

**A REVIEW STUDY OF FLOATING, PRODUCTION, STORAGE, AND
OFFLOADING (FPSO) OIL AND GAS PLATFORM**

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**A project report submitted in partial fulfilment of the requirements for the award
of Bachelor of Engineering (Hons) Petrochemical Engineering**

Faculty of Engineering and Green Technology

Universiti Tunku Abdul Rahman

September 2015

DECLARATION

I hereby declare that this project report is based on my original work except for citations and quotations which have been respectively acknowledged. I also declare that this particular work is by own effort and has not been submitted to this university (UTAR) by a peer or to any other institutions.

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APPROVAL FOR SUBMISSON

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LIST OF SYMBOLS / ABBREVIATIONS

FPSO	Floating, production, storage and offloading
B.C	before Crist
LNG	Liquefied Natural Gas
OCS	outer continental shelf
FPS	Floating production storage
Km	Kilometer
M ³	Meter Cube
Bbl/hr	barrels of oil per hour
Bbl/day	barrels of oil per day
Bpd	barrels per day
LTI	lost time incident
ESPs	electric submersible pumps
m ³ /hr	Meter Cube Per Hour
kW	Kilowatt
t/hr	ton per hour
MW	Megawatt
PLEM	pipeline end manifold
CALM	catenary anchor leg mooring

CHAPTER 1

INTRODUCTION

1.1 Background of Study

The industry of oil and gas involves the usage of various machineries and platforms to derive the many functions needed to run the industry from the ground up (LUKOIL, 2013). The research of finding and identifying the oil in the oil fields, the initial pilot plants to identify the potential of the field and the drilling of the oil and extracting the oil and gas from the fields, and the further processing the oil and gas into various raw products and refining the products to usable end products and storage and transporting these products needs various engineering vessels and machinery. (Devold Harvard, 2013)

The demand for fossil fuel based energy along with other energy sources has continued to increase drastically. (Islam Saiful A.B.M, 2012)

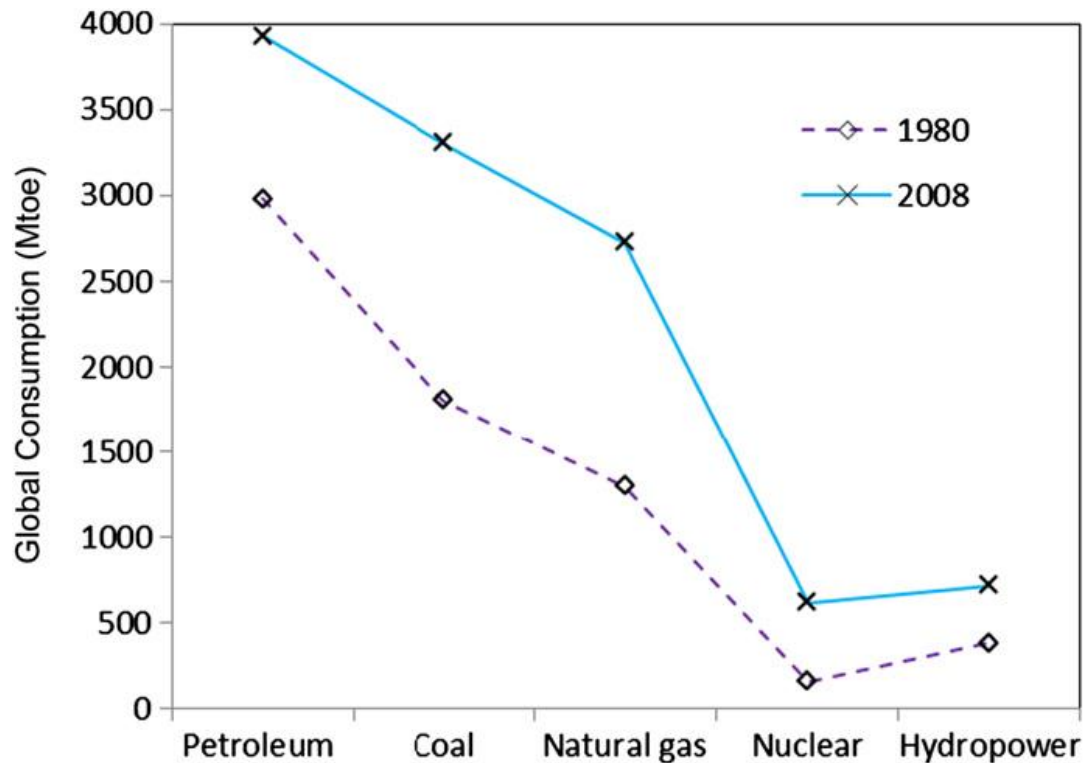


Fig. 1. Increment of global primary energy consumption (Islam Saiful A.B.M, 2012)

To simplify the entire process of turning the crude petroleum into usable oil and gas products several types of oil processing platforms are utilized. Among them are the semi-submersible, floating production, storage and offloading (FPSO), conventionally fixed platforms, compliant tower, spar, vertically moored tension leg and mini tension leg platform and finally sub-sea completion and tie-back to host facility (Devold Harvard, 2013)

Floating production, storage and offloading platform is an oil and gas facility also known as FPSO. The design and mechanism of the FPSO are fairly simple. It's a floating vessel with a hull and a self-propelling engine (Canales Monique 2008).

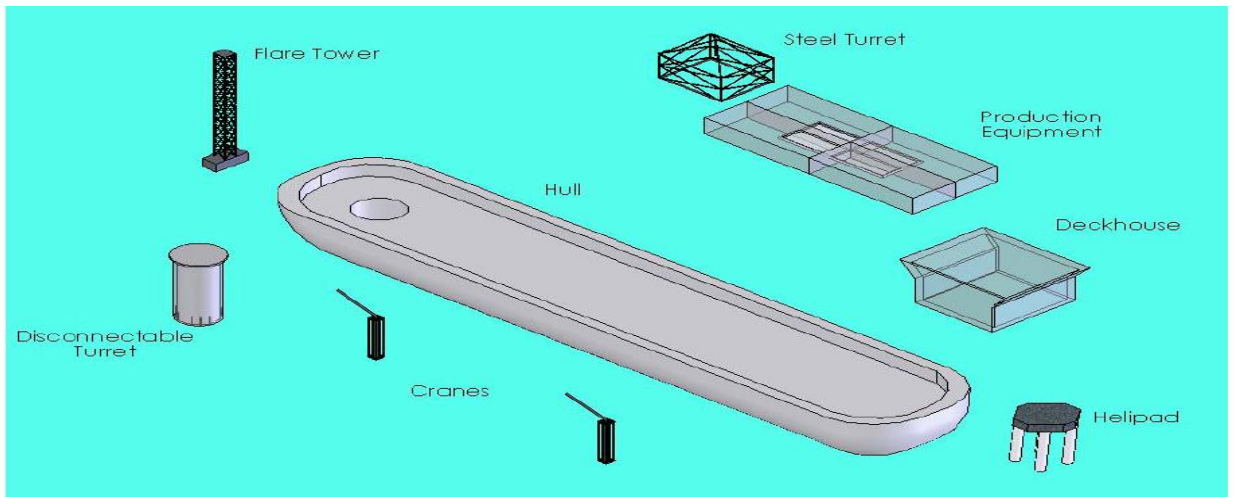


Figure 2: Basic design of a FPSO (Canales Monique 2005)

The 35 percent of FPSO are from converted cargo ships while the other 65 percent are newly built units. The hull of the vessel is lined with all the machineries required to produce, store and offload the oil and gas product derived from the oil wells (Potthurst Rob 2003).

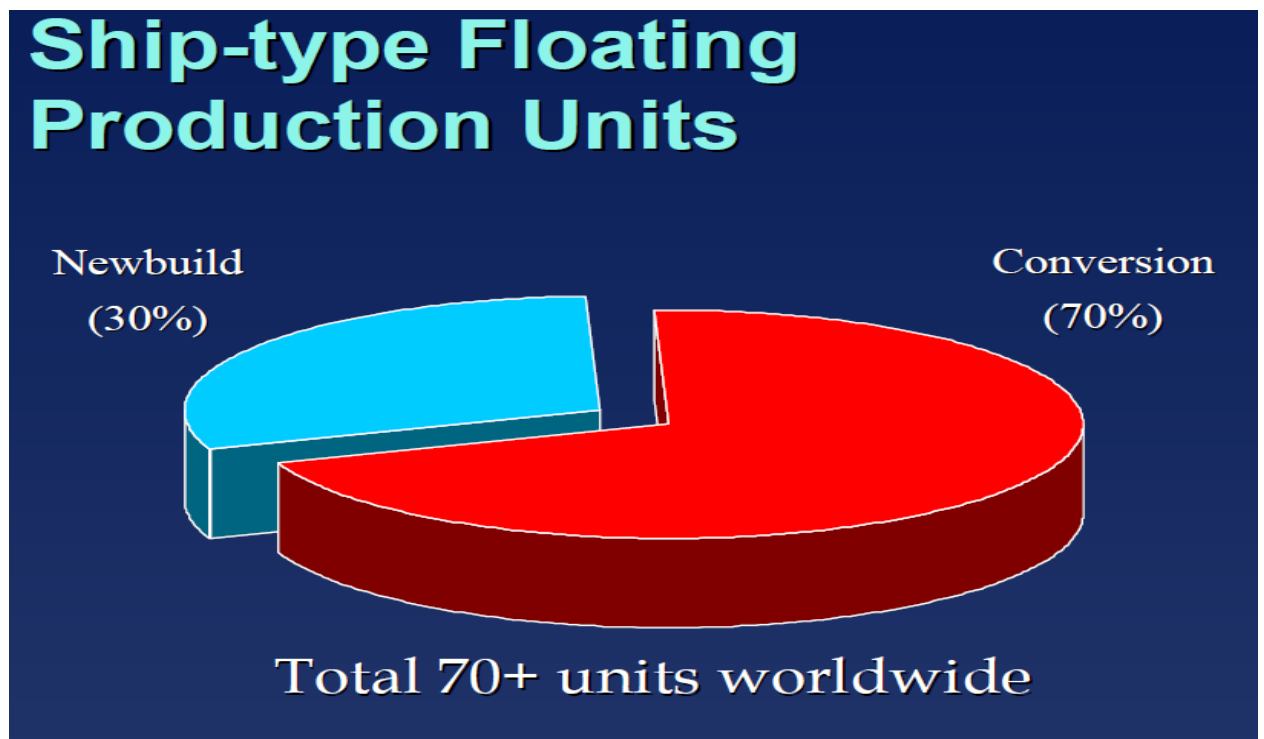


Figure 3: Tanker Conversions to FPSOs (Potthurst Rob 2003)

FPSO are widely used ever since the 1970s. The parts of the oil wells that has seen the operation of FPSO are Angola, Offshore Brazil, Asia Pacific, the Equatorial Guinea (FPSO.com, 2015)



Figure 4: Distribution of FPSO worldwide (Potthurst Rob 2003)

The FPSO platform is desired for usage compared to other platforms due to several reasons. Among them are the economic benefits of the platform. The FPSO platforms can be made with a lower cost than any other oil platforms and also to reduce the capital cost further cargo ships can be converted to a fully functional FPSO (French 2006).

FPSO are efficient in the sense of usability whereby the platform can be used in a wide range of depth fields. Equally effective in deep water and ultra-deepwater fields with just a small adjustments and modifications (FLUOR 2015). Typically the FPSOs are moored with the usage of varying mooring systems. The two mooring systems involved are the central mooring system and the spread-mooring systems. The central mooring system rotates the vessel independently accordingly to the changing weather conditions in the proximity. The spread-mooring systems act as an anchor that holds the FPSO on the desired location on the field. (Chakrabarti Subrata K. 2005).

In-field pipelines are used to transport the hydrocarbons from the subsea wells to the FPSO facility. The FPSO has a turret that in turn has a connection to risers connected to various flow lines. These flow lines transport the oil and gas from the drilled wells to the risers. The risers function to feed these oil and gas crude substances to the turret which brings these material to the upper platform for further processing (Allen Eric, 2005).

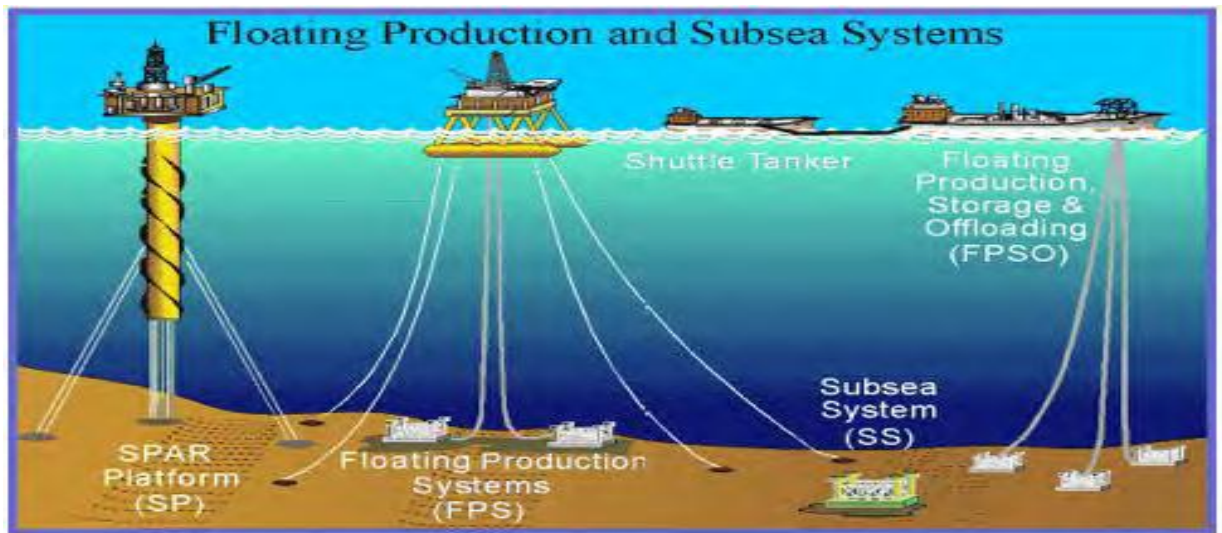


Figure 5: Types of Oil Platforms (Sadeghi Kabir, 2007)

The similarities between the machineries and the equipment onboard the FPSO vessel and that on a semi-submersible, fully submersible or any other platforms are relatively same except for some key differences. FPSO production and processing equipment are made in separated sections usually consisting of water separation, gas treatment, oil processing, water injection and gas compression. After the processing in these upper regions the hydrocarbons are transported to the double hull of the FPSO vessel where it is stored (BLUEWATER, 2015).

The loading hose functions as a transportation device that transfers the crude oil stored within the hull of the vessel to shuttle tankers or oceanic barges which in turn take them ashore. The process of oil loading from the FPSO's stern to the shuttle tankers bow is known as tandem loading. The crude gas however is either channeled to the of shore

facilities by pipelines or reintroduced to the oil fields to increase yield by a method called re-injection (French 2006).

FPSO are a much more desired platform due to the economical and convenience of it. Being able to be moored permanently when wanted and disconnected from the moorings according to the needs of the managements gives the FPSO a wide range of operating situations (Rob Potthurst 2003). FPSO can function in a wider range of offshore field situations. Even in situations with changing weather conditions like the South China Sea which is plagued by cyclones and hurricanes the FPSO can be moored and functioned and when risky weather conditions are detected the FPSO can be disconnected and moved away. Also the terrain which proves immensely challenging for any construction for a semi-submersible or fully submersible platform, FPSO can simply be deployed and moored (RIGZONE, 2013).

Due to the movable characteristics of the FPSO, it is more economically efficient choice of platform for fields with a limited supply of crude oil and gas. Fields where the crude oil and gas yield would not provide revenue to even cover the capital cost and overhead cost of installation of a semi or fully submersible platform can be still put to use by the deployment of a FPSO. (MODEC 2015). Poor infrastructure such as undeveloped pipeline layout in the areas such interior South America and the African continents are also now viable and open for production due to the usage of FPSO. (Houston Offshore Engineering 2015)

1.2 Problem Statement

Primary problem statement in this project would be to research the multiple factors that influence the production of oil and gas in relation to the platforms used and determining the best cost effective flow in order to maximize the profit margin while minimizing the resources used. Currently it is known that FPSO have been in usage for almost 30 years, and through these years it's been clear that FPSOs are more economically efficient to startup because capital cost to produce one is lower compared to a fixed platform. The smaller capital investment makes FPSO the lead choice when it involves small oil fields

with lower predicted gains that would be economically counterproductive to invest and build a large fixed platform to process it. FPSOs can also be reused in more than one particular field. Once a field is depleted a FPSO can simply be demoorred and towed or self-propelled to another oil field.

The much lower abandonment cost is also a important factor when considering the usage of FPSOs in the growing oil and gas market. Apart from researching the economic impact of FPSOs, the design features would also be researched. When fields in rougher and deeper regions are developed the FPSO becomes the lead choice due to its design features that enable it to withstand these conditions. The designs of various FPSOs would be detailed in the results and analysis in order to determine the best working design that is suitable for Malaysian waters.

1.3 Objective

The objectives of the review study of floating, production, storage and offloading oil and gas platform are:

- i. Understand and study the characteristics of FPSO.**
- ii. To understand the design features of FPSO and its relation to the oil field conditions.**
- iii. Compare the advantages and disadvantages of the FPSO platforms to other platforms.**
- iv. Understand and study the oil and gas production processes in a FPSO.**
- v. Understand and recognize the technological advancement in the field of FPSO.**
- vi. Develop and identify solutions to overcome the disadvantages and weaknesses of FPSO to increase the economical profit margin.**
- vii. Understand the oil and gas industry and oil fields in Malaysia that employs FPSO.**
- viii. Understand the impact of FPSO to the oil and gas industry in Malaysia.**

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

The oil and gas industry brought mankind to another era of greater modernity and urbanization. It sparked the globalization and crossed barriers before this was impossible.

The worlds superpowers realized this and tried to develop their oil and gas resources as much and as fast as possible to attain greater economical prowess.

Oil and gas platforms were used to harvest and turn this crude petroleum into something usable and this platforms has seen many developments in the past years as more modern techniques developed and more hostile places were drilled for crude oil.

2.2 Oil and gas overview

The simplest and earliest of usage of naturally occurring oils was in the dawn of humanity as a fuel source for fire. The historical sources state as early as 1000 B.C when the oracle of Delphi in Greece was built. Another source of 500 B.C old cites a usage of natural gas when the Chinese utilized natural gas to simple daily usages like boiling water. As no modern developing and refining and production method existed at that time, these sources of oil and gas were probably sourced from seepage and tar ponds or shallow reservoirs. (Oil and gas handbook)

The American continent brought the ultimate change to oil and gas production when “Colonel” Edwin Drake in the year 1859 searched for, found and successfully pioneered the first oil field in Pennsylvania. (Oil and gas handbook)

Malaysia has produced oil and gas from its reserves at a high rate starting from the beginning of the last century. The country has grown into a potential high producer to feed its own energy demand by its growing population and industrialization (Islam Saiful, 2012)

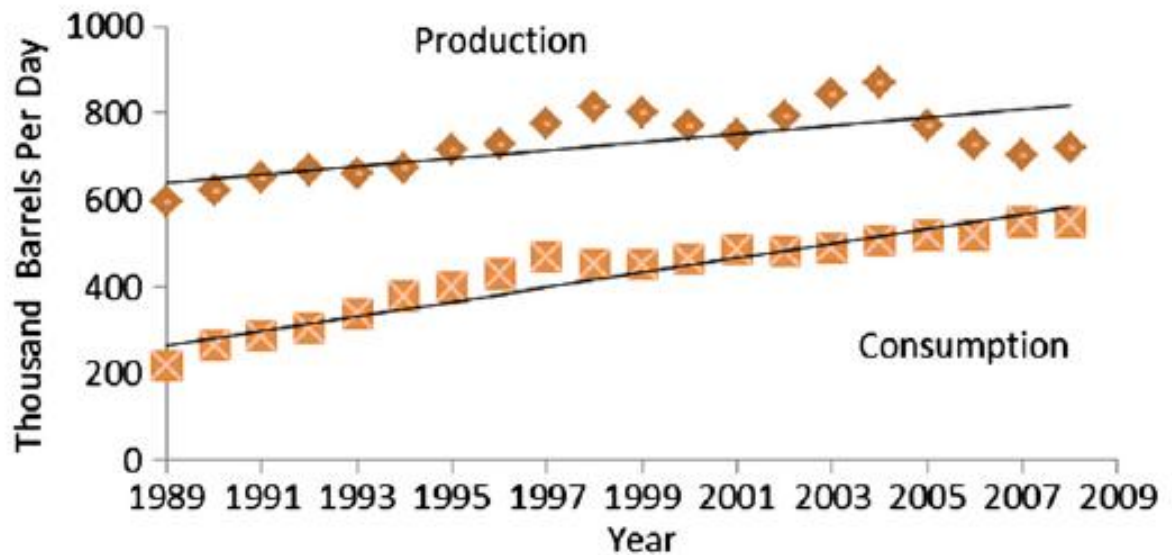


Figure 6: Production and Consumption of Oil in Malaysia (Saiful Islam 2012)

2.1.1 Petroleum Formation

Hydrocarbon merging with multitude of other chemical compounds namely sulphur produces petroleum. Aquatic life once dead and decomposed upon the oceans bed decomposition will occur. Phosphorus, nitrogen and oxygen are released from the decaying organisms by bacteria. The leftover decay consists mainly of hydrocarbon (mixture of carbon and hydrogen). The decaying mass forms a viscous gel like compound after mixing with sand and earth and other materials and is covered by mud from the seabed. After millions of years of pile up of layers upon layers of sand and mud on the seabed the compound due to pressure will be forced to compress. The compound of mixed decay and chemicals must under severe pressure and at a high depth. Normally the depth needed to compress these material into petroleum is 10000 feet or higher. (Petroleum online, 2015)

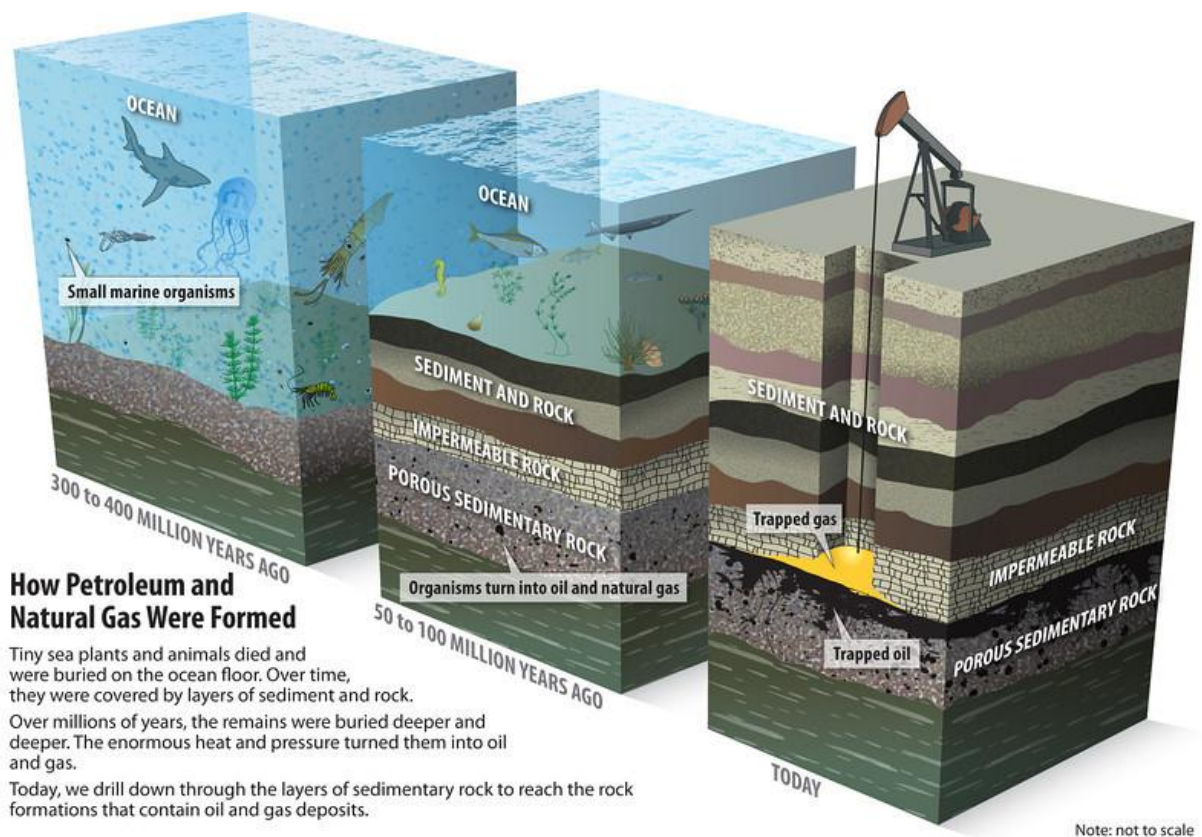


Figure 7: Crude Oil Formation Diagram (artanaid, 2015)

Due to the fluid properties of petroleum, it moves and seeps through the layer of rock that it is formed in. this seeping creates oil pools deep within the sea bed. The rocks surrounding this pool is porous enabling petroleum formed in the surrounding area to be seeped into the pool. Normally sandstones are these kind of rocks. The oil trap is a phenomenon whereby the formed oil and gas is not allowed to seep into or onto the surface due to a layer of impervious rock. (Energy Information Administration, 2011)

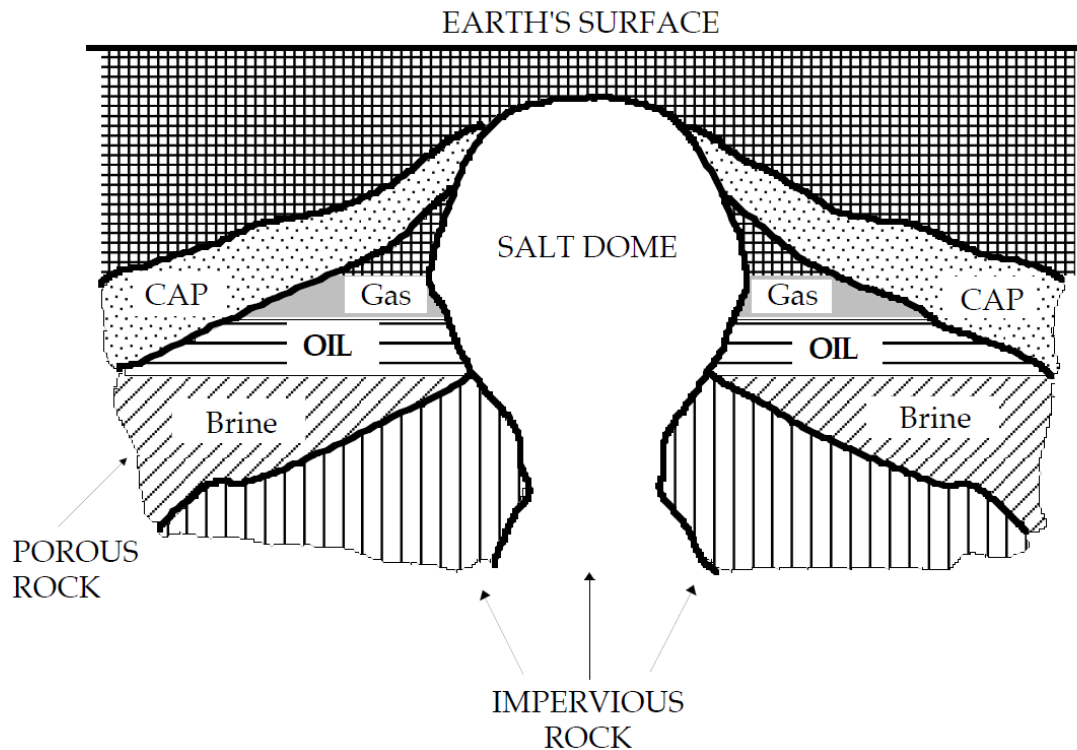


Figure 8: Representative geologic structure of an oil trap: a salt dome (Sadeghi, 2013)

Properties of petroleum is determined by the temperatures of by it is produced. More solid based petroleum products are formed by lower temperatures while higher temperatures produces gaseous products. The gas produced will remain in the mixture

often having a thick liquid base and gas on top of it in the oil field. But too high a temperature (above 450 Fahrenheit) and the formed petroleum would be destroyed. (Petroleum online, 2015)

2.1.2 Petroleum components

Composition of petroleum is usually:

- 1) Carbon (93% – 97%),
- 2) Hydrogen (10% - 14%),
- 3) Nitrogen (0.1% - 2%),
- 4) Oxygen (0.1% - 1.5%)
- 5) Sulphur (0.5% - 6%)
- 6) Very small percentage of trace metals.

The percentage of Paraffins, naphthenes, aromatics and asphaltics influence the personality or property of the crude oil and this is vastly influenced by the geographical factor. The percentage of these components are as follows. Paraffins (15% -60%), naphthenes (30%-60%) and aromatics (3%-30%) while the asphaltics are about 30%-50%).In terms of colorations crude petroleum is a dark brown or black or even yellow and greenish depending on the geographical range of where the oil field is. Viscosity of petroleum is also based on the methods the formation occurred. The physical properties of petroleum could be as extreme as pure solid or high viscous liquid that is almost solid or as a clear light viscous fluid. The solid state would require extreme high usage of resources to be processed while the light end would require very little refining. (Devold Håvard 2013)

2.2 Oil and gas field is defined through certain points of development.

Exploration is the initial process whereby activities to research a prospective oil field and this activity is done through geological testing and seismic prospecting, seismic and drilling activities that take place before a worth of a field is finally decided.(Saiful Islam 2012)

Upstream is the process whereby infrastructure of production and stabilization of the field is made through wellheads and reservoirs. Downstream on the other hand uses the processing. The further processing, gas treatments, LNG production and reintroduction of gases into plants, and oil and gas pipeline is known as Midstream. (Ridza Abdullah Mohammad 2011)

Production of wellhead (drilling, casing, completion, and wellhead) are known as “pre-completion,” and the production facility is “post-completion.” (Devold Håvard 2013)

2.2.1 Wellheads

The wellhead is the structure immediately on the surface of the oil field or reservoir tapping into the oil and gas resource. An injection unit is usually used and water or gas injected into the reservoir to maintain pressure and increase production rate and yield. (Oil and gas handbook)

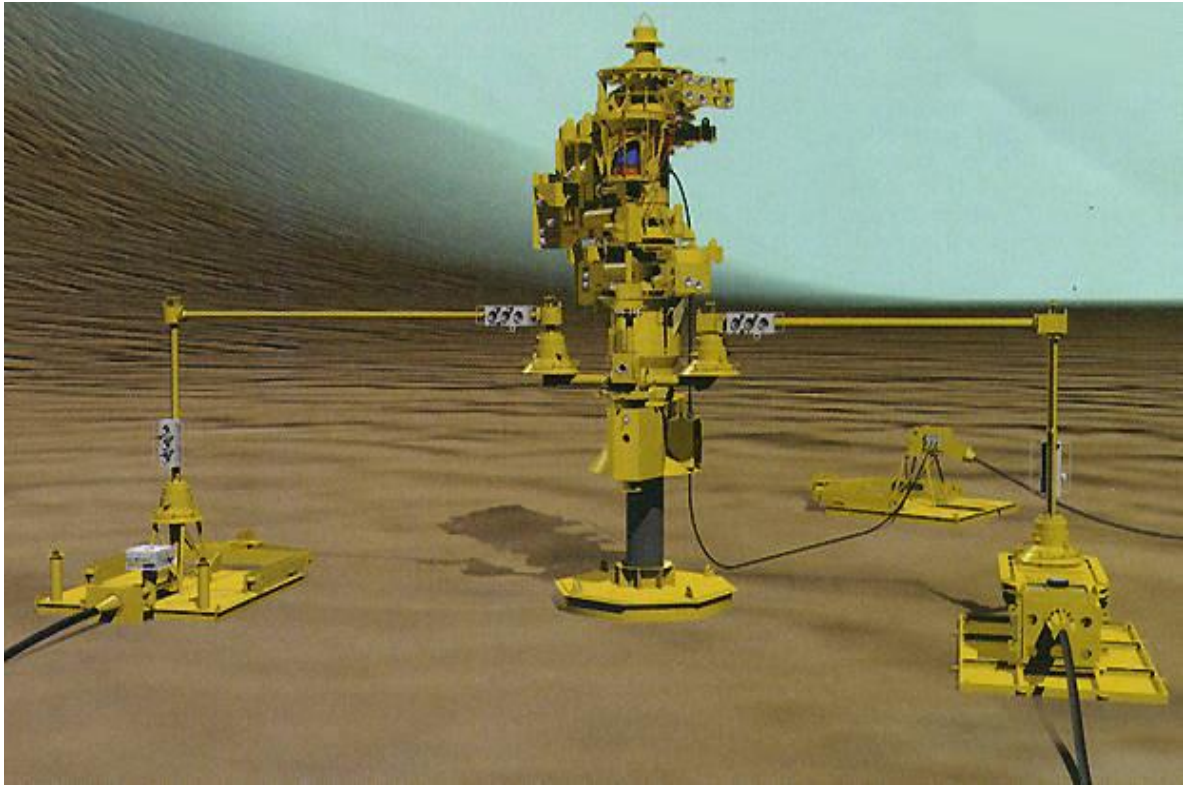


Figure 9: A wellhead on a seabed oil field (off-shore technology, 2015)

The end process is refining whereby the oil and gas are processed into usable products that can be marketed or feasible as raw materials for other processing that make petrochemical products.

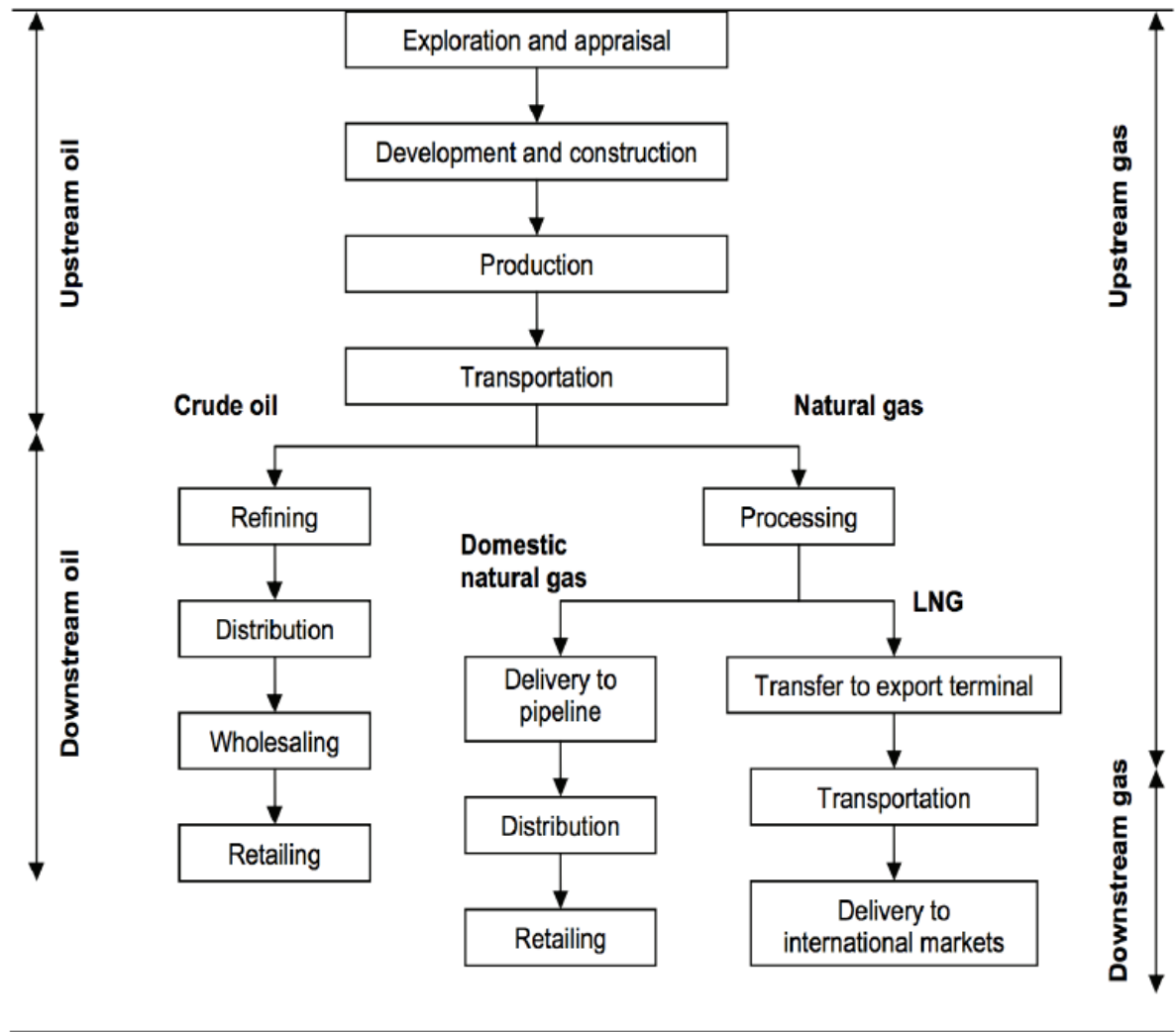


Figure 10: Oil and gas production chart (Ridza Abdullah Mohammad 2011)

2.3 Malaysian oil and gas development

The very first oil ever drilled in this country was in 1910. The first drilled occurred in the state of Sarawak and in the district of Miri. The oil well that was drilled there was named as the grand old Lady. The entire operation was projected by the Shell. The production began with a meager 83 barrels per day (bbs/d) and continued for about 19 years. The production intensified and peaked to about 15000 bbls/d. the production stopped in the year 1929. After this the production and drilling of oil stopped in

Malaysia. The oil was not given emphasis up until 1950 when another project began. (A Barrel Full.com 2015)

The 1960s is when petroleum industry began to take importance in the Malaysian economy. After the oil field discovery off the shore in Borneo, the emphasis of oil and gas increased. The production rate in the years of 1970s were at a record high averaging at around 90,000 to 99,000 bbls/d. (Islam Saiful 2012)

Shell and Esso were the first key industry big names to take hold of the majority of petroleum based activities in Malaysia at that time. Conoco, Mobil, Aquitaine, Oceanic and Teiseki and Petronas competed later on starting from the 1974. (Eugene Thean Hock Lee, 2013)

International countries are contracted to pay royalties and taxes to each state that provides them rights to drill and market the state's oil and gas resources. After the Petroleum Development Act was enforced in 1974 however, the sole rights to control the nation's oil and gas resources fell to Petronas effectively making it the nation's sole oil and gas exploration, development and production company(Eugene Thean Hock Lee, 2013)

2.3.1 OIL PLATFORMS

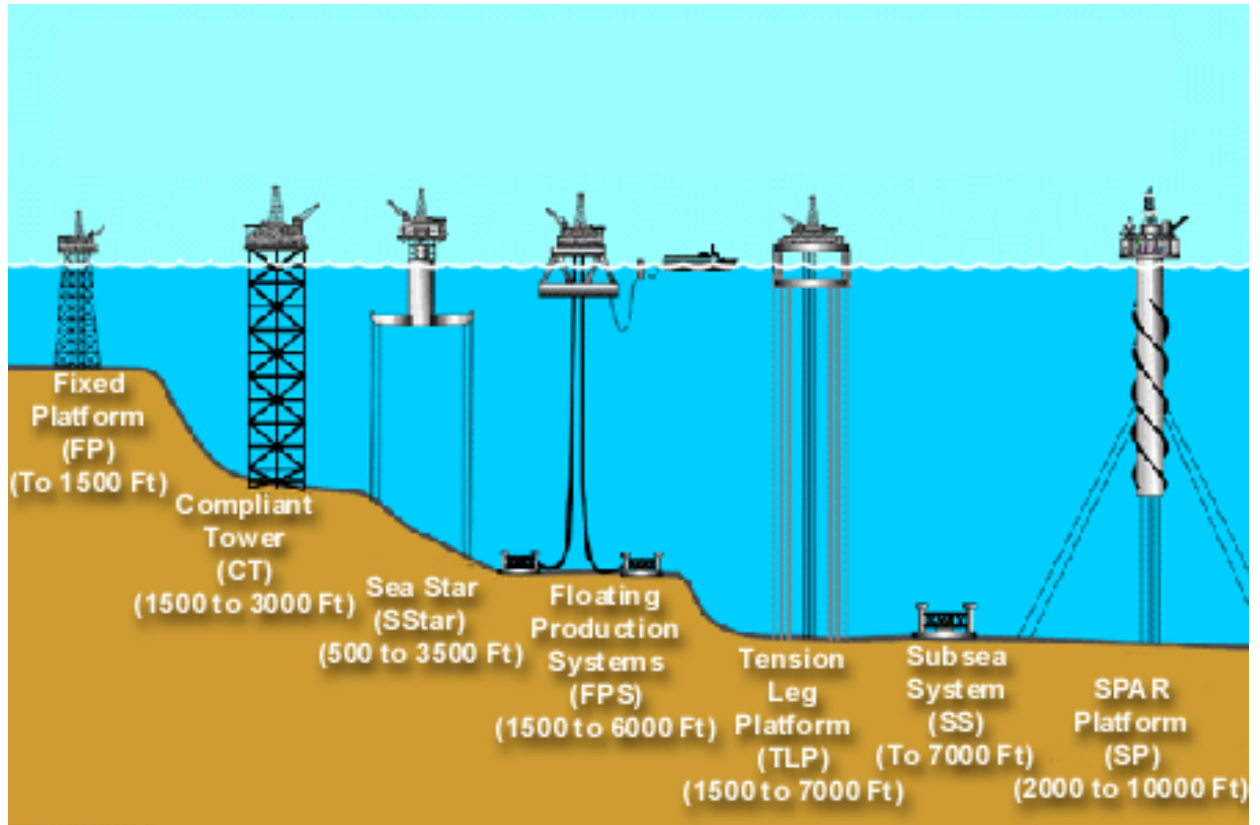


Figure 11: Types of Oil Platforms (Sadeghi.K, 2007)

Platforms used to drill and process the crude petroleum is termed as offshore oil rigs. This vastly depends on the type of geography and the depth and the type of the conditions of the location where the field is located. (Subrata K.Chakrabarti, 2005)

Main function of the rig is to extract the oil and gas from within the field. Oil and gas drilling especially in places that are hundreds of miles from the shore poses many challenges that must be overcome. (Sadeghi, 2013)

Platforms are normally built to facilitate the drills at offshore due to the fact that sea floor depth is few hundred or thousands of feet deep and a platform is needed to mainstream other processes.

Moveable offshore drilling platforms/rigs

Two species of offshore drilling rigs are moveable drilling rigs and fixed type drilling rigs.

Drilling barges

Barges are large and floating platforms usually for shallow water in swamp like areas. Normally utilized for bodies of water inland and moved by tugboats. These barges are not designed to withstand excessively choppy water conditions. (Offshore-technology.com, 2015)

Jackup platforms/rigs

Jack up rigs are different compared to barges as in jack up rigs once towed to a site , legs are extended lowered and the entire platform jacks up from the water's surface supported by the anchoring legs that press and stand from the sea bed. The resting platform above the water's surface make it much safer than barges that only float, but waters too deep more than 500 feet are non-viable for this rig as the legs do not have the length to extend to that extreme depth.(offshore structures ,2015)

Submersible platforms/rigs

Used in shallow water places, this particular rig connects with sea bed with anchor like structures. The main body consists of double hulls on top of each other. The upper hull accommodates the crew and the drilling platform while the lower hull is air intake facility that takes in air when rig is moved to add buoyancy and releases air to make the rig submersible once planted at a field.(offshore structures ,2015)

Semi-submersible platforms/rigs

Widely used in many areas around the world this particular type of oil platform consists of columns and pontoons that can be submerged with the controlled intake of water making the platform submersible. Since it is partially submerged it has the combined usage and advantages as that of a submersible and floating platform whereby stability is ensured and ability to drill in deep places is made possible. (rigzone, 2015)

Consisting of two hulls that can be inflated and deflated at needs controlling the submersebility of this rig. The rigs location is secured by anchors that moor it specifically to a field. The weights of these anchors can reach above ten tons and these along with the submersible pontoons and columns give rigidity and stability to the working production on the surface and within the rigs hull. The one key advantage of semisubmersible is that it can be kept in turbulent waters through dynamic positioning. Semi-submersible are used to drill in waters at the depth of 6000 feet in average. (Akersolutions, 2015)

Drillships

Basically ships that have been modified to carry drilling equipment and a derrick in the middle of the deck. The ship also has a moonpool which is a tunnel like housing that houses the drills length and makes it possible for the drill to extend far into the depth from within the ship's hull. Also utilizing the dynamic positioning systems the drillships can operate in deep waters due to stability provided by the satellite positioning and high accuracy sensors that provide constant adjustments to maintain the position on the top of the drill site, it can operate drilling in deep waters. (Baker huges 2015)

Fixed platforms

At some fields it is possible to fix a platform on the sea floor where the oil field is located. The legs of the oil platform is made from concrete and steel and provides rigid stability to the platform. Some platforms do not even have to fix to the seabed due to immense weight of the legs and the platform that the mass itself provides a sitting stability for the rig. Advantages are mainly great stability and space to place production and processing units. Disadvantages are extremely high capital cost to build and once a field reduces its capacity to provide oil the platform is useless. (Subrata K.Chakrabarti, 2005)

Template (jacket) platforms

Jacket platforms are made of steel and currently used in the Persian Gulf, the Gulf of Mexico, Nigeria, and offshore California (Sadeghi, 1989). Templates are made of three components, mainly the jacket, piles and deck. (Subrata K.Chakrabarti, 2005)

Compliant Towers (Tower platforms)

Very similar to fixed platforms. Made of a thin tower constructed with a base that is contact with the sea bed and this tower acts like flexible absorption mechanism that enables this platform to withstand high winds and waves. This flexibility ensures this platform to even survive extreme hurricane and stormy conditions. (N. Haritos, 2007)

Seastar platforms

Made of a lower hull that can intake water to allow semi submergibility and increase stability. Has legs that connect to the sea bed. These legs are flexible and extendable. Infused with pressure the legs maintain the vessels position and only allow side to side motion. This enables the pressure from water movement and waves to be absorbed allowing the rig to be used in places where a depth of 3500 feet and capital cost to build a larger platform would be counterproductive. (N. Haritos, 2007)

Tension leg platforms

Bigger seastar rigs with bigger legs and the legs are more solid and less flexible. The sideway motion is allowed to as much as 20feet with minimal vertical movement. Operating depth is about 7000 feet. (K.Chakrabarti, 2007)

Floating, Production, Storage and Offloading Platform

Essentially ships that have been modified to receive crude petroleum from the deep fields FPSO use their hulls as storage to facilitate the transfer of oil to shuttle tankers or barges that in return transport the crude to shore. (Global security.com 2015)

FPSO are similar to semi submersibles. The only difference being FPSO house the drilling unit along with the petroleum production unit together eliminating the need to have a separate unit for processing. (Allen Eric, 2006)

The design allows for complete independent processing and storage without the need for separate vessels for even accommodating the labor and housing the supporting utilities. Power and water is housed in one unit and that unit caters for all processing and drilling. (Marathon oil, 2015)

FPSO started to be viewed as an alternative platform as offshore oil field explorations lead to deeper field that were further away from the shore. (International Ship and offshore structures congress, 2007)

In the case of FPSO s the wellhead is attached to the oil field as in the seabed and there it will be kept once the drilling has been completed. Risers connect the wellhead to the storage unit of the FPSO within its hull and this is used as a transportation vessel to transport the petroleum that has been drilled out. (Thiery Damien, 2015)

FPSO were game changers in the oil and gas fields on the Gulf of Mexico Outer Continental Shelf (OCS). Due to the inhospitable geographical range of the undersea range that provided an almost impossible challenge to build any drilling and production system, FPSOs were viable option that were also extremely cost effective. (Allen Eric, 2006)

A subset for a FPSO are ship-shaped floating storage and offloading systems (FSO). These vessels differ whereby as the FPSO has processing units these FSO do not possess those units. These subsets usually smaller are used in the same field as a FPSO usually to support the drilling and production of the existing FPSO to increase yield and production rate. (Dynamic loading approach for FPSO, 2007)

One famous FPS operational in southern Gulf of Mexico (Bay of Campeche) is the Ta'Kuntah that is owned and run by the company PEMEX from 1999. (Rigzone 2015)

Kizomba FPSO

The world's largest FPSO is named the Kizomba. The storage capacity is 2.2 million barrels and it was built by the Korean company Hyundai Heavy Industries in Ulsan. The Esso Exploration Angola (ExxonMobil) commissioned it and it is being operated by that company. The operating field of Kizomba is offshore Angola, West Africa. It is 320km offshore and works in depth of 1200 meters (4000ft) in the deepwater block of the Atlantic Ocean.



Figure 12: Kizomba FPSO (offshore-technology 2015)

The world's largest FPSO is the Kizomba A, it has a storage capacity of 2.2 million barrels. Built at a cost of over US\$800 million by Hyundai Heavy Industries in Ulsan, Korea, it is operated by Esso Exploration Angola (ExxonMobil). Located in 1200 meters (4,000 ft.) of water at Deepwater block 150 statute miles (320 km) offshore in the Atlantic Ocean from Angola, West Africa.

The total displacement that the FPSO displaces in mass is 81000 tons. Dimensions are roughly 285 meters long with a structural beams of 63 meters and height of 32 meters. (935 ft. by 207ft by 105 ft.)

The company responsible for designing the Kizumba is the FMC SOFEC that was subcontracted by the Hyundai Heavy Industries. The mooring system that enables the stability and anchorage of the vessel is also analyzed and made by them. The mooring system follows the classification of DnV.

2.4 FPSO in Malaysian Waters

FPSO ABU

Located at 200km offshore east coast the Malayan peninsular (block PM-8 PSC). The location is informally known as the Abu Cluster field. This main operations of the field is run by Petronas Carigali Sdn Bhd. The cluster contains several components. A major component is the Satellite Platform Abu A and followed by a smaller FSO (a floating, storage and offloading vessel) (FPSO Ventures 2015).

The FSO Abu platform is owned by MISC Berhad. Operations are done by the company FPSO Ventures Sdn Bhd (FVSB). The FPSO was converted by the Malaysian Maritime Heavy (MMHE) from a used tanker by the name of “MT Armata”. The entire conversion was completed at the Malaysian yard belonging to the MMHE and the vessel was towed offshore on the 27th of February 2007. The installation of the vessel on the field of operation was done on the 3rd of March 2007. The platform at that time was 2 km north west of Abu-A MiRIPP platform.

First oil from the field of operation was achieved in May 2007. (FPSO Ventures 2015)



Figure 13: FPSO Abu (kepcorp.com)

The turret was designed to be able to handle depths of 70 meters where the vessel is moored. Total 11 cargo oil tank units are aboard the vessel. The total capacity in volume of storage is 95,789 m³ and two of 11 cargo oil units are designed to act as production tanks. The vessel also carries two slop tanks that have the combined capacity of 5600 m³. The vessel has the capacity to tandem moor off take tankers at the stem. Loading and offloading rate is 30000bbl/hr and 20000bbl/hr respectively. Tankers in the capacity of 60000 to 150000 SDWT can be accommodated in the vessel.(FPSO Ventures 2015)

FPSO Berantai

The location of the Berantai FPSO is 150km offshore Terengganu, Malaysia. It is 10km south from the Tapis field and 30km northeast from the Angsi field. The field comprises of a wellhead platform that is connected to the FPSO. (Offshore technology 2015)

The wellhead and the FPSO were a part of the Phase one of the construction of the field, along with the drilling 13 wells. The FPSO itself is a converted vessel that was completed by the April 2012 in Keppel Shipyard. Crude processing output stands at 35000 barrels per day giving an export output of 15mmscfd. The FPSO is 4 storey high and has two control rooms along with a gym and a television room that caters for the workforce. (Offshore technology 2015)

Sub surface sea flowlines connect the nine slot wellhead platforms to the FPSO. These wellhead platforms act as support that facilitate the drilling of the wells. The legged jacket that underlines the wellhead platform weighs in at 1600t and the topside carries a weight of 1400 t. (Offshore technology 2015)

Phase two of the project would incorporate the drilling of five additional units of wells and the construction a nine-slot wellhead platform. (FPSO ventures 2015)

The FPSO also processes gas that is transported to the Petronas Carigali run Angsi Field through a 30km subsea pipeline. After the Angsi Field, the gas is further transported to the onshore terminal in Kerteh. While the gas are transported through the usage of pipelines, the oil processed are transported by shuttle tankers (Offshore technology 2015)

The FPSO Berantai is one of the most secure and accident free oil and gas platforms in the country currently reaching more than four million man-hours without a Lost Time Incident (LTI). Awards of appreciation were handed out to key individuals and subcontractors for this achievement in a celebration that occurred in the Keppel Shipyard in Singapore in April 2012. (Killojoules.com 2015).



Figure 14: FPSO Berantai (petronas subseaworldnews 2015)

Bertam FPSO

Located 160km offshore Kuantan in the Malay Peninsular the oilfield is within the PM307 Product Sharing Contract (PSC). At a depth of 76 meters the oil reserve is estimated to hold 18.2 million barrels of oil. (www.offshore-mag.com 2015)

20-slot Bertam Wellhead Platforms are connected to an Ikdam FPSO. The subsurface platform is fitted with 14 wells positioned horizontally and rigged with electric submersible pumps (ESPs).

The cost of the field developing is around \$400m. This does not include the modifications needed to make on the FPSO. (www.subseaiq.com, 2015)

The Bertam Wellhead Platform jacket was installed in May 2014. Following that the topsides were constructed and finished on the October 2014. Seadrill's West Prospero Jack-Up rig was contracted to drill the field in 2014. The pilot wells which were three in quantity and two horizontal sections were successfully drilled by December 2014. (Offshore technology 2015)



Figure 15: FPSO Bertam (vesseltracker.com 2015)

Cendor FSO

At the block PM-304 (Censor field) and 140km offshore the east coast is the location of the Cendor oil field that is operated by Petrofac Malaysia Limited (PML). The field consists of a Mobile Offshore Production Unit (MOPU) and a FPSO unit. The FPSO Cendor is owned by MISC Berhad. The contract to operate the FPSO is under FPSO Ventures Sdn.Bhd (FVSB). The oil field is at a depth of 76 meters. (klse.i3investor.com, 2015)

The vessel is converted from a tanker by MMHE and the conversion took almost a year from October 2005 and completed in September 2006. The FPSO was towed to the field on September 2006 upon completion and began operation by the same month giving first oil on the 23rd of September 2006. (fpsoventures.com, 2015)

FPSO is spread moored with 7 storage facilities and the capability to store 75000m³ and can tandem moor off take tankers at both sides of the vessel may it be the stern or the bow. The loading rate and the offloading rates are at a 30000 bbl/day and 14000 bbl/hr respectively. The vessel accommodates tankers in the range of 60000 to 150000 SDWT. (petrofac.com)

Cendor II FPSO

Under construction to cater and increase the production in the Cendor field.



Figure 16: FPSO Cendor (motorship.com 2015)

Kakap Natuna FPSO

Kakap KH field is 175 miles west of Great Natuna Island offshore Indonesia in the Nation Sea. The FPSO Kakap Natuna is operational there. At the beginning of its operation it produced 8000 barrels per day combination output from three well. 7 more wells were added to give a total output of 25000 barrels of oil per day in production of the FPSO (fpsoventures.com, 2015).

The design of the FPSO is made up of a pipeline end manifold (PLEM) that connects a flexible riser that controls a catenary anchor leg mooring (CALM) system that provides adequate stability and precision positioning of the vessel. The entire system is connected to the stern through a stiff delta frame yolk. (oilpro.com, 2015)

In 2003 a new oil field was discovered by the Murphy oil company in the J&K blocks offshore Sabah. Operation was given to Shell and the production starts in the year 2012.

The field being 1200 meters deep was classified as a deep-water field and 19 subsea wells were drilled. The oil transported through pipeline to an oil and gas terminal onshore Kimanis, Sabah.

The development on the wells were accomplished with the Kakap Natuna FPSO that had the production capacity of 150000 barrels per day (modec.com, 2015).



Figure 17: FPSO Kakap Natuna (offshore-technology, 2015)

Kikeh FPSO

Located 120km offshore Sabah and Northwest from the Labuan Island this particular oil field is at the depth of 1300 meters. The Murphy Sabah Oil company is in charge of the operation of the field subcontracted by its partner in this project Petronas Carigali. The Kikeh field has over 400 to 700 million barrels of oil in a recoverable manner. (Offshore-technology.com, 2015)

The entire operation components are a FPSO and a Spar Dry unit. The FPSO receives the production that the Spar drills out from the wells. The spar in particular has 24 slots. (Kikeh Deepwater Block, 2007)

The FPSO unit deployed in Kikeh is designed to operate at 1350 meters. The MDFT Labuan Company own it and the operation responsibility is given to MDPX Sdn Bhd. This project is a twin partnership project between the SBM and Misc Berhad. (Offshore-technology.com, 2015)

The vessel used as a base for the Kikeh FPSO is a tanker built in the 1974. The conversion work completed in 2007. The dimensions of the vessel is as follows:

Length: 337 meters.

Breadth: 54.6 meters

Weight: 273000t.

Storage Capacity: 2 million barrels.

Offloading rate: 37500 barrels per hour.

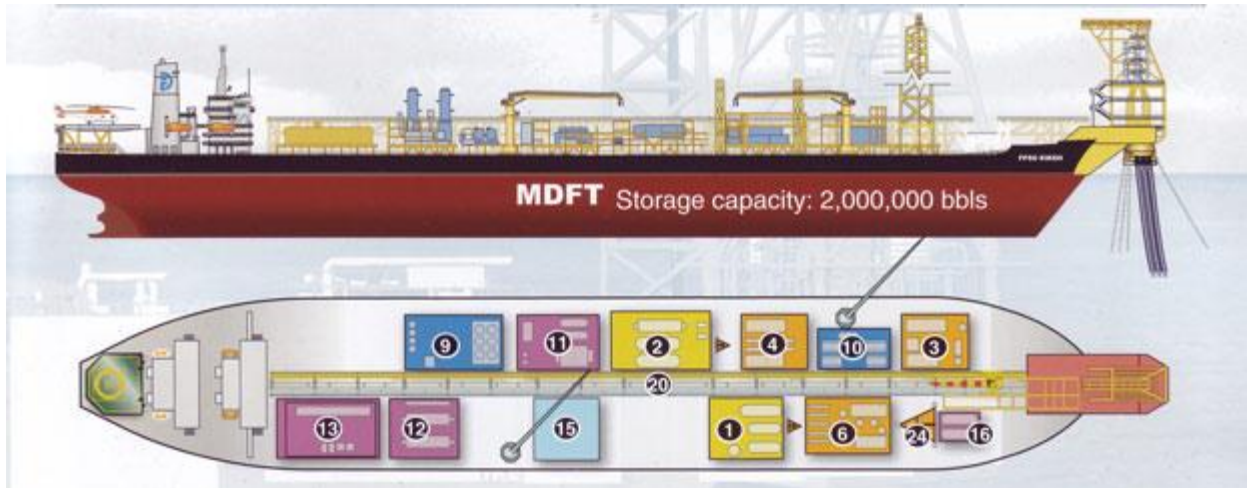


Figure 18: FPSO Kikeh Storage (offshore-technology 2015)

The FPSO is expected to return a production outflow of 120000bpd and water injection is expected to run at 260000bpd. The compression of gas is 135 million cubic feet a day. (Offshore-technology.com, 2015)

The external turret of the FPSO has 17 risers. These risers are flexible with a diameter of 8in to 10in. These risers are segregated to 9 operational risers; 4 risers that are in standby mode; 3 umbilicals and one spare riser.

The swivel of the FPSO has built in within it:

- 1) 12in Subsea production line within it along
- 2) 14in production line capable of withstanding high pressure,
- 3) 10in oil import line,
- 4) 10in low pressure production line
- 5) 16in water injection line
- 6) 8in test / pigging line
- 7) Multi-path double-drum
- 8) high-voltage power electric line
- 9) low-voltage / signal line
- 10) 8in gas export line

Three turbo meter runs coupled with proper loops make up the metering system.

The vessel has carbo pumps that has capacity of 4500 m³/hr.

Two units of 12MW steam generators and another two units of 1800kW diesels make up the power source for the FPSO. There are also two units of 87t/hr boilers in the hull.

Export is done through the utilization of the tandoom moor system. This FPSO is the largest of all FPSO made in Malaysia and also holds the record for the largest external turret of any FPSO in the world. (Azmi and associates, 2008)



Figure 19: FPSO Kikeh in shipyard (Modex.com 2015)

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION

Methodology for the review study of floating, production, storage and offloading oil and gas platform (FPSO) is explained in this chapter. Chapter 1 outlined the background of FPSO, and the problems and statements faced in this study. Literature review detailed the development of oil and gas and its importance and the FPSOs development and the FPSOs in Malaysia through chapter 2.

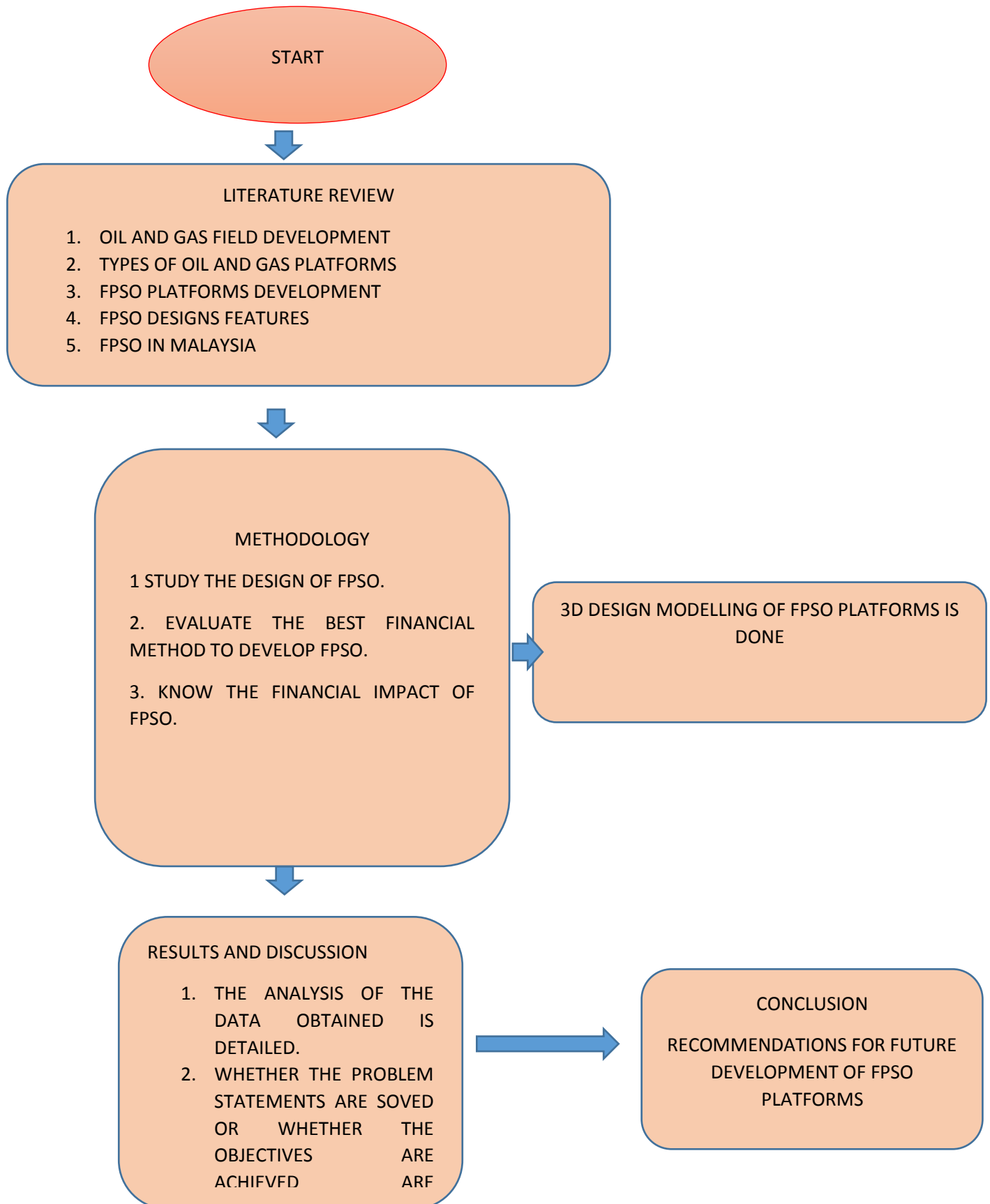
The methodology will focus on increasing the efficiency of the FPSO and making it more economically viable and effective for Malaysian waters. Technological developments needed for the improvement and the basic design changes on FPSO will be discussed and detailed.

The main features that give impact towards the efficiency of the FPSOs operation is the design of the FPSO. Most FPSO are converted from tankers and therefore there would some key features that would not be incorporated in the hull due to design restrictions and that impacts the operational efficiency of the vessel.

The review study of floating, production, storage and offloading oil and gas platform would focus generally in ways to improve this operational efficiency especially

corresponding to the waters offshore Malaysia where the majority of oil fields in this country are located.

3.2 PROJECT PATHWAY



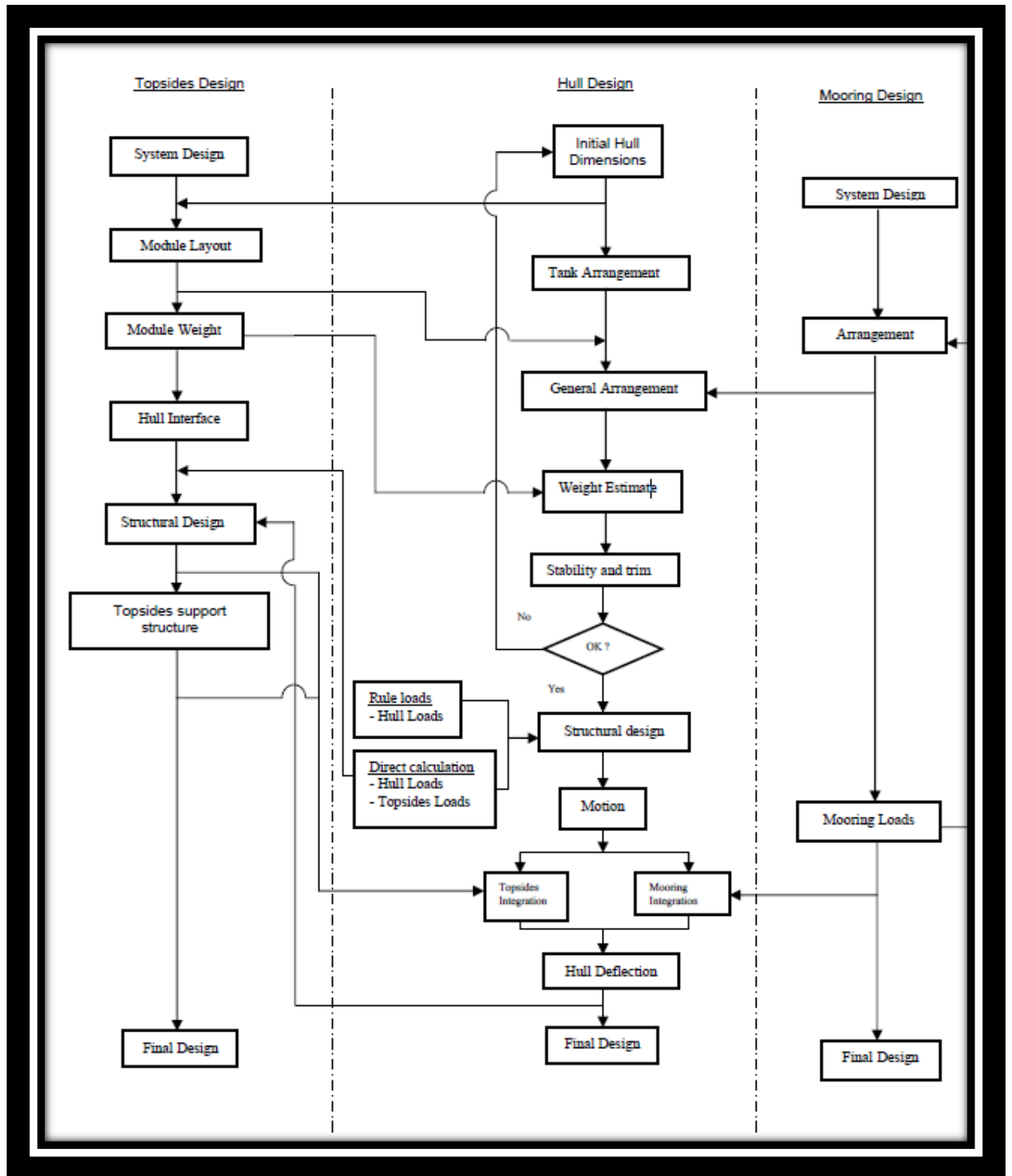


Figure 20 - Example FPSO Simplified Hull Design Procedure

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Economics and development

Deepwater oil and gas developments being given the spotlight currently for the past decade to satisfy the increasing need for fossil fuel. This was different from previous situations where shallower water oil fields were given the emphasis. Currently most oil and gas fields are over 1000 feet deep. (Hughes, 2010)

Over the next half a decade at about 150 deepwater exploration projects are about to be started. These projects are being done in a global scale. The area of particular interest is the area bordered by Brazil, the Gulf of Mexico and West Africa. This area is known as the golden triangle. The reason why this area is of interest is because it constitutes to about 77% of the deepwater exploration projects planned for the next half a decade. (Hughes, 2010)

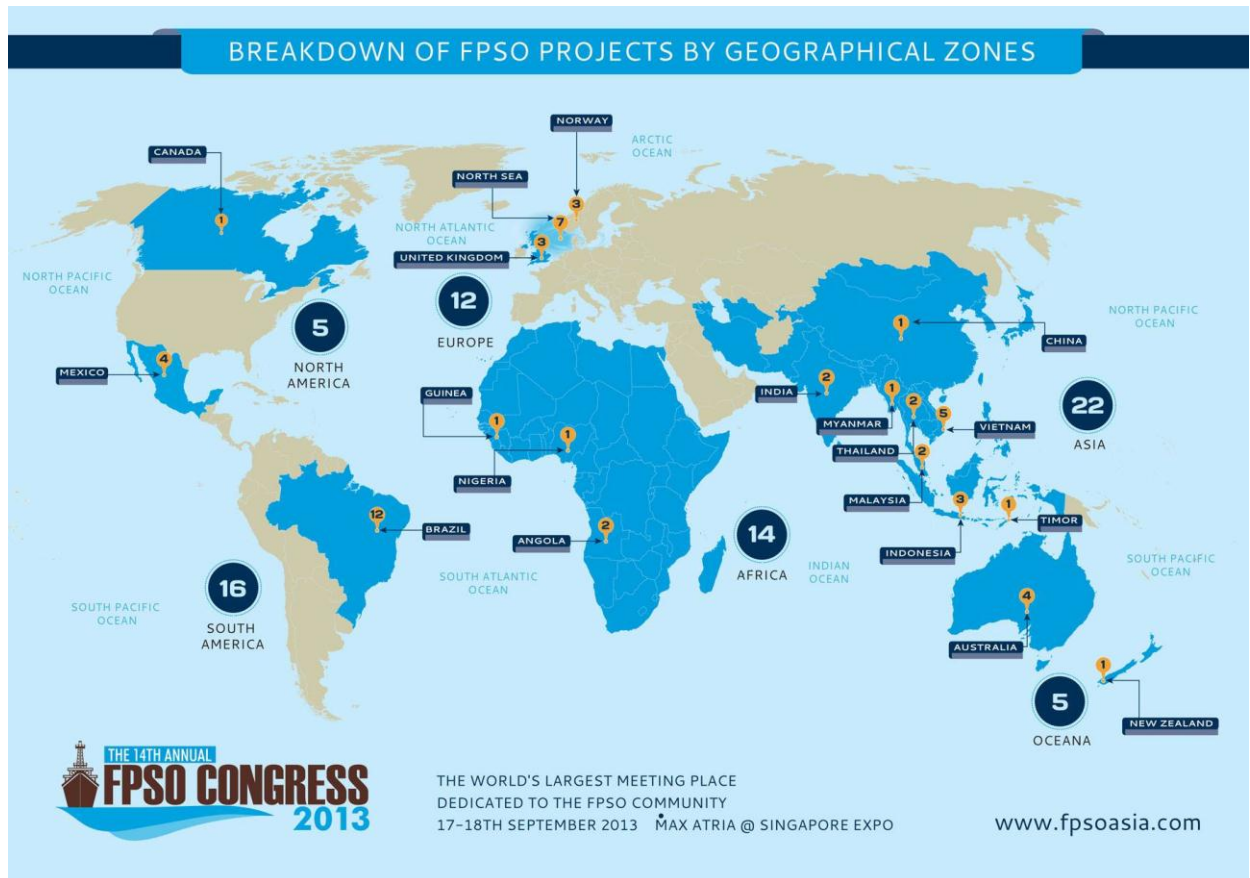


Figure 21: FPSO Projects (Oilandgasiq.com, 2015)

With the world's economic in turbulence due to the unstable price of crude oil due to various crisis, the developing projects and planned projects of oil and gas explorations and production are reimbursed to minimize losses. This being said, the deep-water oil and gas developments are predicted to grow proportionally with a predicted capital investment of \$167 billion in the year 2014 alone. The technologies used in this sector is a big factor for this. FPSO s play a huge part in this. (Hughes, 2010)

Current Deepwater development methods have come under fire due to some recent incidents which affected the environment and economic. The risks involved to the environment and the costs involved in extracting oil and gas thousands of meters below the sea are high therefore every form of technology is studied to obtain the most suitable

technology. Deepwater sector is most viable currently due to the shallower fields being depleted of hydrocarbons due to over harvesting. Starting the new millennium major oil and gas companies have committed to the explorations of depths of 7500 feet and below-a sector the US Minerals Management Service has deemed as the “ultra-deepwater” sector. The year 2013 saw the Company BRITISH PETROLEUM extracting oil and gas from the deepest field located in the Gulf of Mexico at a depth of 35000 feet. Studies tell that the deep water section of Gulf of Mexico holds as much as 3.8 billion barrels of oil with 21.5 trillion cubic feet of natural gas. And this is the eastern coastal region. The Atlantic coastline hold another 3.8 billion barrels of oil with 15.1 trillion cubic feet of natural gas between Delaware and Florida. Deepwater oil and gas developments constitutes to about 15% in the global offshore oil and gas production. (Hughes, 2010)

Although the Gulf of Mexico saw the risings of spars and tension leg platforms (TLPs) initially, the major workhorse now is the FPSO when the industry moved to the deepwater sections. Most oil and gas company’s globally operating offshore fields have understood the effectiveness of this platform. (McCaul, 2015)

The fleet of FPSO are growing with a 25 percent in increase compared to the units’ operational half a decade ago and a whopping 85% higher than the numbers operational a decade ago. The increase has been 144 units of FPSO in the past 15 years. (McCaul, 2015)

Out of the 264 floating production platforms in existence 63% are FPSOs. While the others are semi submersibles, tension leg platforms, production spars, production barges and floating regasification/ storage units. Another 102 units are floating offloading units (FSOs). (McCaul, 2015)

The most number of production units are in service in the Brazil waters. Currently 55 floating production units are stationed offshore in this country consisting of 35 FPSOs, 18 production semis, and 2 FSRUs. The second highest number of production units in service is in the waters of West Africa with 48 FPU while Gulf of Mexico has about 47 units, followed by Northern Europe with 39 units and Southeast Asia with 27 units. The trend of FPSOs is a dominant one increasing by the years

according to the industries development, with a total of 61% in terms of the preferred platforms in many situations. (McCaul, 2015)

4.1.1 Backlog of Production Floater Orders

The orders of Production Floaters are at a very high level meaning the demand for it is very high. The current backlog is about 77 production floaters. The majority of these consists of the FPSO which are at a demand of 44 units. Others include 7 production semis, 5 TLPS, 5 spar units, 12 FSRUs and 4 FLNG units. Inventory of the floater production will expand by 29% with the delivery of the equipment. The orders are made of 46 units that is built and designed from the ground up with a purpose built hull. The remaining 31 units are converted from cargo ship hulls that are retired. 46 units are owned by field operators while 31 units are supplied by subcontractors who lease the service. (Addison and Energy, 2015)

Still Brazil makes up the majority for the orders with 26 units that are going to be deployed in its offshore region which is 34% of the entire backlog orders.

4.1.2 Planned Projects

Planned oil and gas projects requiring the usage of floating production storage and offloading units are also on the increase with a 134 projects planned five years back that number has risen to 216 last year and currently 248 projects are in the planning stage. Brazil is the hotspot dominating the majority of these planned projects with the highest demand of FPSOs. The large amount of presalt oil reserve that exists offshore Brazil is fundamental in giving rise to deepwater blocks. Africa is the second largest while Southeast Asia, Gulf of Mexico and Northern Europe make up the rest. (Addison and Energy, 2015)

The increasing amount of planned projects influences large increase in demand for deepwater drill equipment for the past ten years. 150 drillships or deepwater semis are being demanded since 2003. This incident removed the throttle that deepwater development and exploration had. And this also spearheaded the high increase of FPSOs in the planned pipeline projects. (Addison and Energy, 2015)

The reasons for this FPSO dominance are not a matter of technology – all the technologies are basically proven – but ultimately a matter of economics. The key drivers for establishing the type and shape - and ultimately the cost - of a floating production platform include:

- Reservoir and petroleum – what is the geometry and connectivity; what are the likely recoverable reserves; what are the rock properties; what are the fluid properties; what is the depth below mud line; is there any salt? These in turn drive choice of:
- Drilling & completions strategy: well count, well locations; flow assurance; intervention strategy; dry versus wet trees; leading to a production profile.
- Water depth, metocean conditions and distance from shore determine issues such as the type of riser; station keeping; whether a pipeline is feasible. (Addison and Energy, 2015)

4.2 Types of Oil and Gas platforms and Their Characteristics

4.2.1 Semi-submersible

The floating systems when first were introduced, the semi submersibles were highly sort after. The platform is extremely stable because of its combination of the hull mass and the amount of its displacement plus the wave penetration of the hull due to its column structure in addition to its height that makes the waves however strong they are pass

through the entire body without harming the topsides or giving any kind of horizontal movement. The entire platform has very limited roll, pitch, sway, surge, heave and yaw. This design feature allows it to work in many types of challenging conditions. (Petrowiki.org, 2015)

The semi-submersible platform is made of topsides which house the processing and production units which are above the platform supported by the hull and the stabilizing system is the spread moors. Vertical motion is checked by the small water plane area that the semi possess. Wave influenced movement is not affected by the spread mooring of the semis. The working depth is varied with some at 100ft while the deepest is at 9,472 ft offshore Brazil in 2003. The deep-water block in Brazil that houses this semi-submersible uses dynamic positioning system (DP) and a surface blowout preventer (BOP). The deepest in Malaysian region was set in 2002 with a spread moored system at 6,152 ft. (Rigzone.com, 2015)

There is a risk in semi submersibles when working in shallow waters which is that there is a possibility that the lower hulls might collide with the surface blowout preventer unit when the semi-submersible moves from the location. Minimal water depth is set according to few factors mainly the distance of the surface blowout preventer unit that is in the subsea level with its stack at the time when disconnection happens to the marine riser which is below it. The hull below in case the platform moves off the location. The factors of heave, tidal range, slip joint space out, and ability to stay in location are also vital. (Petrowiki.org, 2015)



Figure 22: Semisubmersible (Rigzone.com, 2015)

Advantages of the Semisubmersible:

- Less sensitive to water depth than TLPs
- Wide range of payload capacity
- Installed as a fully integrated system
- Maximum execution plan flexibility
- Support of remote wells
- Drilling and work over capability (using subsea BOP)
- Can be easily redeployed

Limitations of the Semisubmersible

- Platform motions
- Cannot support TTRs
- SCR fatigue

The above mentioned limitations are general in nature. The critical objective when developing a Semi configuration is to minimize motions to meet functional requirements such as SCR support and processing up time.

The Semi is perhaps the least complex to integrate and install but the overall motions performance is less favorable than the Spar or TLP. The motions therefore have more impact to functional capability and performance. (Rigzone.com, 2015)

4.2.1.1 Semi Submersibles in Malaysia

The largest semi-submersible in Malaysia currently is the Gumusut – Kakap. The hull of this mega structure itself weighs in at about 19,000MT and was designed by Shell. The storage capacity of this vessel is 20,000 barrels if in terms of crude oil, 25832 barrels of methanol, and 4,145 barrels of diesel and 7122 barrels of water. The topsides are designed by the company Technip GeoProduction (M) Sdn Bhd. The topsides are weighed at about 20,000 Metric Ton. (Misc.com.my, 2015)

The structure is divided to few main parts. To make logistics easier the modules are integrated and categorized as South, North, East and West on the topsides. The topsides also consists of living quarters that can accommodate 140 man, a Temporary Living Quarters that can hold up to 132 man and 11 technical buildings that are control rooms for Production, Subsea, Flash Gas Control, Switchgear, Warehouse and Generator buildings. The production rate is at 150,000 barrels of crude oil per day with a gas re injection of 300 million standard cubic feet per day and 225000 barrels of water per day. There are 19 well slots in the topsides. The built of the platform began with the assembly of the modules that made up the topsides. The modules where built onshore and then transported and lifted by utilizing a lifting tower and strand jacks following the super lifting methodology. (Misc.com.my, 2015)

The blocks that made up the hull that are made of columns and pontoons were built section by section and erected on skid rails in a way that it would be adjacent facing the modules that are the topsides. The two structures are then joined together with

the modules first being raised by the super lift frame to a height of about 45 meters from the ground up. The hull is then pushed beneath the risen topside modules and then the super lift lowers the modules on the hull and the modules and components are secured in place. The entire process is very time consuming and takes a huge amount of economic resources. The built consumed 40 million man hours and 5000 personnel were involved in the construction. The superlift is the largest onshore topside lift and was purpose built for this process. The semi is currently stationed of about 1200 meters of depth and expected to remain in service for another 30 years. (Misc.com.my, 2015)

4.2.2 SPAR

The SPAR platform is a structure that has drilling, production, and storage built into one mega structure. The structure is made of a big cylinder in a vertical position that holds the topsides. The majority of the mass of the platform is located under the water and this adds to the structures stable placement. (Rigzone.com, 2015)

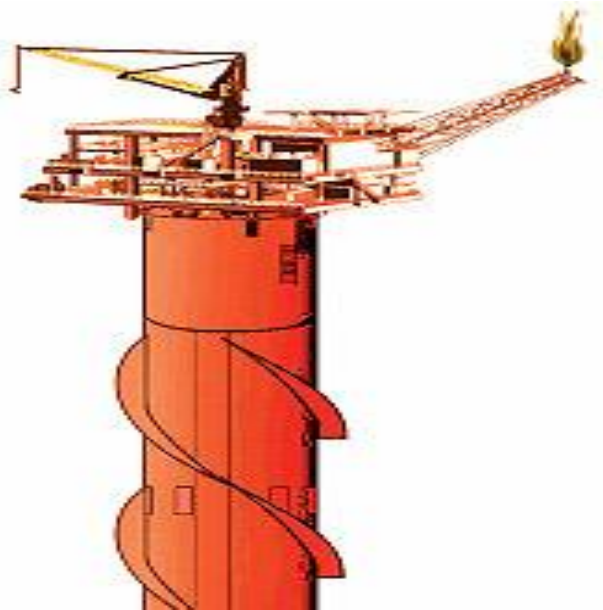


Figure 23: Traditional Spar (Rigzone.com, 2015)

4.2.2.1 Traditional Spar

Spars were designed back in the year 90s when oil and gas development began in the Gulf of Mexico. The first Spar made was for the Neptune field in the Gulf of Mexico.

Spar Types:

1. Original Spar Design
2. Truss Spars
3. Cell Spars



Figure 24: Truss Spar (Rigzone.com, 2015)

4.2.2.2 Truss Spar

The design of the Truss is modeled around a hull that is in a cylindrical shape but shortened compared to other spar versions. This hull has a truss inbuilt into the lower section of it. Stabilizing plates are also integrated below it to reduce motion of the

structure in the vertical axis. The truss spar weighs lesser than the original version due to the less amounts of material particularly steel used in its construction and the capital cost to build it is also low. (Rigzone.com, 2015)

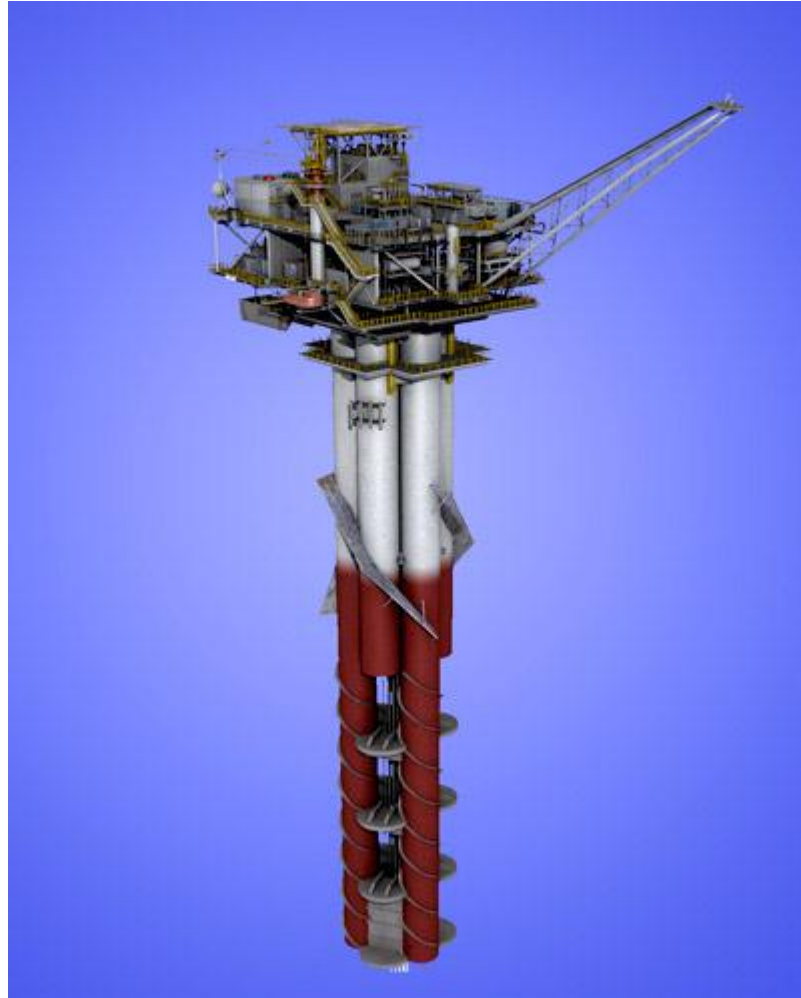


Figure 25: Red Hawk Cell Spar (Corporation, 2015)

This particular Spar is the latest rendition. The Cell Spar is actually a smaller version of the original design. A central vessel is surrounded by 6 other vessels. These are pressure vessels and are mass produced easily and takes very little cost to make. These vessels are in place to give buoyancy for the structure while the platform is kept in position by structural steel. The structural steel giving support connects the vessels lower part to the deep draft design adding to the stability of the structure. (Rigzone.com, 2015)

4.2.2.3 Mad Dog Spar



Figure 26: Mad Dog Spar (Corporation, 2015)

The buoy was made to accommodate the gathering of oceanographic information and the vital and central equipment of the structure is the deep-draft floating chamber which makes up the cylindrical shaped hollow hull. To add to the stability the hull is engraved with strake spirals that surround it. The low end of the cylinder has a ballast. The ballast consists of a material that has higher weight than water. This formulation ensure that the center of gravity is below the center of buoyancy. This design namely the deep-draft specification ensures that the platform is highly tolerant to wind, wave movement and current motions. This ensure the platform to play host to subsea and dry tree components in its operation. The totally sealed cylinder structure enables the risers and the

equipment to be totally protected from water damage or moisture impartment. The hollow hull also acts as a storage for completed oil and gas products. (Rigzone.com, 2015)

4.2.2.4 Neptune Spar.



Figure 27: Neptune Spar (Corporation, 2015)

The topside is located on the hull itself. The topside contains the drilling plant, production facility and the manpower accommodation. The drilling process is done controlled from the topside and carried out through the hollow hull that is conveniently cylindrically shaped. The hollow hull houses the drilling units and import/export as well as the risers that give wake to production. The entire structure is moored to the seabed. (Rigzone.com, 2015)

Normally various mooring is used to anchor the hull to the sea floor. Although this is done, SPAR platforms do not need to be dependent to mooring to be stable and in position. This is due to the fact that their center of gravity is below the center of buoyancy. (Rigzone.com, 2015)

4.2.3 Floating, production, storage and offloading platforms (FPSO)

Two types of FPSO exist, purpose built for the oil field operation or converted from old and decommissioned tanker ships. The converted FPSO are made with firstly stripping down the tankers and installing the mooring machinery in it. FPSOs are of different specs and some have higher processing capabilities that can be utilized for the LPG (Liquid Petroleum Gas) storage in liquid phase. The design of the FPSO is influenced by the area of the operation. Normal calm waters without much disturbance a converted FPSO can be operational without much modification. (MOSES and Rex, 2012)

The basic design is a simple box shape. The production components begin with the risers which are connected to the turret, which is a component that is charge of the stabilization of the entire vessel. The turret makes the vessel to sway and move and rotate in whatever direction that the wind and waves and currents are making the vessel to do so. This reduces the force of the current and the wind on the mooring of the vessel. (MOSES and Rex, 2012)

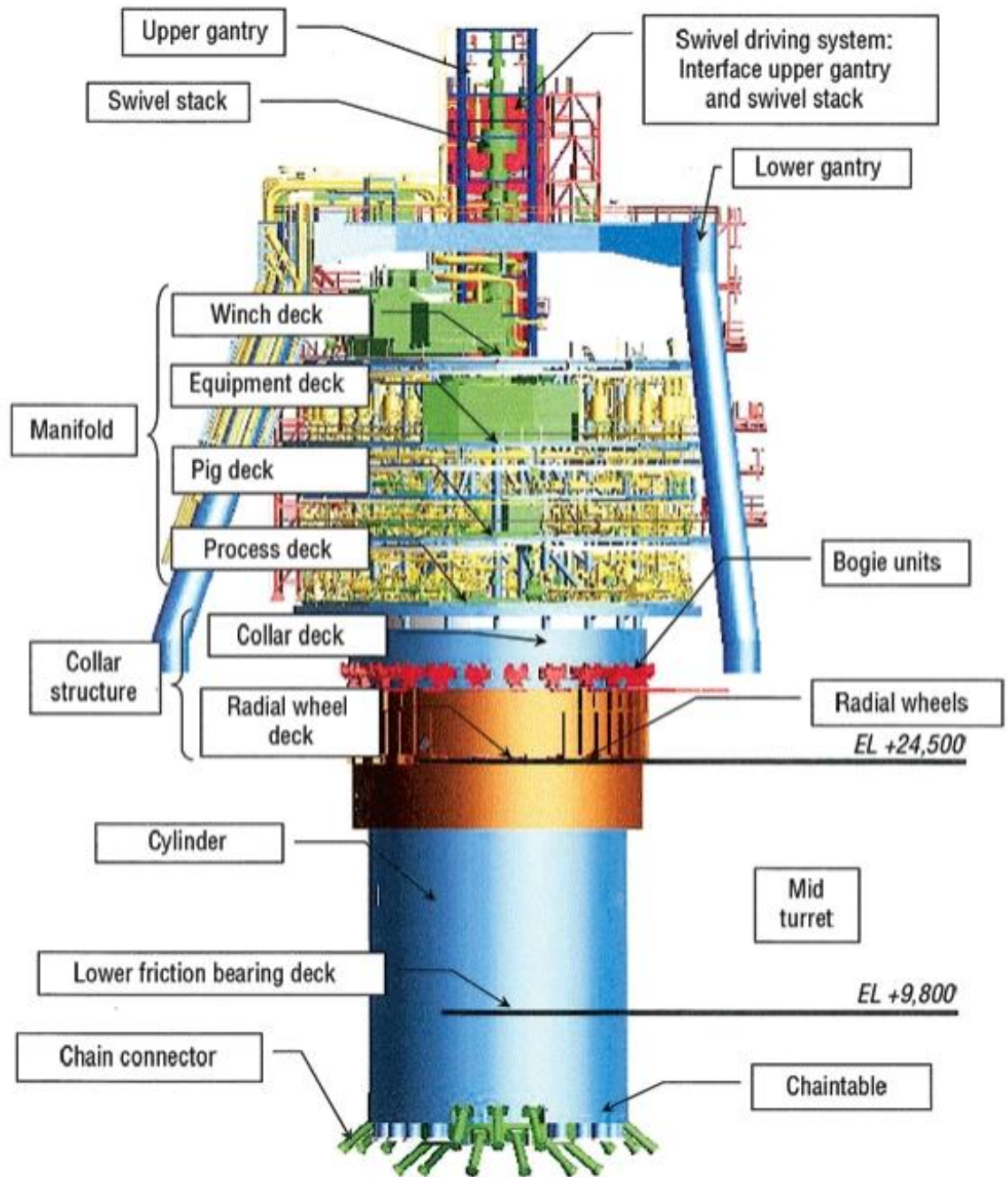


Figure 28: Turret components (Howell et al., 2006)

The turret encompasses the mooring of the FPSO along with the installation equipment of the anchor and the risers and the anchor legs and the fluid transport along with the risers and its support. The turret also houses the manifold. Pig launching and receiving, metering, chemical injection and the subsea control systems in a self-contained multipurpose structure. (Howell et al., 2006)

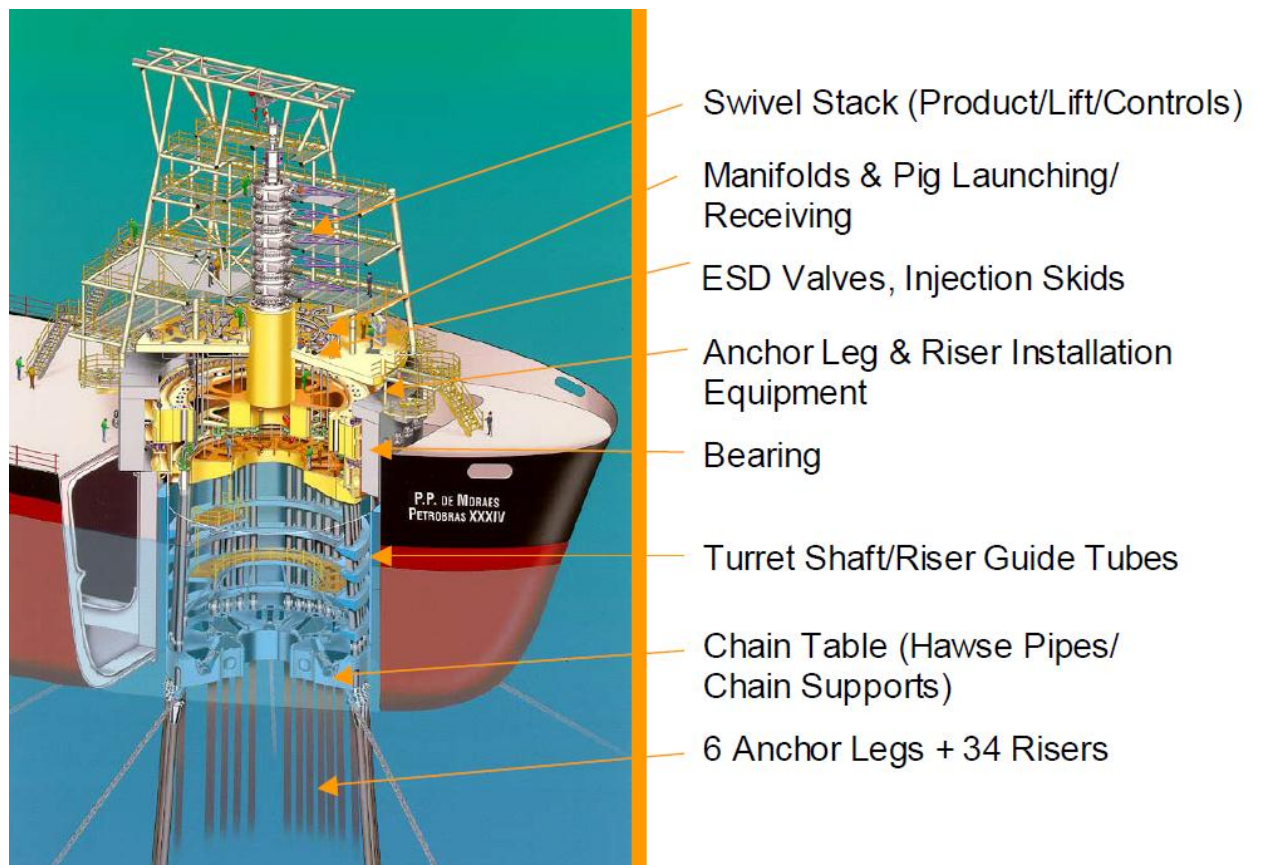


Figure 29: Turret of an FPSO (Howell et al., 2006)

In calm waters the turrets are outside the vessel in the either end of the hull of the FPSO. Places like West Africa see the operation of FPSO s like these. The turbulent waters for example the North Sea see the operation of FPSO with internal turrets. The

turrets are designed to be either permanently moored or be removed depending on the conditions. (MOSES and Rex, 2012)

4.2.3.1 Mooring of an FPSO

FPSO's mooring system consists of the line, anchor and the connectors. Each serve a specific purpose. The mooring has the main function of maintaining the vessel afloat regardless of the depth and the condition of the water. The mooring line joins the vessel to the anchor located on the seafloor. (Rigzone.com, 2015)

The mooring line is a vital component and the strength of it is important for the safety of the vessel. It is usually fabricated of synthetic fiber rope, wire or chain. In some case all three materials will be used. The materials used in the fabrication is determined by external aspects such as the wind, waves and the current patterns in the area of the field. Permanent mooring of the FPSO uses the line made of chains especially in low depth areas with 100metres or lesser. Deeper places with 300 meters and declining uses steel wire line since the chain with increased density sinks faster and reaches the desired depths faster. The lightest of all materials is the synthetic fiber but the cost to manufacture it higher. While normally mooring uses the combination of chain with wire or in some cases purely just chain the ultra-deep water section which exceeds the depth of 2000 meters sees the usage of combinations of chain with synthetic fiber or wire with synthetic fiber

Six ways of moorings can be done. They are categorized as catenary, taut leg, semi-taut, spread, single point and dynamic positioning. (Rigzone.com, 2015)

4.2.3.1.1 Catenary systems.

Used predominantly in shallower regions. The line hangs freely and the shape is influenced by the movement of the ship and it constantly changes shape. The mooring line is stationed horizontally in the seafloor. For this aspect of the design the length of the line must be longer than the depth of the water. Complications arise because as the length of the line is longer the mass of the line increases and as the water gets deeper and deeper the payload of the FPSO is reduced dramatically as the line is dropped out. To curb this issue, synthetic rope is used since it has very little weight. The disadvantage is that in deeper regions this system is economically expensive.

Polyester rope is used in this design. The rope is pre tensioned up to point when it becomes tensed. The rope is angled at a 30 to 45 degrees to the seafloor when connected to the anchor. Normally suction piles or vertically loaded anchors are used with this mooring system. The FPSO drifts with the current or wind and this motion tenses the line and sets the entire mooring up. (Rigzone.com, 2015)

4.2.3.1.2 Semi taut

This system is a combination of taut line and catenary lines in one system and utilized in deeper regions. (Rigzone.com, 2015)

4.2.3.1.3 Spread mooring

The most versatile mooring system this design utilizes many lines dropped over the stern and the bow of the vessel attached to the anchor in the seabed. The FPSO is stationed in a permanent location depending on the water and the weather aspects. Since the anchors are holding the vessel in place by giving a force on all sides the vessel does not move in any direction. Sway is also very minimal. This system ensures maximum stability and can be utilized in various combinations in spread pattern or a group and in any depth. (Rigzone.com, 2015)

4.2.3.1.4 Single point mooring

This system connects all mooring lines to a single point. The connection between subsea manifolds with the weathervaning tanks are done with an ability for the connection to rotate and move freely in all angles. This eliminates twist and breakage in turbulent waters. A buoy along with mooring and anchoring components are utilized with the product transfer. (Rigzone.com, 2015)

4.2.3.1.5 Dynamic positioning

This system uses a computer signal that maintains the stability and the position of the vessel by controlling the thrusters and propellers accordingly. It starts, stops and differentiates the speed and force of the thrusters and propellers constantly adjusting the ship's position. The most effective method of positioning and also the most expensive. (Rigzone.com, 2015)

4.2.3.2 Anchors

The holding capability of the anchor defines the mooring's strength. The holding capability is influenced by the digging depth and the soil characteristics of the field. There are three species of anchors: drag embedment, suction and vertical load anchor. (Rigzone.com, 2015)

4.2.3.2.1 Drag embedment anchor (DEA)

It's the most used on FPSOs particularly in the Gulf of Mexico. The mechanism starts with the anchor being dragged on the seafloor. Once it reaches the targeted depth the friction it makes with the seabed soil creates an opposite reaction force and along with the mass of the soil it has pulled while being dragged stops and holds it in place. This works best for catenary moorings since it's a horizontal process and this design cannot be used for any vertical applications. (Rigzone.com, 2015)

4.2.3.2.2 Suction piles

Deepwater field FPSOs are reliant on the suction pile anchor. Tube shaped piles are forced into the seafloor. Then a pump takes out the water and this water is driven out from above the tube. This action of sucking the water and the sucked water moving upward and exiting above creates a sucking force that pushes the tube further into the seafloor. This design is efficient in sand, clay and mud type soils but inefficient in gravel since the gravel allows water motion among it. This system is extremely stable when in position since the resistance between the pile side and the soil holding it place makes it impenetrable by vertical or horizontal forces. (Rigzone.com, 2015)

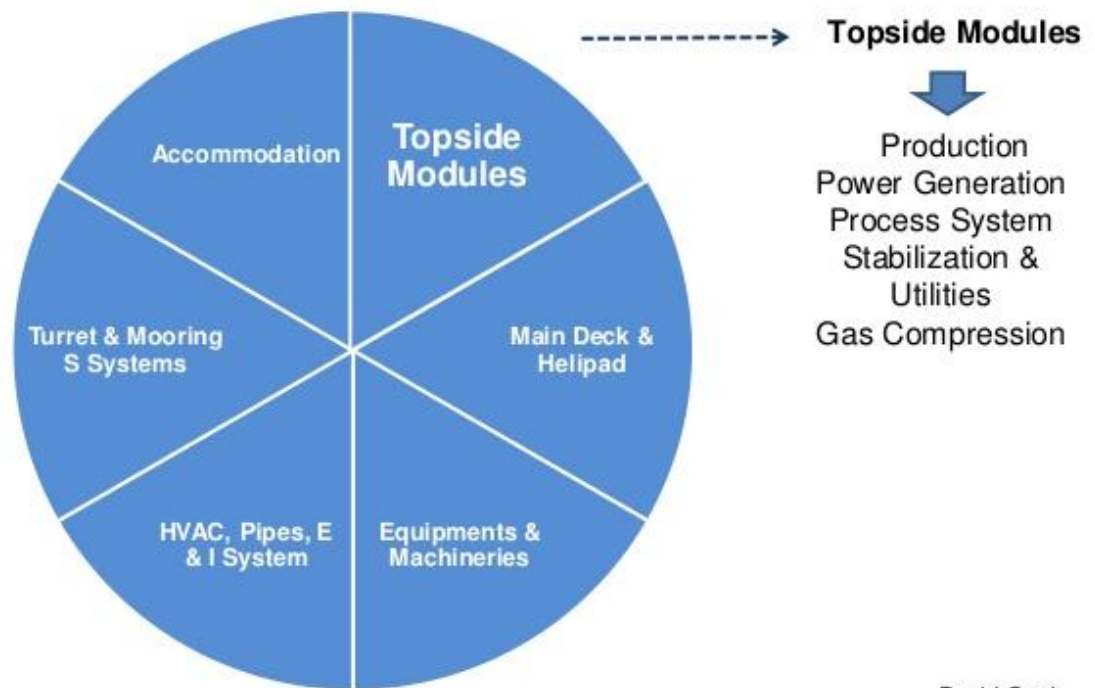
4.2.3.2.3 Vertical load anchor

The mechanism is likewise that of drag embedment in terms of the initial placement of the anchors. The added advantage is both vertical and horizontal impacts because since it's utilized in taut leg type of moors the line touches the seabed at an angle. (Rigzone.com, 2015)

4.2.3.3 Major processes in the Topsides

Topside Process Modules (production stabilization & utilities gas compression power generation, gas dehydration)

FPSO - Main Components



David Seah

Figure 30: Topside Modules (Seah, 2015)

Topsides processors that occur are the receiving of fluids from subsea well through the turret pipe lines, processing inlet fluids to separate crude oil from water and natural gas, Dewatering and stabilize the crude oil in order to meet the export quality specs (max h₂s) Storing of the stabilized crude in dedicated vessel cargo tanks and offloads to the shuttle, Compressing and dehydrating associated gas and send to the oil wells as lift gas, treating the produced Fuel gas for burning in boiler, gas turbine and flare in order to meet the air emission regulations and to limit the h₂s in the gas and

treating the produced water in order to meet the regulations for discharging to the sea.
(Rajendran Nair, n.d.)

The major processes in the FPSO are contained in the production manifold, crude oil separation and treatment, crude oil stabilization, crude oil transport and storage and offloading, produced water treatment and stripping and lift gas/kick off gas compression.
(Rajendran Nair, n.d.)

Major utilities include the fresh water generation unit, seawater for topsides, and compressed air unit and nitrogen generation along with various drains for transportation.
(Rajendran Nair, n.d.)

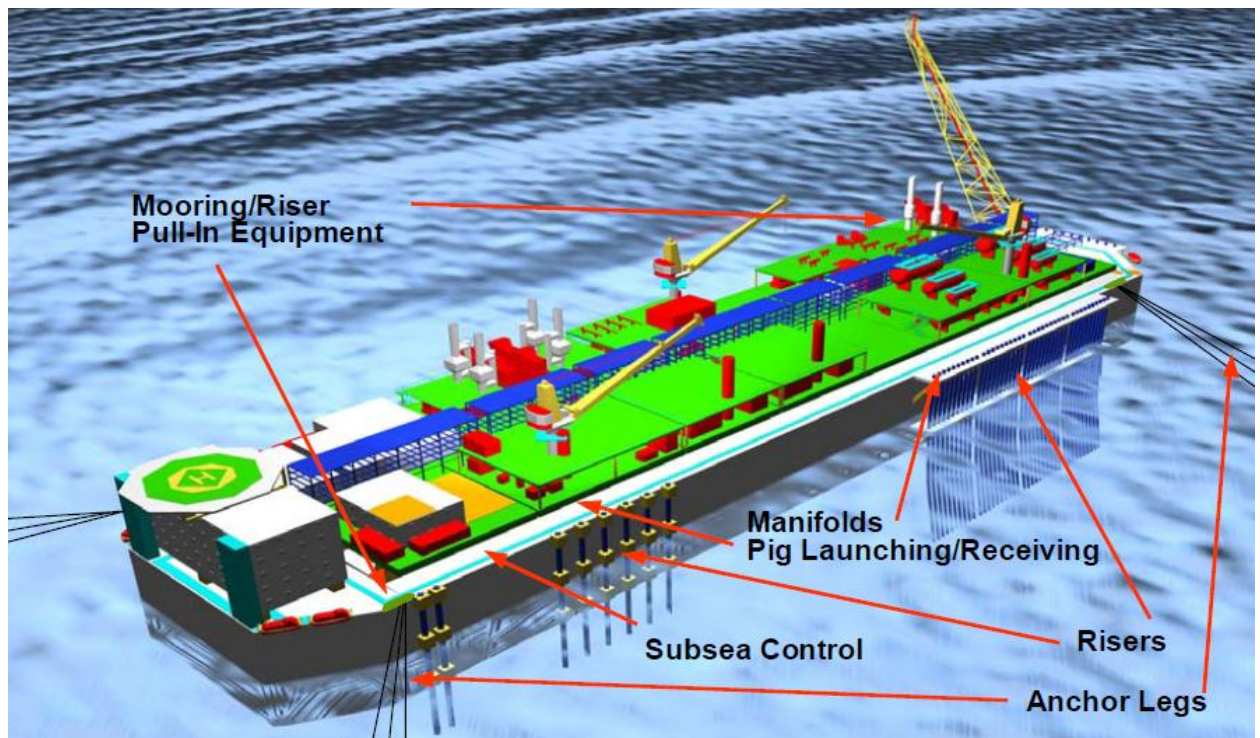


Figure 31: Configurations of an FPSO (Howell et al., 2006)

4.2.3.3.1 Topsides

Topsides provide the necessary equipment for the processing of various type of hydrocarbons and this enables onsite conversion into usable end products that can be marketed. Intricate facilities are needed to handle hydrocarbon extracted because different types of hydrocarbons behave differently. The hydrocarbon types can differ according to geographical areas. Crude is made of black oil, condensate, sweet and sour hydrocarbons. The topside designs are also influenced by oil property nuances, payload of the vessel, the oceans condition and the mooring used in the field. (Rajendran Nair, n.d.)



Figure 32: Topside Configurations

Cost effectiveness -The minimum capital investment to design and fabricate the topsides and reduce cost in long term by using hardy material that would eliminate the need for maintenance.

Schedule improvement -Modules would be faster to fabricate and install and ready the vessel for deployment for operation.

Flexibility – interchangeable modules that can be replaced or modified to suit another working field after operation in one field has finished and moving on to another field.

Interchangeability – changeable to other operating modules with other functions that would be needed in the future or in different working conditions.

Scalability –Scaled accordingly to compare with production

Expandability- layout to provide room for more modules in the future

Quality control- field proven and dependable

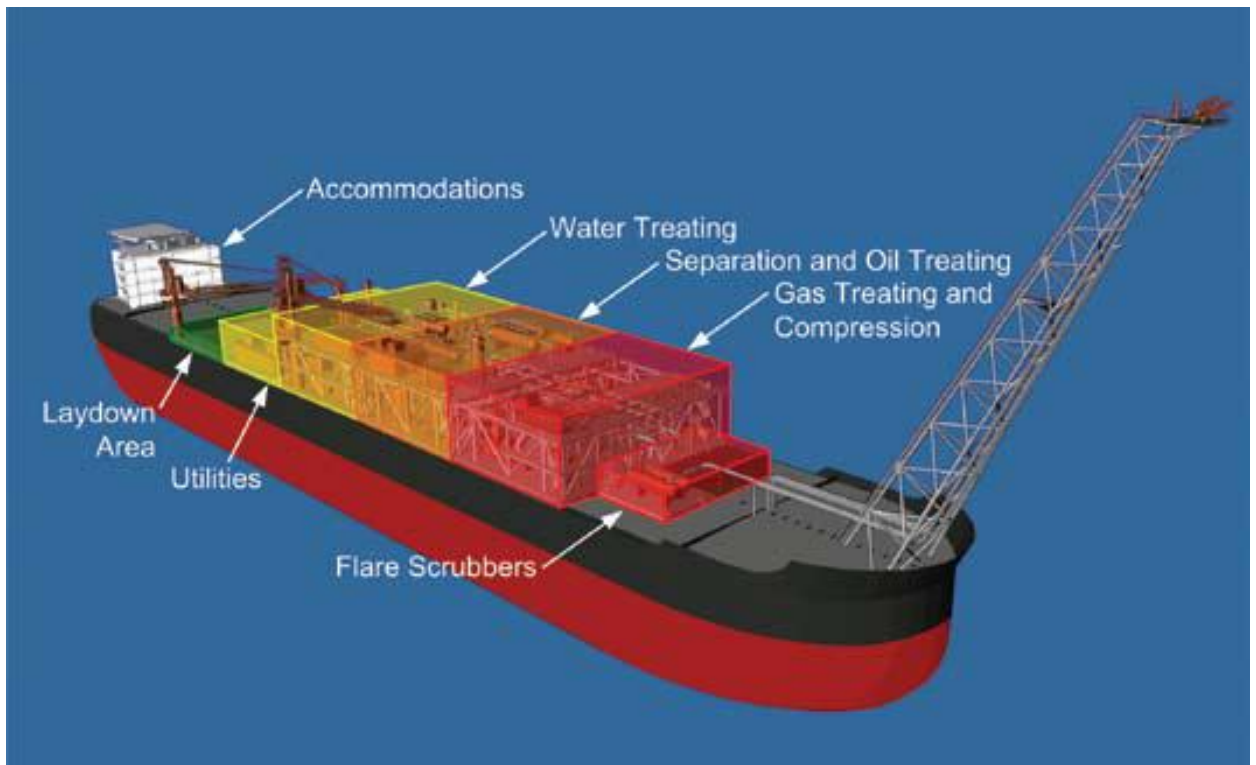


Figure 33: FPSO Topsides Modules Integrated (Mueller and Roobaert, 2008)

Layout is influenced by the risk level of the modules with the most hazardous modules installed further from the living quarters and are shaded red in the picture above. The modules with high risk are the ones containing gas compressors, production modules and vents and flares and storage for oil and gas. (Rajendran Nair, n.d.)

These designed modules can be custom made to meet the operating field's condition and specially made for each type FPSO.

- Standardized design modules would meet applicable safety standards and industry design practices, and can be tailored to meet operator requirements.

Normal configuration has a pipe rack in the middle of the vessel in the length of the bow to stern and these pipes should be in proper arrangement with minimal intersections.

The standardized layout uses a central corridor with modules on either side or pipe racks running from bow to stern. (Mueller and Roobaert, 2008)

The vessels center of the body is filled with the stabilizers and main contactors which serve as a basis to control the stability of the ship and also since the major mass is located in the center this enables lesser motion of the vessel. High speed rotation equipment such as turbines and generators are centered along the middle of the FPSO to ensure a proper centralized center of gravity. Reciprocating compressors are placed transversely in cylindrical housing along the hull and this coupled with hulls bulkhead counter reacts the forces emitted by the work done and balances itself.

Pipe racks are usually integrated to the modules when it's built to reduce the cost and increase the space utilizing efficiency on board the vessel. The production, separation and treating units are connected and segmented to ease operation. Other processing units are added depending on the demand of the operator. (Mueller and Roobaert, 2008)

Crude oil heating systems, desalting process units, heavy oil dilution unit, sand and sulphur removal units are only included into the design if the raw material properties needs it. The number of stages of the process, treating unit types and the equipment utilized purely is determined by the crude composition and production yield requirement. (Rajendran Nair, n.d.)

The gas process side sees the recovery, dehydration, compression being carried out to supply gas for end product or re-injection. The compressed gas also serve as a lift gas that increases the oil production. (Mueller and Roobaert, 2008)

Hydrocarbon dew point control units are installed whenever a minimization of hydrocarbon dew point is needed and Btu reduction is done. Sour gas treating units are vital. Gasses such as H_2S and CO_2 must be removed or treated efficiently. (Mueller and Roobaert, 2008)

Water treating is done by the extraction of oil from the water produced and the water is either injected into the field or used overboard for other applications. The sand and other soil removed is evacuated elsewhere. The water injection pumps that are utilized to maintain the pressure of the reservoir are inbuilt into the injection units. Seawater that is used to inject back into the reservoir needs to be deoxygenated and that too is carried out by the unit. (Rajendran Nair, n.d.)

4.3.2.4 ADVANTAGES

The first and foremost advantage of the FPSO is the fact that it can be used to store the oil produced from the fields. It is cost effective to do so than to have an additional storage space for storage purposes. It is also convenient that in a case of emergency and the storage and offloading vessels can't reach the platform in time that the production will not have to be stopped. The produced oil can just be stored. (MOSES and Rex, 2012)

FPSOs are used in normally isolated areas with no pipeline facilities to transport the oil and gas produced. Therefore the only viable transportation of the products to the shore is by a shuttle vessel. FPSOs are compatible to be moored alongside most mainstream type shuttle vessels and can safely and efficiently transfer the oil. (MOSES and Rex, 2012)

FPSOs have progressed fast with a hold on 63% of all floating production systems used globally and are estimated to be higher in usage for the next years to come. The factor that governs their dominance is the existence of foolproof technology and efficiency of the entire platform. In terms of weather and sea conditions the FPSO has many features predominantly the geostationary turrets and various mooring systems that enable it to withstand extreme and challenging conditions. This added with its storage capacity and its movability allows it to be a viable option for smaller oil fields that would be irrational to build a long term oil platform since the yield of oil would be lower there. FPSOs also do not require any underwater and subsea facilities except a few wellhead and manifolds. No expensive and fragile pipelines are needed therefore the environmental impact is further reduced and the abandonment costs are even more lowly compared to other platforms. (MOSES and Rex, 2012)

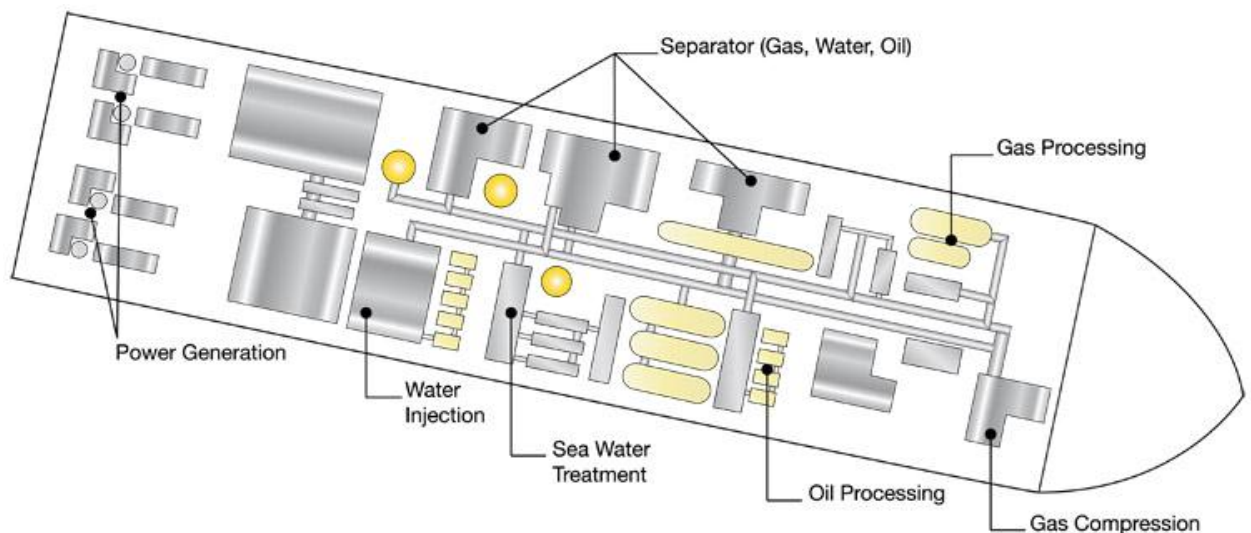


Figure 34: Integrated Modules of an FPSO (Leser.com, 2015)

The usage of FPSO gives accessibility to areas of deepwater regions and ultra-deepwater regions where pipelines and fixed platforms are impractical to be built due to the cost needed and the challenging conditions.

Great distances from ashore, high levels of depth, and unstable and inconsistency in seafloor configurations and extreme weather and rough seas are all factors that make it hard but not impossible for an FPSO to overcome. The oil fields normally located in places like this and previously untouchable by production companies are now within reach due to the FPSOs technologies. Time is an essential part of any oil and gas development and FPSOs holds the fastest time in terms of the time take from the first fabrication of the vessel and the discovering of the oil to the starting of the extraction and processing and shipping out the finished product. (MOSES and Rex, 2012)

The platform can be installed faster in the field since its technically simple compared to other platforms. The speed of the vessel is also a great factor. Capital investment is returned earlier since production starts sooner. The utilization of shuttle tanks to transfer the oil and gas produced also cuts down on the initial costs of building pipelines and the various risks involved. Pipelines also cost a long time to build and setup up. Pricing for the products is also dependent on the platforms in some cases. In the case of FPSO the operator has the mobility to direct the shuttle to the refinery that gives the best value of money attaining the most economically viable price for the end product. (Minerals Management Service Gulf of Mexico OCS Region, 2001)

Apart from all of this the fact that FPSOs can be reused for more than one projects brings the platform to the attention of many companies. Other platforms once used for a project are either abandoned or scrapped while FPSOs can be reused as much as wanted with some minor maintenance and modifications. Leasing the platform to other operators and companies is another economically suitable way to gain income. In terms of space FPSOs are made of a ship hull. The entire hull and the bow and the stern is utilized to house various components that is used for processing. These topsides are

installed in modules and can be resized and remodified accordingly. (Minerals Management Service Gulf of Mexico OCS Region, 2001)

Costs depend on the design of the FPSO, with being as low as \$100 million to about \$700 million in some cases. The major cost is the topsides with the hull normally only taking about 10 percent or less than the total cost. The topsides are expensive because of the various equipment needed for the production and the processing. But the capital investment is easily gained back within the first operation ends and starting the second and third lease the FPSO is giving a clean revenue for the company. (Fpso.net, 2015)

CHAPTER 5

CONCLUSION

All the studies done has proven that FPSO is the future for oil and gas developments. The various advantage of lower cost of manufacturing, the ease of travel and relocation and lower cost of abandonment of the platform further pushes major oil companies to see FPSO as the alternative.

The lowering fuel prices which pushes these major companies to cut cost and downsize due to imbalanced political and economic situations added with the fossil fuel reservoirs that are being depleted to excessive usage pushes explorations to new and untouched rural areas of the globe.

The journey to new oil fields would mean a platform that is versatile and flexible as well as reliant and capable to output a high production rate to supply the demand of the users. The FPSO is the only such platform with the said advantages and features. No other platform can be even moved and stationed without taking up as much as twice the time and the cost.

The further fact that FPSOs can be manufactures from a used cargo ship and after being used to the maximum the topsides can be converted into another ship also gives a much needed culling in manufacturing costs. The factor that permits the platform

to be re used in more than one particular oil field also increases the dependability on FPSO. The capital investment is reimbursed and the platform continues to provide revenue to the owners in its years of service. This is a long term investment and continues to provide advantages for the company.

FPSOs are also stable and safer compared to the other platforms and can work in hazardous and treacherous waters. Areas of the globe where it is impossible to construct and build any kind of platforms due to the geographical reasons and lack of facilities can utilize a FPSO because the platform is built elsewhere and moved to the field and moored. This reduces the risks involved and in terms of safety of the workers involved is guarded since there is very little underwater and subsea maintenance and infrastructure operation done when it involves this platform.

FPSOs is the future of the oil and gas industry and various new technological advancements must be integrated into this platform to further increase its efficiency to benefit the energy market globally.

CHAPTER 6

MILESTONE

Master schedule and the S-Curve are used to guideline the progress of the report to achieve the target deadlines without fail.

Week	Milestone
2	Project Proposal / Selection
3	Preliminary Research Work
7	Preparation of Chapter 1: Introduction
7	Monthly Report 1
9	Preparation of Chapter 2: Literature Review
9	Monthly Report 2
11	Preparation of Chapter 3: Methodology

12	Monthly Report 3
12	Progress Report Submission
13- 18	Research on study
19- 20	Thesis writing
20- 25	Thesis reedit
25-30	3d modelling done

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