drilling fluid out of it. Common bit size is 17 ½, 12 ¼, 7 7/8 and 6 ¼, There are different types of bits:

1. Roller-Cone or Rock Bits - Cone shaped and cut the layer of hard earth.
2. Strata Bits - Bits that can be used to cut the soft and medium strongly layer of the earth such as sandstone or limestone.
3. Diamonds Bits - No cone-shaped or serration. Instead diamond installed on the side and in bits. It is used to drill the hard layer.

4. Core Bit - Is a special type of diamond bits. Used to take a core sample (core sample) for the purpose of analysis.

Figure 2.16: Type of Drilling Tool Bits

Drilling Process

Drilling process begins by providing a drilling network consisting of kelly connected with swivel at the top and at the bottom of the drill pipe. Drill pipe is connected more with the drill collar and ends with a drill bit as seen in Figure 2.17). Once the connection is completed, extended drill string is paired with kelly bushing and master bushing and put in a rotary table. When the rotary table is turned on, the drilling began. At the same time, the mud pump was turned on to run the circulating system. Drilling or mud is continuously circulated down the drill pipe and back to the surface equipment. It purposes to balance the underground hydrostatic pressure, cool the bit and flush out the rock cuttings. The risk of an uncontrolled flow from reservoir to the surface is greatly reduced by using blowout preventers- a series of hydraulic actuated steel rams that close quickly around the drill string or casing to seal off a well.

Drilling will be stopped for a moment when the depth reaches 30 feet. This is because the extended pipe must be added with a further drill pipe to continue drilling as deep as 30 feet. The addition of this drill pipe by pulling out the extended drill, then kelly opened and a further drill pipe installed. After that, Kelly was reassembled and drilling continued to a depth of 30 feet. This process continues until it reaches a predetermined depth.

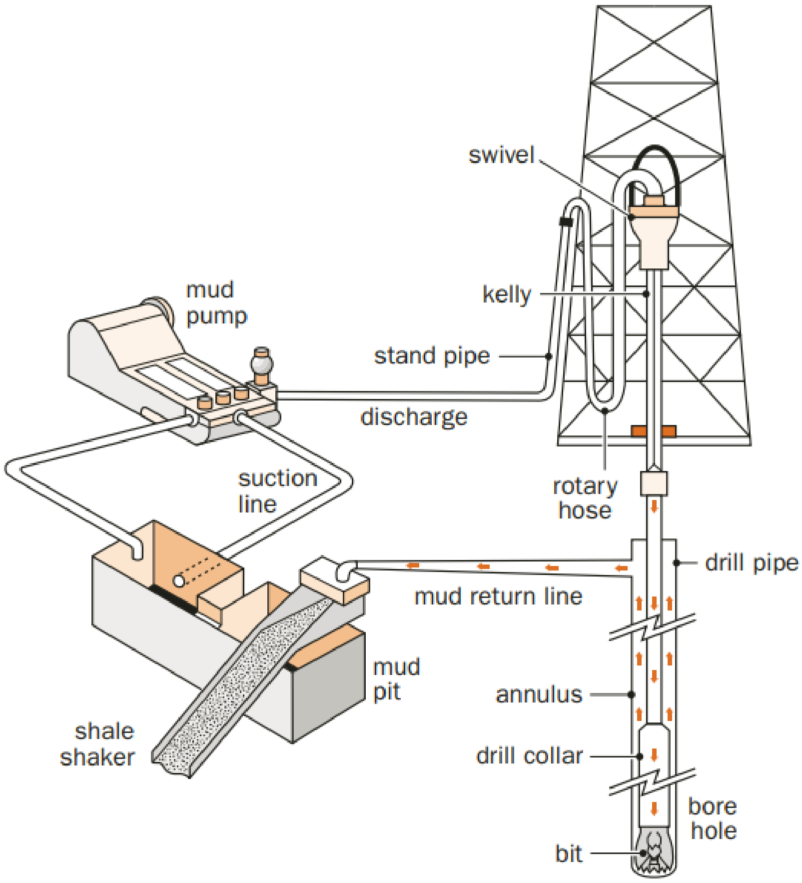


Figure 2.17: Circulation System of Drilling Mud

Mud circulation system

This system is important because it provides support for the rotation system. In this system, the drilling fluid is the most important material and known as mud. Usually mud will be pumped into the hole through a series of pipes, flow out on the bit at the end of the pipe at the bottom of the well and return to the surface. This mud is a mixture of various components such as water, viscous oil, and heavy additives and so on. Figure 2.17 shows the circulation path of drilling mud. Once the drilling is commences, mud is pumped from the mud pit tank through a hose and swivel and down through the drill string. It then passes through the drill bit and starts to move upward through annulus, carrying rock cuttings with it. Back at surface, it travels through a hose and shale shaker which removes the rock cuttings and ends up back in the mud pit (Alphonsus, 1991).

Types of Mud

1. Water-based mud
2. Oil-based mud
3. Gas-based mud.

Mud Movement

High pressure pumps suck mud from the mud storage tank or mud pit as in Figure 2.17, and it is pumped into the stand pipe through a rotary hose, swivel and then down to the kelly and drill string. Mud flow out through the nozzle founded in bit and brings up drilling cuttings through the annulus. Almost at the surface, the mud flow out through return line mud to shale shakes. Here cuttings separated from the mud and clean mud of debris re-enters the mud pit. Refer to Figure 2.17 in mud circulation system during drilling process.

Mud Function

1. Clean and remove cuttings - cuttings or debris in the borehole drilling and lift the cuttings on.
2. Smoothing and cool the bit and drill string during the drilling process conducted
3. Keep cuttings - cuttings in suspension when circulation system halted
4. Support, patching, covering walls with producing wells from collapsing mud cake.
5. Prevent premature explosion or oil injection, gas and water below as the density weight mud is higher than the formation pressure.

Casing, Tubing and Cementing Installation Process

Every well has its own specific features (depth, exploratory, development or appraisal well, onshore or offshore, vertical, directional or horizontal) but the basic criteria are the same for all well types.
The first step to be taken by engineers to work out the drilling programed is to construct, the trend of the pressure gradient curves according to depth (geostatic, pore pressure and fracture gradients) to design the well casing profile.

The casing levels, the diameters and weight of the strings, the pressures and temperatures concerned, and the volumes of drilling mud to be used, are all aspects participating in determining the choice of rig type, blowout prevention systems (BOP, choke manifold, hydraulic circuit) and wellheads).

The choice of rig is closely bound up with the depth it is wished to reach and with the weight of the strings concerned. According to the weights of the strings to be handled, rigs are used that have different characteristics, and what is of basic importance is the strength of the whole assembly, (travelling block, crown block, hook and derrick floor) from which the string hangs while being lowered into the well.

Casing Installation

Although the drilling mud help prevent the wellbore from caving in and does help to seal off porous formations that have been drilled, a more reliable method to accomplish this is to case the well. Casing the well involves lining the borehole with steel pipe (Figure 2.18) and cementing it in place.

To install the casing, a first step is pull the drill string out of the hole. The drill string, of course cannot be remove one piece. Every third join in the drill string will be unscrewed and the stands of pipe will be stack against the derrick. When all the drill string and bit have been removed, the casing is lowered into mud-filled hole by screwing together 12 meter lengths of casing pipe end to end. The casing is slightly smaller in diameter than the borehole and is secured in place by pumping cement into an annular space between the outside of the casing borehole. When the cement sets, the drilling will continue using slightly smaller bit than before. As well as it deepened, additional casings of concentrically smaller diameters are added to seal off the deeper formations.

Casing is placed in the wellbore to prevent borehole from collapse and prevent fluid from moving between zones in the wellbore. The casing is cemented in the wellbore to provide structural support and maintain the integrity of borehole as well as isolates underground formation. Well tests are conducted to establish flow rates and formation pressure. This test may generate oil, gas, and formation water that each of those need to disposed of. Blowout Preventer is a broad range of specialized equipment on the working part of drilling rig. At time, mud level in the mud pit would probably start to rise because mud would coming out of hole faster than it being pumped back down the drill pipe, this is called “kick”. Such a kick could lead to a blowout. The driller immediately activate the backup system - Blowout Prevent (BOP). The casing must be strong enough to the BOP.

There are four kinds of casing such as flow casing, surface casing, intermediate casing and production casing. Some equipment used for installing casing in the well bore are :

i. Guide Shoe
ii. Float Collar
iii. centralizer & wall scratchers

Guide Shoe

Guide Shoe is located at the end of the casing network. It is used as a driver at the end of the casing to avoid casing from stuck when lowered into the borehole.

Float Collar

It is located at the top of the guide shoe and functions as the restrictor in the casing to prevent the plug (bottom plug) cements move further down. It also has a check valve (check valve) which seeks to prevent the backflow of cement into the casing.

Centralizer & wall scratchers

Centralizers installed on the casing to ensure that the casing has always been at the center of the hole. It is important to ensure proper distribution of cement around the casing. Wall scratchers was installed around the casing and it acts like a brush for the wall of the well to remove the mud cake formed. It operates due to a rotary casing networking.

Tubing installation

After installation of production casing, task completion insert extended of last pipe called as tubing. Fluid flow from the reservoir into the well surface through the tubing. In contrast to the casing, tubing is not cemented but hanging from the wellhead installed on the surface. The length of the tubing between 20 feet to 34 feet and a diameter of between 1 ½ to 4 ½.

Tubing usage is for production to increase the flow rate because of its smaller diameter than the casing. In addition, the production of oil to the surface can cause a blockage due to flow out of sand. It is easier to replace the tubing from the casing in the event of a blockage.

Packer

Packer is a tool that installed together with tubing to airtight the space between tubing and casing. The packing is a bracelet made from metal and rubber that fits around tubing to provide sealing between the top and bottom from where it is installed. Because of this type of sealing packing, it forces fluid formation and flow in the tubing.

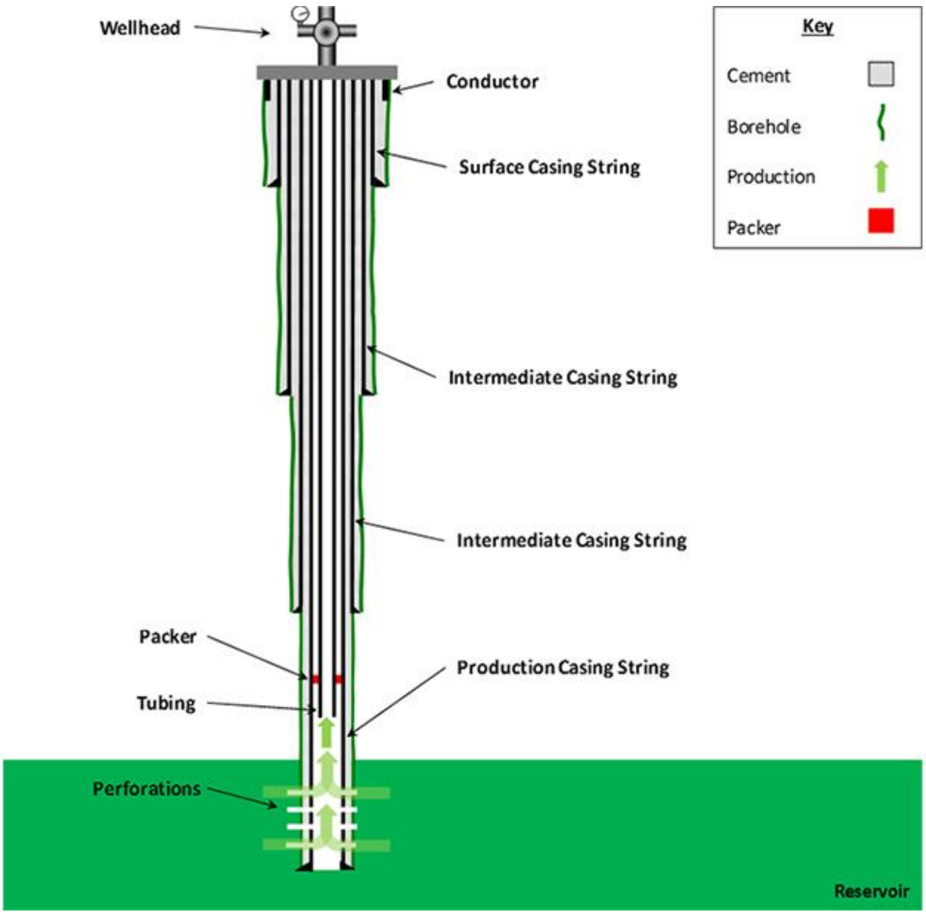


Figure 2.18: Casing Installation

Cementing

Once the casing is inserted into the wellbore using certain equipment, as discussed in the casing installation section, then the next process is the cementing process. An L-shape cementing head is fixed to the top of the wellhead to receive slurry (mud) from the pumps. Two wiper plugs, or cementing plug that sweeps inside the casing and prevent mixing which are bottom plug and top plug. Cement mud is pumped behind it, see Figure 2.19 for the detail installation.

Transfusion of Mud

Usually wells pumped with water to clean the dirt on the wall well to ensure bond between the cement and the well wall is good. Bottom plug with diaphragms on top, first entered into the wellbore before cementing process. The purpose of it is to separate mud and cement.

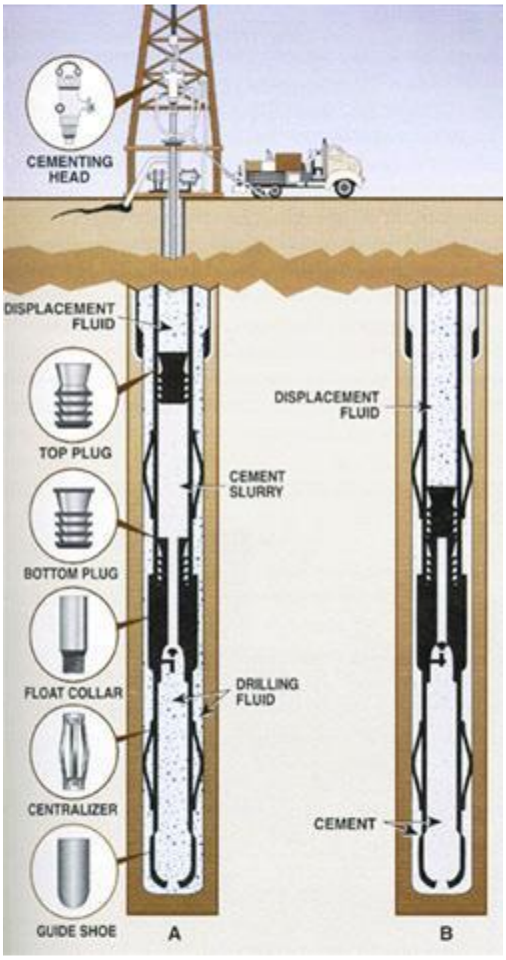


Figure 2.19: Cementing a Well [source MPG Petroleum]

Transfusion of Cement

Once the bottom plug reach float collar, a number of cement should be mixed and pumped into the well. After a number of cement inserted into the hole, then plug (top plug) is inserted into the well. So on the surface of the cement will be closed and it separates the cement and mud at the top. Next, mud will enter into the well. Due to cement and mud pressure, the bottom plug will reach the float collar. Ongoing pumping will break down bottom plug diaphragm. This resulted the cement to flow through the bottom cover directly under the casing and up to the annulus between the casing and the well banks. To enable the top plug going down, then the mud should be pumped into the well.

2.3 Offshore Platform Production Facilities

In offshore platform activity, the choice of the rig is determined, not only by the weight of the strings, but also by the depth of the water in the area of operations. A whole range of structures are used. Common offshore structures are Shallow Water Complex, Gravity Base, Compliant Towers, floating production, and many sea bottom installation with multiphase piping to shore and no offshore topside structure at all.

Drilling rigs installed on offshore vessels or platforms are built to reach the maximum possible depths and have all the material and equipment necessary for drilling on board. Replacing outlying wellhead towers, deviation drilling is used to reach different parts of the reservoir from a few wellhead cluster location. The composition of the wellhead depends on the pressures that can be reached during the various working phases – both drilling and production – and on the diameters of the strings to be lowered into the well.

Pump and Meter Oil Transfer System.

Oil pumping.

Needed to transfer oil to offshore oil storage such as oil storage tankers. If the oil is stored on land (Onshore), then pumping through the pipeline is necessary. Usually pumping is more complex and a large pump required if total production is high.

Meter system

Measurement of the quantity of oil produced by a platform is important in the production management level. This is because crude oil from various platforms may be combined and channelled in a large pipe (single pipe) directly to storage on land. Thus, to determine the quantity of oil produced by each platform so each platform must be equipped with measurement systems.

Power Generating System

The system is designed to generate and distribute primary power needed to run all of the system components and sub-components of the system are present in the complex modern rotary drilling. Main power produced by three or four engines that can supply 1000 to 3000 horsepower. Engines used for power generation is using diesel as fuel.

Well-head installation

Wellhead is the equipment used to determine and control the flow of fluid from flowing. Wellhead in the strength of different sizes, shapes, and it depends on the conditions it works. For example, wellhead consists of a number of resistant equipment made to be able to bear high pressure. Wellhead has a simple design in which it supports the tubing in the well. Wellhead design is a combination of casing head, Casing spools, tubing head, casing/tubing hangers and Christmas tree.

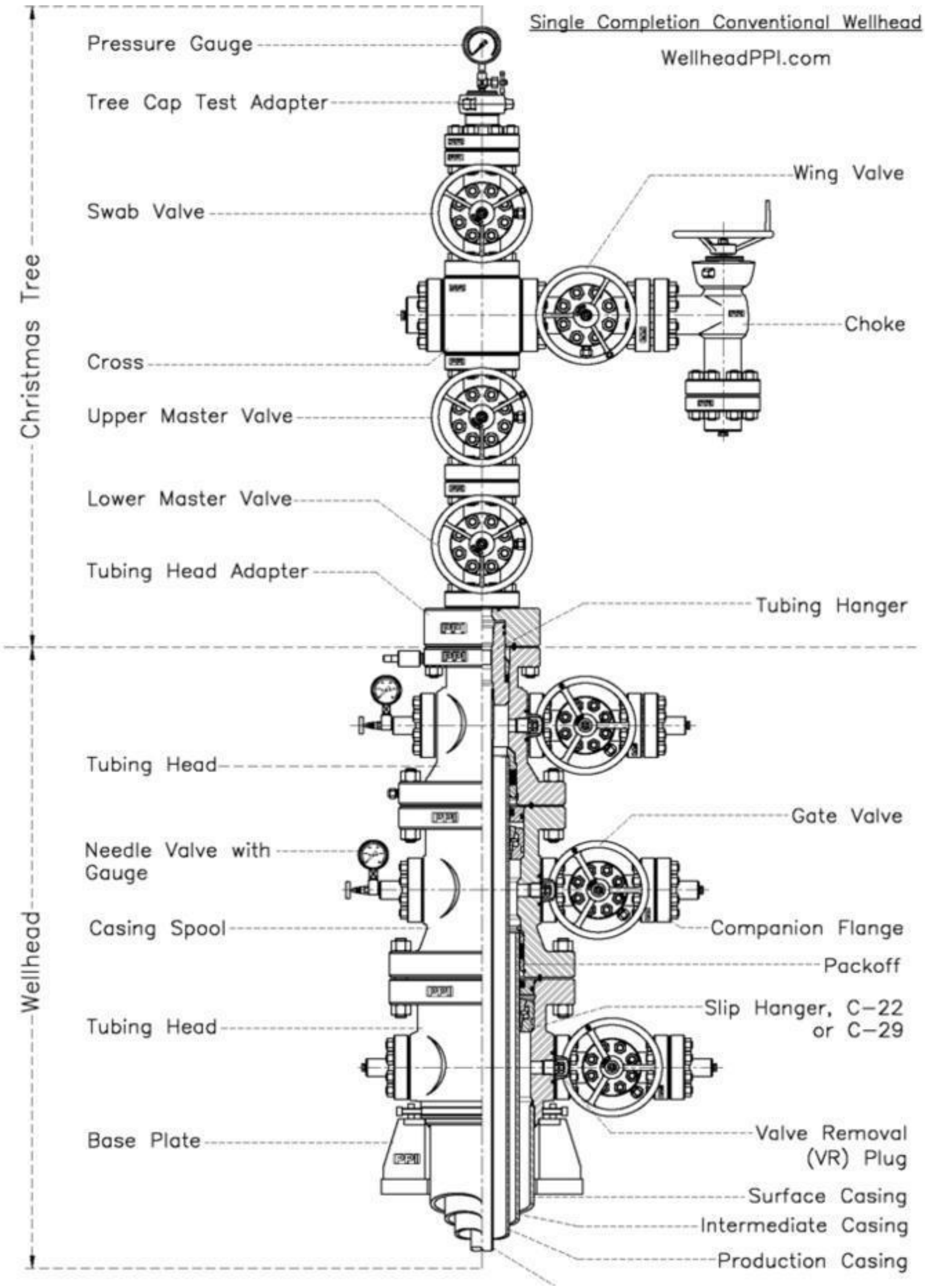


Figure 2.20: Conventional Well Head and Christmas tree
[Sourse: PetroPi Industries Ltd]

Casing head

Consists of several parts and is equipped with a number of casing networks where each casing network installed and cement in the well. It is used for binding or cover the casing. Usually at the head casing there are packer used to prevent fluid flow from the well in the atmosphere. Each head casing also has a place for the pressure gauge which will alert you in the event of a leak.

Tubing Head

The tubing head is always installed on top of the casing head wherever casing head used. Used to support the tube network (Tubing string) also closes the pressure in the casing and tubing annulus. It provides a channel and connected to a particular valve to enable oil or gas flow control.

Christmas Tree

High pressure wells have to be equipped with some of the valve assembly for controlling the flow of oil and gas from the wells and installed on top of the tubing. Low-pressure wells are also installed with a Christmas tree, but it is less complex if used for low pressure compared to high pressure. However its usage is the same, controls the flow of fluid in the well.

Gauge pressure is usually installed to measure the pressure in the casing and the tubing. By knowing the pressure in the well in a variety of conditions, so it is easy to control the well in the event of a leak.

There are several types of valves installed on christmas trees. This valve can be closed and opened to control the flow of fluid from the well.

The valve are:

i. Manual Master Gate Valve.

ii. Manual Wing Gate Valve.

iii. Manual Swab Gate Valve.

iv. Automatic Shut Down Valve (SDV)

v. Choke Valve.

Manual Master Gate Valve.

It is the outside of the valve through the production wells can be controlled. The valve assembly is made directly on the tube production (production tubing). When the valve is fully closed it will prevent oil from production wells go into the oil processing system. When it fully opened it will allow oil to flow into other parts of the control valve.

Manual Wing Gate Valve

This valve is installed directly from the production wells into processing system and when the main valve fully opened so the production from the well can be run. It is controlled manually and may also be controlled automatically.

Manual Swab Gate Valve

Specific valves are used to allow certain equipment (eg, Wireline and punching tools) enters into the wells. It also allows the flow / static pressure for the well head off directly through the pressure gauge.

Automatic Shut Down Valve (SDV)

Installed above master gate and usually opened and closed by a pneumatic system. External mechanism is similar to the manual gate valves. The difference is only in terms of operating convenience only. Where 'hand wheel' is replaced by a large piston-cylinder arrangement. When adequate pressure is applied to the cylinder, the piston will be forced to move against spring pressure in one direction to open the valve. Valve is closed by spring action if the air cut off by the security system or due to power supply failure.

Choke Valve

Choke is a blockage in the well fluid route through a Christmas tree. Used to control fluid production from the well. Choke may be fixed: the size of the openings. If adjustments need to be made then a new choke with different size is required and installed or choke opening size adjusted by turning the control handle.

Separation system

Some pure well have pure gas production which can be taken directly to gas treatment and /or compression. A well is often produce a combination of gas, oil and water and various contaminants which must be separated and processed. Separators come in many forms and designs. A classical design is gravity separator where well flow is fed in horizontal vessel (Figure 2.21). The retention time is typically 5 minutes, allowing the gas to bubble out, water to settle at the bottom, and oil to be taken in the middle. The pressure is often reduced in several stages (high and low pressures separator etc.) to allow controlled separation of volatile components. A sudden pressure reduction might allow flash vaporization leading to instabilities and safety hazards.

Offshore platforms are used to explore, extract and process oil and gas retrieved from seabed. Wellhead fluid is pump from the wellhead platform through the riser for processing to separate the oil, gas and water to produce final product of platform. One of the processing platform is features is separation unit. Separation itself is mainly done by gravity, but it also assisted by special chemicals and heat.

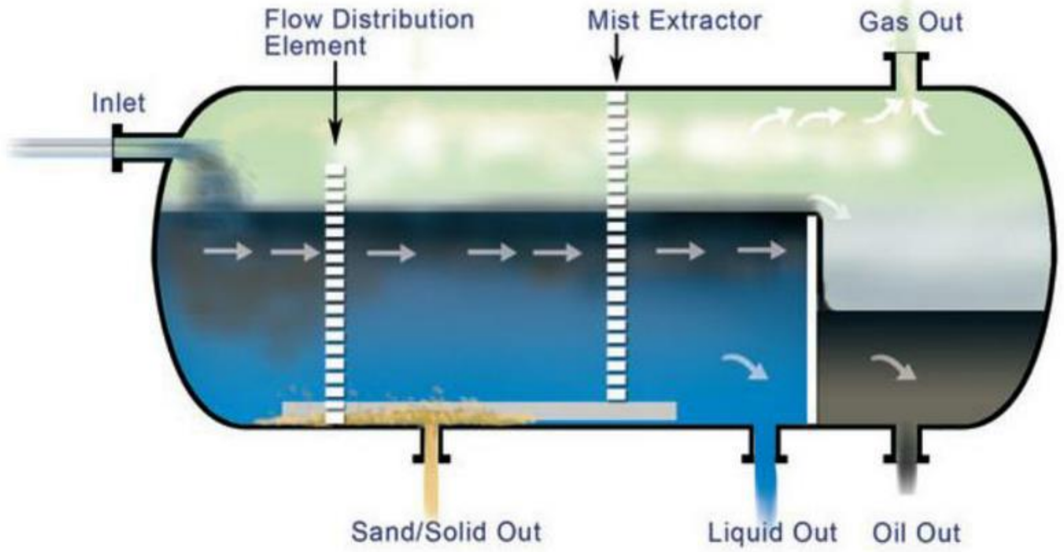


Figure 2.21: Three phase Separator Unit

[Source: drillingformula.com, 2017]

The length of time is important factor to determine how well the component will separate. One they have done so, the gas is channel to gas compression and dehydration module.

Separated waste water flows into a water conditioning unit, to remove any additional chemicals. The separated oil will flow into the oil manifold and flows into crude heater, heated with hot oil (removed additional water). Demulsified chemical are added to promoter further breaking up the water-oil-emulsion.

There are two types of separator commonly used, vertical and horizontal. Separator use of centrifugal force and gravity to separate the well fluids. Separator can consists of two or three types phase. Two-phase separator separates into liquid and gas wells. Three-phase separator separates the well fluid to a liquid, gas and water, however at this treatment level oil and gas still contains some water. Wells Fluid containing little free water also flowed into a three-phase separator.

Gas and Water Disposal System

The gas gathered from separators, surge tanks, and any export gases from other processing platform is compressed, turbine-driven is usually used. It is then dehydrated inside a glycol contactor, using Tri-Ethylene Glycol (TEG) to absorb moisture from gas. The Glycol contactor is a tray column of many bubble cap trays. As TEG contacts with compressed gas in the bubble trays, it absorbs the moisture from the gas, thereby dehydrating it. This dehydrate gas is to send to feed gas lift well and export gas line. TEG is now rich in moisture, is sent off to be converted back to lean glycol, and recycle back to contactor. Figure 2.22 shows the flow process of gas dehydration.

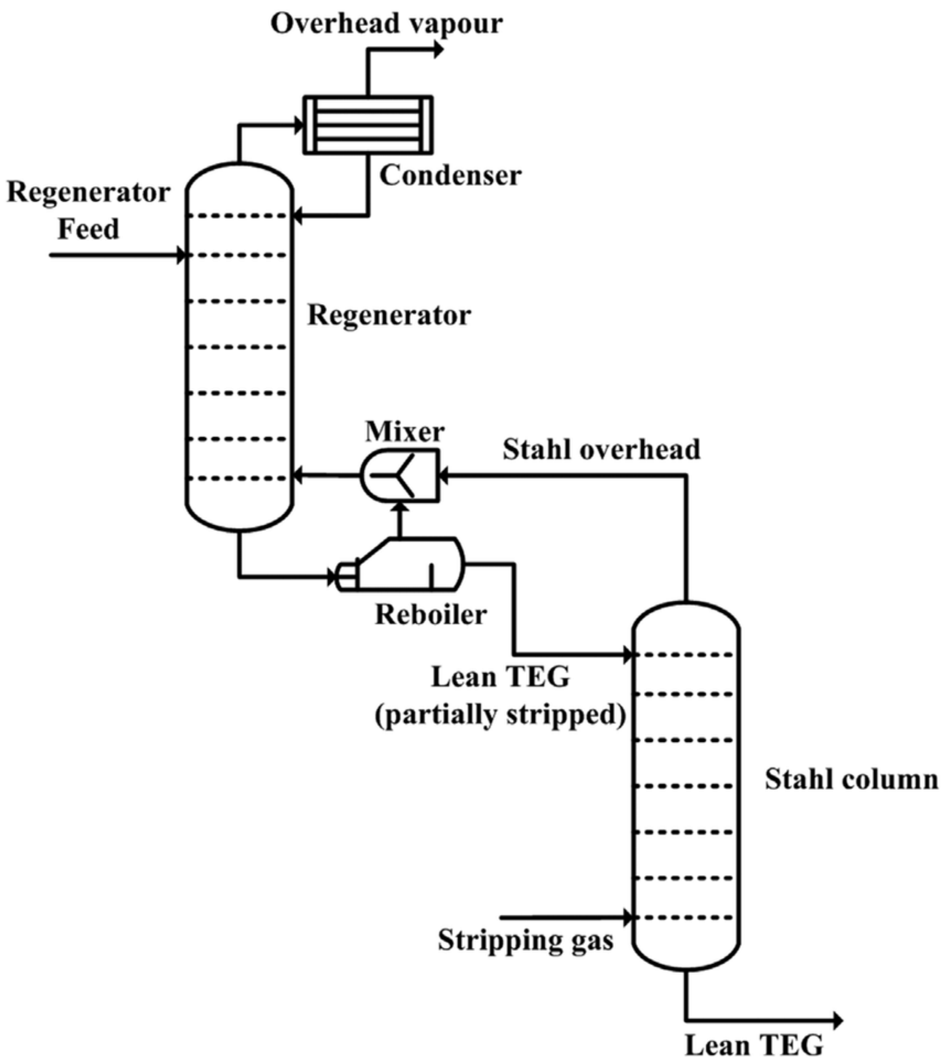


Figure 2.22: Gas dehydration (TEG)
[Source drillingformula.com, 2017)

In addition the simplest equipment to separate water and gas is to use a tank that uses the concept of gravitational force to separate the fluid and gas. Water is heavier than gas will be settled to the bottom. Lighter gas will come out through the top of the tank to enter the gas collection system. Water that has been isolated to be processed and treated in the CPI's special tool (Corrugated plate interceptors) to ensure a balance of crude oil produced. For useless gas, flare booms used to dispose of the gas.

Activity 2.1 Review Questions

1. Describe the basic concept of petroleum geology.
2. What is hydrocarbon reservoir?
3. Identify two common concepts during deposition process over geologic time scale.
4. Define petroleum.
5. What is the element of hydrocarbon?
6. List the unwanted substance in oil and gas content.
7. What is the meaning of petroleum in Greek word?
8. What is commodity discovered before oil became commercial?
9. List commodity in demand after the invention of electricity and combustion engine.
10. Define petrochemical.
11. List the primary products of feed stock.
12. Identify the typical feedstock of petrochemical process.
13. Draw a cross section of anticline trap. Give the name of oil water and gas field in the traps.
14. Draw a cross section of stratigraphic traps. Give the field names of oil accumulation, reservoir rock, impermeable rock, over/under burden and unconformity in the traps.
15. Draw a cross section of structural traps. Give the field names of oil accumulation, reservoir rock, impermeable rock, salt intrusion and over/under burden in the traps.
16. Explain the different between pinchout and unconformity traps.
17. What is the drive mechanism and the primary production?
18. List five important types of drive mechanism?
19. Explain each of five drives mechanism to transport oil from the production wells.
20. Describe the analogy of solution gas drive.
21. Draw table to distinguished value of recovery percentage between solution gas drive and water drive.

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