OFFSHORE ENGINEERING

INTRODUCTION TO OFFSHORE OIL AND GAS INDUSTRY

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PRESENTATION TO THE STUDENTS

Offshore Engineering is a branch of Petroleum Engineering a key part of Oil and Gas Industry which is characterized by high technical and technological level of international dimension.

A professional Oil & Gas engineer must be able to operate in very different socio-environmental places and must possess excellent interpersonal skills and communication.

For this reason many universities in Asia and Europe provide teaching only and entirely in English. Knowledge of “Technical English” is a must for an Oil & Gas Engineer and continuous honing is necessary for every professional in this field.

Offshore Engineering cover a vast area of knowledge.

This Offshore Engineering course (03501322) will introduce the students to the fundamental disciplines of the oil industry, such as offshore structure, offshore foundation, drilling and production, offshore environment and design criteria, fabrication, installation, platform decommissioning, sub-sea pipelines transportation and processing of hydrocarbons, and Project Management.

What is the industry expecting from a qualified Offshore engineer?

- Theoretical basis of mathematics and other scientific disciplines, and ability to utilize these knowledge to interpret and describe complex engineering problems;
- Capability to plan and design systems, process and services;
- Knowledge of industry process and business organization;
- Good command of English language (and even better another foreign language i.e. Chinese / Japanese / French / Italian) both in writing and speaking.
- Interpersonal skills and good aptitude to work in team
- High moral and ethical behavior.

Once graduated an Engineer can find various job possibilities, ranging from research & design and innovation to advanced design, fabrication and construction, commissioning & operation, to project management.

Private and public enterprises are in condition to offer on-the-job training and assist the newly qualified engineers in their career development.

In my lecture I will start to present some basic information about Oil & Gas, and then describe the historical developments of the offshore industry.
I will introduce the types of offshore structures and some basic concepts of design, which is based on strict observance of Rules and Regulations and has to follow International Standards and Codes and then continue to illustrate some construction methods and installation techniques or a fixed type offshore platform.

I will continue the lesson with a brief reference to the methods of drilling and production, some brief environmental aspect of decommissioning offshore platforms and some concepts of sub-sea pipelines.

In the chapter “The Future of Offshore” I will discuss what lies ahead in our business and present a case study relevant to the Gulf of Tahiland.

Last but not least, I will make a brief presentation in powerpoint on Health and Safety (HSE) aspects in Oil and Gas. Health and Safety in reality is a major subject which demands particular emphasis. The Oil & Gas industry is at the forefront of safety issues and gives utmost priority to all the safety, health and environmental aspect in its entire business. I believe that terminating the lesson with this vital principles will be the best to focus the importance of the issue.

To assist you and make it easy for apprehending new technical vocabulary, I have prepared a Glossary in English with most frequently used technical jargon. I do invite you to memorize these words, because you will use and encounter them frequently when you will become part of this industry.

Thank you.

* * *
INTRODUCTION

Due to the rapid growth of the offshore field, particularly in the exploration and development of offshore oil and gas fields in deep waters of the oceans, the science and engineering in this area is seeing a phenomenal advancement.

The offshore industry requires continued development of new technologies in order to produce oil in regions, which are inaccessible to exploit with the existing technologies.

Sometimes, the cost of production with the existing know-how makes it unattractive. With the depletion of onshore and offshore shallow water reserves, the exploration and production of oil in deep water has become a challenge to the offshore industry. Offshore exploration and production of minerals is advancing into deeper waters at a fast pace. Many deepwater structures have already been installed worldwide. New oil and gas fields are being discovered in ultra-deep water. Many of these fields are small and their economic development is a challenge today to the offshore engineers. This has initiated the development of new structures and concepts. Many of these structures are unique in many respects and their efficient and economic design and installation are a challenge to the offshore community.

An offshore structure has no fixed access to dry land and may be required to stay in position in all weather conditions. Offshore structures may be fixed to the seabed or may be floating. Floating structures may be moored to the seabed, dynamically positioned by thrusters or may be allowed to drift freely.

The engineering of structures that are mainly used for the transportation of goods and people, or for construction, such as marine and commercial ships, multi-service vessels (MSVs) and heavy-lift crane vessels (HLCVs) used to support field development operations as well as barges and tugs are not discussed in this course.

* * *
OVERVIEW

CRUDE OIL
The oil found in the subsurface is called crude oil and is a mixture of hydrocarbons, which in form range from almost solid to gaseous. Crude oil is a naturally occurring mixture of hundreds of different hydrocarbon compounds trapped in subsurface rock. These hydrocarbons were created millions of years ago when plant and algae material died and settled on the bottom of streams, lakes, seas and oceans, forming a thick layer of organic material. Subsequent sedimentation covered this layer, applying heat and pressure that 'cooked' the organic material and changed it into the petroleum we extract from the subsurface today.

Crude oils are generally differentiated by the size of the hydrogen rich hydrocarbon molecules they contain. For example, light oil containing lighter hydrocarbons flows easily through wells and pipelines and when refined, produces a large quantity of transportation fuels such as petrol, diesel and jet fuel.

Heavy oil containing heavier hydrocarbons, in contrast, requires additional pumping or diluting to be able to flow through wells and pipelines; when refined, it produces proportionally more heating oil and a smaller amount of transportation fuels.

Crude oil is a complex mixture of hydrocarbons with minor proportions of other chemicals such as compounds of sulphur, nitrogen and oxygen. The different parts of the mixture must be separated, before they can be used, and this process is called refining.

Crude oil from different parts of the world, or even from different depths in the same oilfield, contains different mixtures of hydrocarbons and other compounds. This is why it varies from a light-colored volatile liquid to thick, dark, black oil - so viscous that it is difficult to pump from the subsurface.

Crude oil also contains sulphur, which has to be removed from any fractions that are going to be burnt as it forms sulphur dioxide, which contributes to acid rain. Therefore, any fractions that are converted into fuels must pass through so-called hydofiners, removing the sulphur content.

Crude oil can be measured in a number of different ways. Production and distribution companies commonly measure crude oil in barrels (bbl). In SI units 1 bbl is 0.158983 m3.

While measuring by volume is useful, oil can also be measured as a source of energy. The energy unit used is Barrels of Oil Equivalent (BOE), which denotes the amount of energy contained in one barrel of crude oil. An energy unit by weight is also used – this is called Ton of Oil Equivalent (TOE).
NATURAL GAS
Natural gas is a combustible mixture of small-molecule hydrocarbons. These are made of atoms of carbon and hydrogen. For example, natural gas used in the home is mainly methane, which is a molecule made up of one carbon atom and four hydrogen atoms, and is referred to as CH₄. While natural gas is formed primarily of methane, it can also include ethane, propane and butane. The composition of natural gas can vary widely.
Table 1.2 outlines the typical makeup of natural gas before it is refined.

No mixture can be referred to as natural gas as each gas stream has its own composition. Even two gas wells from the same reservoir may have different constituents.

Natural gas is considered ‘dry’ when it is almost pure methane, having had most of the other commonly associated hydrocarbons removed. When other hydrocarbons are present, natural gas is ‘wet’.

Natural gas has many uses, residentially, commercially, and industrially. Found in reservoirs underneath the earth, natural gas is commonly associated with oil deposits.

Natural gas can be measured in a number of different ways. Measured at normal temperatures and pressures the volume is expressed in normal cubic feet (Ncf or Nf³) or normal cubic metres (Nm³). Normal denotes a temperature of 0°C and a pressure of 1 atm.

Production and distribution companies commonly measure natural gas in thousands of cubic feet (Mcf), millions of cubic feet (MMcf), or trillions of cubic feet (Tcf). While measuring by volume is useful, natural gas can also be measured by its calorific content. The energy oil units BOE and TOE can also be used for gas and denotes the amount of gas corresponding to one BOE or one TOE. One Bbl of crude oil corresponds to approx. six Mcf of natural gas.

FORMATION OF OIL & GAS
Crude oil was generated over millions of years from the remains of tiny plants and animals that became incorporated into muddy sediments. Subsequent deposition of sediment caused the organic-rich “source rock” layer to be buried ever deeper and exposed to increasing temperatures. With increasing temperature first heavy then light oil was formed from the organic material, and finally gas. Organic material deposited in sediments during the Jurassic and Cretaceous geological ages 180 to 65 million years ago (the time of the dinosaurs) generated most of the oil we find in the North Sea today.

There are three essential elements in the creation of a crude oil and gas field:

1) The existence of a “source rock” - The geologic history of such a rock enabled the formation of crude oil. This usually is fine grained shale, rich in organic matter.

2) The generated oil or gas move (“migrate”) into a permeable layer called a reservoir. Reservoirs typically consist of sandstones and limestones. Once inside the reservoir buoyancy will move the oil and gas upwards. The oldest oil-bearing rocks date back more than 600 million years; the youngest, about 1 million, most oil fields have been found in rocks between 10 million and 270 million years old (In Denmark typically it is 65+ million years old).

3) A “trap” is required to capture the oil or gas. The trap prevents the oil from escaping the reservoir by way of its shape and organization of rock types. Usually it involves a non-permeable layer on top that acts as a seal. Traps are generally formed by tectonic forces that either breaks the continuity of the reservoir (“fault”) or buckles it (“fold’), but there are many different types of traps.

Subsurface temperature, which increases with depth, is a critical factor in the creation of oil. Petroleum hydrocarbons are rarely formed at temperatures less than 65°C and are generally carbonized and destroyed at temperatures greater than...
260°C. Most hydrocarbons are found at “moderate” temperatures ranging from 105° to 175°C.

MIGRATION
As the source rocks become buried under more sediment, the pressure rises and the hydrocarbons are very slowly squeezed from the source rocks into neighboring porous rocks, such as sandstones. This process is called expulsion. Originally the pores within the neighboring rocks were filled with water. The oil and gas now entering these rocks are less dense than water and as a result are expelled from the pores and float upwards through the water held within the porous rocks. The hydrocarbons move very slowly, from where they were originally generated. This movement can take place over many km vertically and many tens, or even hundreds of km laterally. This process is called migration.

Eventually impervious rocks can stop the migration of the hydrocarbons, through which they cannot move, the pore spaces between the grains of the rocks being too small. These impermeable rocks are called seals. Examples include mud and shales. Slowly the hydrocarbons accumulate in the porous rock at the point where their upward movement is stopped. The structure in which the hydrocarbons accumulate is called a trap, and the porous rock in which the hydrocarbons are trapped is called a reservoir. It must be stressed that these reservoirs are not huge subterranean lakes of oil, but areas of porous rocks holding the oil or gas within their pores as in a sponge.

Reservoirs can contain any combination of oil and gas: oil with no gas, gas with no oil or both gas and oil together. Because gas is less dense than oil, it rises to the top of the reservoir, while oil, being the heavier, remains at the base. When discovered,
and once an estimate has been made of the size and value of the trapped hydrocarbons, the accumulation is usually called a field.

The crude oils and natural gases within each field are unique. Some crude oils are black, heavy and thick like tar, while others are pale and flow very much like water. Natural gases also vary a lot. Some are almost identical to those we burn in our central heating boilers or cookers. Others are higher energy gases, which we use as building blocks for petrochemical products. Of the hydrocarbons that are formed in the source rock, only a small percentage is trapped. Most seep away and may sometimes form oil seepages with thick black pools or tarry deposits on the surface of the land or on the seabed. These seepages are important indicators of the presence of subsurface hydrocarbons and can help geologists in their search for previously undiscovered oil and gas fields.

CHEMICAL COMPOSITION
Crude oils and refined petroleum products consist largely of hydrocarbons, which are chemicals composed solely of hydrogen and carbon in various molecular arrangements. Crude oils contain hundreds of different hydrocarbons as well as inorganic substances including sulphur, nitrogen, and oxygen, as well as metals such as iron, vanadium, nickel, and chromium. Collectively, these other atoms are called heteroatoms.

Certain heavy crude oils from more recent geologic formations contain less than 50% hydrocarbons and a higher proportion of organic and inorganic substances containing heteroatoms. The refining process removes many of the chemicals containing these. All crudes contain lighter fractions similar to petrol as well as heavier tar or wax constituents, and may vary in consistency from a light volatile fluid to a semi-solid.

Petroleum products used for engine fuels are essentially a complex mixture of hydrocarbons
Petrol is a mixture of hydrocarbons that contain 4 to 12 carbon atoms and have boiling points between 30º and 210ºC.
Kerosenes used for jet fuel contain hydrocarbons with 10 to 16 carbon atoms and have boiling points between 150º and 240ºC.
Diesel fuels and the low-grade heavy bunkering fuels contain hydrocarbons with higher numbers of carbon atoms and higher boiling points.
In addition, diesel fuels and bunkering fuels have greater proportions of compounds containing heteroatoms.

The major classes of hydrocarbons in crude oils are shown in figure 1.5 together with their characteristics.
The hydrocarbons normally found in natural gas are methane, ethane, propane, butanes, pentanes as well as small amounts of hexanes, heptanes, octanes, and heavier gases. Normally straight chain hydrocarbon gases are present in natural gas. However, cyclic and aromatic hydrocarbon gases are also occasionally found in them.
In addition to hydrocarbons, natural gas commonly contains appreciable amounts of other compounds/gases called impurities. Impurities also include heavier hydrocarbons i.e. pentane plus. Such components usually have a deleterious effect on the properties and performance of natural gas and make handling and processing difficult. Therefore, they must be removed or converted into less harmful compounds.

Some components like H2S, H2O, nitrogen, helium, pentanes and heavier hydrocarbons may cause extremely unreliable and hazardous combustion conditions for the consumer. Of course, they must also be removed converted into less harmful compounds.

Some definitions of different gases are:

- **Dry Natural Gas**: Gas which contains less than 0.1 usg/mcf (USA gallon/million cubic feet) of C5.
- **Wet Natural Gas**: Gas which contains greater than 0.1 usg/mcf of C5.
- **Rich Gas**: Gas which contains greater than 0.7 usg/mcf of C3+.
- **Lean Gas**: Gas which contains less than 0.7 usg/mcf of C3+.
- **Sour Gas**: Gas which contains H2S and/or CO2.
- **Sweet Gas**: Gas which contains no H2S and/or CO2.
- **Sales Gas**: It is domestic/industrial or pipeline gas which mainly consists of methane and ethane.
- **Condensate**: It contains pentanes and heavier (C5+) hydrocarbons.
- **Natural Gasoline**: A specification product of set vapor pressure.
- **Well Effluent**: Untreated fluid from reservoir.
- **Raw Gas**: Raw plant feed as it enters the plant.
OIL & GAS RESERVOIRS – GEOLOGY & EXPLORATION

An oil reservoir or petroleum reservoir is often thought of as being an underground “lake” of oil, but is actually composed of hydrocarbons contained in porous rock formations.

Millions of years ago oil and natural gas were formed from the fossil organic material that settled on the seabed along with sand, silt and rocks. As they settled, layer upon layer accumulated in rivers, along coastlines, and on the bottom of the sea. Geological shifts resulted in some of these layers being buried deep in the earth. Over time, layers of organic material were compressed by the weight of the sediments above them, and the increasing pressure and temperature transformed the mud, sand, and silt into rock, the organic matter into petroleum. The rock containing organic matter is referred to as the source rock.

Over millions of years the oil and gas, which were formed, migrated upwards through tiny, connected pore spaces in the rocks. A certain quantity seeped out onto the surface of the earth. But most of the petroleum was trapped by non-porous rocks or other barriers that would not allow it to migrate further. These underground oil and gas traps are called reservoirs and are not underground “lakes” of oil, but porous and permeable rocks that can hold significant amounts of oil and gas within their pore spaces. This allows oil and natural gas within them to flow through to a producing well.

Some reservoirs may be only hundreds of meters below the surface of the earth; others are thousands, sometimes tens of thousands of meters underground. Reservoirs in the North Sea are typically found 2-3 km under the seabed.

Most reservoirs contain oil, gas, and water. Gravity acts on these fluids and separates them according to their density, with gas on top, then oil, and finally water. However, other parameters, such as fluid/rock properties and solubility can restrict complete gravitational separation. When a well produces fluids from a subsurface reservoir, typically oil and water, and often some gas will be recovered.

The larger subsurface traps are the easiest oil and gas deposits to locate. In mature production areas of the world, most of these large deposits have already been found, with many producing since the 1960s and 1970s. The oil and gas industry has developed new technologies to identify and gain access to smaller, thinner bands of reservoir rock that may contain oil and gas. Improved seismic techniques have improved the odds of accurately identifying the location of reservoirs that are smaller and more difficult to find. There is still a lot of oil and gas to be discovered and produced, but these future discoveries will be in deeper basins, and in more remote areas of the world. There will also be many small reservoirs found in existing oil and gas producing areas using advanced technologies.

Technological innovation not only makes it easier to find new deposits of oil and gas, but also enables industry to extract more from each individual reservoir that is discovered. For example, new drilling techniques have made it feasible to intersect a
long, thin reservoir horizontally instead of vertically, enabling oil or gas from the reservoir to be recovered with fewer wells.

OIL EXPLORATION
Oil exploration is an expensive, high-risk operation. Offshore and remote area exploration is generally only undertaken by very large corporations or national governments.

Typical shallow shelf oil wells cost tens of millions Euros. Deep water wells can even cost hundreds of millions Euros. But hundreds of smaller companies search for onshore hydrocarbon deposits world-wide, where some wells cost as little as half a million Euros.

When the well is drilled, it is time for Logging Methods of exploration. The electronic tools are run into the borehole to make different types of measurements in order to view in a graphical manner and determine reservoir geo-physical parameters such as porosity, permeability and saturation for analysis, evaluation, and modeling purposes of the subsurface features.

Types of measuring regimes include wire line and while drilling measurement. In a wire line regime, the measurements of formation properties with electrically powered instruments occur continuously while logging tools are run along the walls of the well. Measurement while drilling is a technique of conveying well logging tools into the well borehole down hole as part of the bottom hole assembly. Mostly, the logging tools consist of source or transmitters and detectors or receivers of different signals. The logging methods are designed to determine such properties of fluids and rocks
like natural and induced radioactivity, electrical potential and conductivity, nuclear reactions and travelling of sound waves.

Gamma ray log measures naturally occurring gamma radiation to characterize the rock in the borehole, especially to indicate shale having high natural radioactivity, to distinguish from reservoir rocks.

The resistivity log is fundamental in formation evaluation because the difference in conductivity of different rocks helps to indicate hydrocarbons.

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HISTORICAL DEVELOPMENT

The offshore exploration of oil and gas dates back to the nineteenth century. The first offshore oil wells were drilled from extended piers into the waters of Pacific Ocean, offshore Summerlands, California in the 1890s (and offshore Baku, Azerbaijan in the Caspian Sea). However, the birth of the offshore industry is commonly considered as in 1947 when Kerr-McGee completed the first successful offshore well in the Gulf of Mexico in 4.6 meters of water off Louisiana. The drilling derrick and draw works were supported on a 11.6 m by 21.6 m wooden decked platform built on 16 / 61cm pilings driven to a depth of 31.7 m.

Since the installation of this first platform in the Gulf of Mexico over 50 years ago, the offshore industry has seen many innovative structures, fixed and floating, placed in progressively deeper waters and in more challenging and hostile environments. By 1975, the water depth extended to about 150 m.

Within the next three years the water depth dramatically leapt twofold with the installation of COGNAC platform that was made up of three separate structures, one set on top of another to reach over 300 m. COGNAC held the world record for water depth for a fixed structure from 1978 until 1991. Five fixed structures were built in water depths greater than 300 m in the 1990s. The deepest one of these is the Shell Bullwinkle platform reaching 412 m and installed in 1991. The progression of fixed structures into deeper waters up to 1988 is shown in fig. 1.1.

![Figure 1.1 - Progression of fixed platforms in the GOM - depths in meters (Courtesy Shell)](image)

Since 1947, more than 10,000 offshore platforms of various types and sizes have been constructed and installed worldwide. As of 1995, 30% of the world’s production of crude came from offshore. Recently, new discoveries have been made in increasingly deeper waters. In 2003, 3% of the world’s oil and gas supply came from deepwater (> 300 m).
This is projected to grow to 10% in the next fifteen years. The bulk of the new oil will come from deep and ultra-deepwater production from three offshore areas, known as the “Golden Triangle”: the Gulf of Mexico, West Africa and Brazil.

Figure 1.2 illustrates the recent growth in ultra-deepwater drilling in the Gulf of Mexico. Drilling activity is indicative of future production.

Fixed structures became increasingly expensive and difficult to install as the water depths increased.

Although nearly all of these platforms are of steel construction, around two dozen large concrete structures have been installed in the very hostile waters of the North Sea in the 1980s and early 1990s and several others offshore Brazil, Canada and the Philippines.

Among these, the Troll A (fig. 1.3) gas platform is the tallest concrete structure in existence. It was installed offshore Norway in 1996. Its total height is 369 m, and it contains 245,000 m³ of concrete.

Gravity structures differ from other fixed structures in that they are held in place strictly by the weight contained in their base structures. The Troll platform, for example, penetrates 36 m into the seabed under its own weight.
The first floating production system, a converted semi-submersible, was installed on the Argyle field by Hamilton in the UK North Sea in 1975. The first ship-shaped floating production and storage system was installed in 1977 by Shell International for the Castellon field, offshore Spain. There were 40 semi-submersible floating production systems (FPSs) and 91 ship-shaped floating production and storage systems (FPSOs) in operation or under construction for deepwaters as of 2002. Petrobras has been a pioneer in pushing floating production to increasingly deeper waters in their Campos Basin fields, offshore Brazil.

Table 1.1 lists the progression of field development offshore Brazil in ever-increasing water depths.

<table>
<thead>
<tr>
<th>Field</th>
<th>Well</th>
<th>Water Depth ft (m)</th>
<th>Year</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marimba'</td>
<td>RJS-284D</td>
<td>1355 (413)</td>
<td>1987</td>
<td>Wet Christmas tree</td>
</tr>
<tr>
<td>Marlim</td>
<td>MRL-3</td>
<td>2365 (721)</td>
<td>1991</td>
<td>Monobuoy &amp; FPS</td>
</tr>
<tr>
<td>Marlim</td>
<td>MRL-4</td>
<td>3369 (1027)</td>
<td>1994</td>
<td>Subsea completion</td>
</tr>
<tr>
<td>Marlin Sul</td>
<td>MLS-3</td>
<td>5607 (1709)</td>
<td>1997</td>
<td>Deepest moored production unit</td>
</tr>
<tr>
<td>Roncador</td>
<td>RJS-436</td>
<td>6079 (1853)</td>
<td>1998</td>
<td>FPSO depth record</td>
</tr>
<tr>
<td>2000 BC</td>
<td>RJS-543</td>
<td>9111 (2778)</td>
<td>2000</td>
<td>Drilling depth record at that time</td>
</tr>
</tbody>
</table>

Table 1.1 – Progression of offshore deep-water field development in Brazil

In 2010 there were more than 7,000 offshore platforms around the world in water depth up to 1,850 m

Selection of Deepwater Production Concepts

Platform size depends on facilities to be installed on top side i.e. Oil rig, living quarters, Helipad etc.

Classification of water depths are commonly divided as follows:
- \(< 350 \text{ m} \) - Shallow water
- \(< 1,500 \text{ m} \) - Deep water
- \(> 1,500 \text{ m} \) - Ultra deep water
The types of production concepts available for deepwater production are illustrated in fig. 1.4.

Most floating production systems, and virtually all of the semi-submersible, FPSs and FPSOs, produce oil and gas from wells on the seabed, called “subsea wells”. Unlike wells on fixed platforms and on land, subsea wells do not allow operators to have direct access to the wells for maintenance, or for re-completion (drilling into new reservoirs from an existing well).

The well consists of a wellhead, which supports the well casing in the ground, and a pod, which contains valves to control the flow and to shutoff the flow in the case of an emergency or a leak in the riser. This pod is called a “submerged Christmas tree”, or simply a “wet tree”. Subsea wells are expensive, but not as expensive in deepwater as placing a platform at the site.

![Production Platforms Diagram](image)

**Fig. 1.4 – Types of production concepts for offshore deepwater production**

If a subsea well ceases to produce, or if its rate of production falls below economic limits, it is necessary to bring in a mobile drilling unit to remove the tree and perform the workover. This can be an extremely expensive operation and if the outcome of the workover is in doubt, the operator may choose to abandon the well instead. Because of this, much of the oil and gas in reservoirs produced through subsea trees may be left behind.
Subsea wells may also result in lower reservoir recovery simply because of the physics of their operation. The chokes and valves placed in a subsea tree result in a pressure drop in the flow of oil or gas. When the well formation drops below a certain threshold, production ceases to flow. The difference in cut-off pressure between a subsea well and a surface well can be as much as 70 bar vs. 7 bar.

These facts motivated operators to seek floating platforms, which could support Christmas trees at the surface, “dry trees”. Fixed and compliant platforms were safe for this kind of production because they could protect the well casings from the environment.

Floating platforms generally had too much motion to protect the wells during extreme storms. A group of engineers in California invented a floating system in the early 1970s, which could be tethered to the sea floor, effectively making it a tethered compliant platform. This gave rise to what is called the Tension Leg Platform (TLP). The first commercial application of this technology, and the first dry tree completion from a floating platform, was the Conoco Hutton TLP installed in the UK sector of the North Sea in 1984. Dry trees are possible on a TLP because the platform is heave-restrained by vertical tendons, or tethers. This restraint limits the relative motion between the risers and the hull, which allows for flowlines to remain connected in extreme weather conditions.

The deep draft Spar platform is not heave-restrained, but its motions are sufficiently benign that risers can be supported by independent buoyancy cans, which are guided in the centerwell of the Spar.

Today, many deepwater fields in the Gulf of Mexico are being developed by a combination of surface and subsea wells.

Deepwater floating production systems are generally concentrated in the “Golden Triangle” of the Gulf of Mexico, offshore West Africa and Brazil (fig. 1.5).

TLPs have been installed in the Gulf of Mexico, West Africa, the North Sea and in Indonesia. FPSOs have been installed in virtually all of the offshore oil producing areas of the world with the exception of the Gulf of Mexico. Semi-submersible FPSs are prolific in the North Sea and Brazil.

* * *
OFFSHORE PLATFORM DESIGN CONCEPTS

A) PLATFORMS TYPES

Offshore platforms can broadly categorized in two types:

FIXED STRUCTURES THAT EXTEND TO THE SEABED (FIG. 1.6)

- Steel Jacket
- Concrete gravity Structure
- Compliant Tower

STRUCTURES THAT FLOAT NEAR THE WATER SURFACE (FIG. 1.6)

- Tension Leg platforms
- Semi Submersible
- Spar
- Ship shaped vessel (FPSO)

Figure 1.6 - Types of Offshore Platforms
TYPE OF PLATFORMS (FIXED)

JACKETED PLATFORM

– Space framed structure with tubular members supported on piled foundations.
– Used for moderate water depths up to 400 M.
– Jackets provides protective layer around the pipes.
– Typical offshore structure will have a deck structure containing a Main Deck, a Cellar Deck, and a Helideck.
– The deck structure is supported by deck legs connected to the top of the piles. The piles extend from above the Mean Low Water through the seabed and into the soil.

– Underwater, the piles are contained inside the legs of a “jacket” structure which serves as bracing for the piles against lateral loads.
– The jacket also serves as a template for the initial driving of the piles.

(The piles are driven through the inside of the legs of the jacket structure).
COMPLIANT TOWER

– Narrow, flexible framed structures supported by piled foundations.
– Has no oil storage capacity. Production is through tensioned rigid risers and export by flexible or catenary steel pipe.
– Undergo large lateral deflections (up to 10 ft) under wave loading. Used for moderate water depths up to 600 M.
CONCRETE GRAVITY STRUCTURES:

– Fixed-bottom structures made from concrete – Heavy and remain in place on the seabed without the need for piles
– Used for moderate water depths up to 300 M.
– Part construction is made in a dry dock adjacent to the sea. The structure is built from bottom up, like onshore structure.
– At a certain point, dock is flooded and the partially built structure floats. It is towed to deeper sheltered water where remaining construction is completed.
– After towing to field, base is filled with water to sink it on the seabed.

A 'Statfjord' Gravity base structure under construction in Norway. Almost all of the structure will end up submerged.
TYPE OF PLATFORMS (FLOATING)

Tension Leg Platform (TLP)

– Tension Leg Platforms (TLPs) are floating facilities that are tied down to the seabed by vertical steel tubes called tethers.
– This characteristic makes the structure very rigid in the vertical direction and very flexible in the horizontal plane. The vertical rigidity helps to tie in wells for production, while, the horizontal compliance makes the platform insensitive to the primary effect of waves.
– Have large columns and Pontoons and a fairly deep draught.

TLP has excess buoyancy which keeps tethers in tension.

Topside facilities, no. of risers etc. have to fixed at predesign stage.

– Used for deep water up to 1200 M
– It has no integral storage.
– It is sensitive to topside load/draught variations as tether tensions are affected.
SEMISUB PLATFORM

– Due to small water plane area, they are weight sensitive. Flood warning systems are required to be in-place.
– Topside facilities, no. of risers etc. have to be fixed at pre-design stage.
– Used for Ultra deep water.
– Semi-submersibles are held in place by anchors connected to a catenary mooring system.

Column pontoon junctions and bracing attract large loads.

Due to possibility of fatigue cracking of braces, periodic inspection/maintenance is a prerequisite

Oil Platform P-51 off the Brazilian coast is a semi-submersible platform
SPAR:

- Concept of a large diameter single vertical cylinder supporting deck.
- These are a new and emerging concept: the first spar platform, Neptune, was installed off the USA coast in 1997.
- Spar platforms have taut catenary moorings and deep draught, hence heave natural period is about 30 seconds.
- Used for Ultra deep water depth of 2300 m.
- The center of buoyancy is considerably above center of gravity, making Spar quite stable.
- Due to space restrictions in the core, number of risers has to be predetermined.
FLOATING PRODUCTION, STORAGE AND OFFLOADING (FPSO)

– FPSOs have integral oil storage capability inside their hull. This avoids a long and expensive pipeline to shore.
– Can explore in remote and deep water and also in marginal wells, where building fixed platform and piping is technically and economically not feasible.
– FPSOs are held in position over the reservoir at a Single Point Mooring (SPM). The vessel is able to pivot around the mooring point so that it always faces into the prevailing weather.
B) PLANNING AND DESIGN CONCEPTS (FIXED PLATFORMS)

In this chapter I will present the concepts for planning and designing of Fixed Offshore platforms.

The reference guide is API Standard RP-2A- WSD.

The standard provides guidance for new platform as well as relocation of existing platforms and assessment of existing platform in the event it becomes necessary to make a determination of the ‘fitness for purpose’ of the structure.

I wish to highlight that before the actual design is started a workable and economical analysis must be performed and the location of the platform must be specific before the design is completed.

Orientation
Information needed will also be relevant to Orientation referenced to the True North and water depth and tides as accurately as possible so that elevations can be established for boat landings, fenders, decks and corrosion protection.

Safety
The safety of personnel both for manned and unmanned platform and possible destruction of equipment require careful attention to fire protection methods. The selection of the system depends on the function of the platform.

Deck elevation
Deck elevation is to be determined with care since large forces and overturning moments result when waves strike a platform’s lower deck equipment. Unless the platform has been designed to resist these forces, the elevation of the deck should be sufficient to provide adequate clearance above the crest of the design wave. In addition consideration should be given to provide an air gap to allow passage of waves larger than the design wave.

Well Conductors
Exposed well conductors add environmental forces to a platform and require support. Their number, size and spacing must be known early in the planning stage. These conductors may not assist in resisting the wave force.

---

1 Fixed platform: A platform extending above and supported by the sea bed by means of piling, spread footings or other means with the intended purpose of remaining stationary over an extended period.
2 A manned platform is a considered continuously occupied by persons accomodated and living thereon, while an unmanned platform is the one where persons may be employed at one time, but upon no living accomodations or quarters are provided
**Layout and Weights**

Layout and weights of drilling equipment and material and production equipment are needed in the development design, along with handling of personnel, material, along with type and size of supply vessels, and the anchorage system. The number, size and location of the boat landings should be also determined at the time of initial planning.

Provision for handling spills and potential contaminants should be provided in a deck drainage system that collects and stores liquids for subsequent storage and handling.

**Design Data**

In designing a fixed platform normal and extreme environmental considerations are to be considered.³

**Wind Forces**

Wind forces are exerted upon the portion of the structure that is above the water, as well as on any equipment, deck houses and derricks, that are located on the platform. The wind speed may be classified as (a) Gusts that average less than one minute duration, and (b) sustained wind speed that average one minute or longer in duration. The wind data should be adjusted to a standard elevation, such as 10 m above mean water level.

**Waves**

Wind-driven waves are a major source of environmental forces on offshore platforms. Such waves are irregular, vary in height and length and may approach a platform from one or more direction simultaneously. Because of the complex nature of the technical factors that must be considered in developing the criteria, knowledgeable experienced specialists in the field of meteorology, oceanography and hydrodynamics should be consulted.⁴

---

³ Normal Environmental Conditions are expected to occur frequently during the life of the structure; Extreme Environmental Conditions will occur rarely during the life of the structure but are important in formulating the platform design loadings.

⁴ (Ref. to API Standard 2A paragraph 1.3.3. for necessary design parameters)
Tides
Tides are important considerations in platform design, and data refer to (a) astronomical tides, (b) wind tide, and (c) pressure differential tide. The latter two are called storm surge. The design shall take into consideration the various elevations.

Currents
Currents are important in the design of the platforms as they affect the location and orientation of boat landings and the forces on the platform. The most common categories of current are (a) tidal current, (b) circulatory current and (c) storm generated currents.

Ice
In severe temperature conditions, ice loads must be considered, while in milder climates above certain latitudes the governing design factor may be seismic or waves induced but ice features would still influence the design and construction of the platform.

Geological Conditions
In many offshore areas, geological processes may occur within the lifetime of the platform. In depth site investigations are required in the development of the design criteria.

Earthquakes and seafloor conditions
Seismic forces should be considered in platform design for areas that are determined to be seismically active. Seismic risk is rated in terms of possible severity of damage to the offshore structures. Seismic considerations should include investigation of the subsurface soils for instability due to liquefaction, submarine slides and ground motion. Platforms in shallow waters that may be subject to Tsunami should be investigated for the effects of resulting forces.

Soil engineering analysis shall be complete with study of faults seaﬂoor instability and scour 5; presence of shallow gas in the near surface, in addition of being a potential drilling hazard may be important to engineering the foundation.

Marine Growth
Offshore structure accumulate marine growth to some degree. Marine growth is generally greatest near the MWL (Mean Water Level) but in some areas may be significant well below the MSL. Marine growth increases wave forces and mass of the structure and should be considered in design.

5 Scour is removal of seafloor soil caused by currents and waves.
Soil Investigation
Knowledge of soil conditions existing at the site of construction is necessary to permit a safe and economical design. On site investigations are performed to define the various strata and their corresponding physical and engineering properties.

The primary purpose is to provide data for a geological assessment of the foundation soils. Geophysical data provide evidence of slumps, scarps, irregular topography, mud, collapse features, sand waves, gas bubble in sediments, gas seeps, buried channels, and strata thickness.

On site investigations include sampling and testing program, with one or more soil borings to provide samples suitable for engineering property testing.

The foundation investigation for pile supported structures should determine these parameters: (a) axial capacity of piles in tension and compression; (b) load-deflection of axially and laterally loaded piles, (c) pile driveability and (d) bearing capacity.

***
C) DESIGN CRITERIA AND PROCEDURES

The safety of life and property depends upon the ability of the structures to support the load for which it was designed and to survive the environmental conditions that may occur. Over and above this overall concept, good practice dictates use of certain structural additions, equipment and operating procedures so that injuries to personnel will be minimized and risk of fire, blast and accidental loading (for example collision of ships) is reduced. Governmental regulations and other applicable regulations are to be met.

The following loads and any dynamic effects resulting from them should be considered in the development of design loading conditions.

DEAD LOADS (DL)
Dead loads are the weight of the platform structure and any permanent equipment and auxiliary structure which does not change during operations, and hydrostatic forces acting on the structure below the waterline, including external pressure and buoyancy.

LIVE LOADS (LL)
Live loads are the loads imposed on the platform during its use, and which may change during operation. They include the weight of drilling and production equipment, the weight of living quarters, heliport and other support equipment, live saving equipment, diving equipment and utilities. The weight of consumables and liquids in storage tanks. The forces exerted on the structure from drilling operations, material handling, vessel mooring and helicopter loading. The forces exerted on the structure from deck crane use, including the movement of its loads.

ENVIRONMENTAL LOADS
Environmental loads are loads imposed on the platform by natural phenomena, including wind, current, wave, earthquake, snow, ice, and earth movement. Environmental loads should be anticipated from any direction unless knowledge of specific condition may be assumed more reasonable.

The wave loading of an offshore structure is usually the most important of all environmental loadings.

The forces on the structure are caused by the motion of the water due to the waves.
Determination of wave forces requires the solution of,

a) Sea state using an idealization of the wave surface profile and the wave kinematics by wave theory.\(^6\)
b) Computation of the wave forces on individual members and on the total structure, from the fluid motion.

Design wave concept is used, where a regular wave of given height and period is defined and the forces due to this wave are calculated using a high-order wave theory. Usually the maximum wave with a return period of 100 years, is chosen. No dynamic behavior of the structure is considered. This static analysis is appropriate when the dominant wave periods are well above the period of the structure. This is the case of extreme storm waves acting on shallow water structures.

TEMPERATURE LOADS

Temperature gradients produce thermal stresses. To cater such stresses, extreme values of sea and air temperatures which are likely to occur during the life of the structure shall be estimated. In addition to the environmental sources, accidental release of cryogenic material can result in temperature increase, which must be taken into account as accidental loads. The temperature of the oil and gas produced must also be considered.

DESIGN LOADING CONDITIONS

The platform should be designed for the appropriate loading conditions which will produce the most severe effects on the structure.

API 2A – paragraph 2.2.2. gives the following combinations:

1. OEC (Operating environmental conditions) + DL + LL (MAX)
2. OEC (Operating environmental conditions) + DL + LL (MIN)
3. DEC (Design environmental conditions) + DL + LL (MAX)
4. DEC (Design environmental conditions) + DL + LL (MIN)

Environmental loads (with the exception of earthquake load) should be combined in a manner consistent with the probability of their simultaneous occurrence.

\(^6\) Wave theories describe the kinematics of waves of water. They serve to calculate the particle velocities and accelerations and the dynamic pressure as functions of the surface elevation of the waves. The waves are assumed to be long-crested, i.e. they can be described by a two-dimensional flow field, and are characterized by the parameters: wave height (H), period (T) and water depth (d).
Earthquake loads should be imposed on the platform as a separate environmental loading condition.

Formulas and coefficients are illustrated in detail in the API 2A, and the designer is referred to the relevant chapters for reference.

An important consideration is to be given to the deck clearance, since large forces result when waves strike a platform’s deck or equipment. Omnidirectional guideline wave heights with a nominal return period of 100 years, together with the applicable wave theories, should be used to compute the wave crest elevation above the storm water level. By adding a safety margin, or air gap of at least 5 ft. (1.5 m) to allow for platform settlement, water depth uncertainty, and for the possibility of extreme waves it will be possible to determine the minimum acceptable elevation of the bottom beam of the lowest deck.

STRENGTH REQUIREMENT
Strength requirements are intended to provide a platform which is adequately sized for strength and stiffness to ensure no significant structural damage for the level of earthquake shaking which has a reasonable likehood of not being exceeded during the life of the platform.
To conduct this study a Structural Modeling, Response Analysis and Response Assessment are performed by the designer.
Additional guidelines are given to size the tubular joints, the supports of equipment, piping and other deck installation, and where determined necessary, the capacity of the joints or support shall be increased.

FABRICATION AND INSTALLATION FORCES
Fabrication forces are those forces imposed upon individual members, component parts of the structure or complete units during the unloading, handling and assembly in the fabrication yard or during transportation, unloading or launch.

For those installation forces that are experienced only during transportation and launch, and which include environmental effects, basic allowable stresses for member design may be increased by 1/3.

Special study should be conducted for lifting forces during erection lifts and installation stages.
Lifting eyes and the connection to the supporting structural members should be carefully designed for a horizontal force of 5% the static sling load, applied simultaneously with the static sling load.

For lifts to be made at open sea pad-eyes and other internal members should be designed for a minimum load factor of 2 applied to the calculated static loads.
All other structural members should be designed with a load factor of 1.15
During transportation a detailed analysis should be conducted and must take into consideration the environmental forces affecting the structure, the sea fastening to the barge (when used) analyzed for the gravitational, inertial and hydrodynamic loads.

In case of large barge-transported structures the relative stiffness of the barge is significant and should be considered in the structural analysis.

Fatigue life of certain members should be investigated for long trans-ocean tows.

**LAUNCHING FORCES**

Members should be designed to resist the gravitational and inertial forces required to upright the jacket.

Consideration should be given, other than the localized forces, to dynamically induced forces resulting from launching, in addition to environmental forces.

During launch the structure should be designed to resist the pressure-induced stresses during submergence.

**STRUCTURAL STEEL DESIGN AND FOUNDATION DESIGN**

Detailed information and guidance can be found in the following chapters of API 2A:
- Chapter 3 Structural Design
- Chapter 4 Connections
- Chapter 5 Fatigue
- Chapter 6 Foundation Design
- Chapter 7 Other Structural Components
- Chapter 8 Material

**FIRE, BLAST AND ACCIDENTAL LOADING**

I will conclude this chapter with a brief reference to Fire, Blast and Accidental Loading.

These events could lead to partial or total collapse of an offshore platform resulting in loss of life and/or environmental pollution.

Considerations should be given in the design of the structure and in the layout and arrangement of the facilities and equipment to minimize the effects of these events.

Implementing preventive measures has historically been and will continue to be the most effective approach in minimizing the probability of occurrence of an event the resultant consequence of the event.

API Recommended Practices 75, 14G, 14J and other 14 series documents provide the guidance for facility and equipment layout.

It is clear that the Operator is responsible for the overall safety of the platform and as such defines the preventive measures for fire containment or evacuation rather than focusing on control system.

Nevertheless the Operator’s Safety Management System will be the document which needs to safeguard against these events.
D) CODE AND STANDARDS

IMAGINE IF EVERY NUT AND BOLT IN THE WORLD WERE MADE IN A DIFFERENT WAY.
And imagine that every time you needed to put a nut and bolt together, you needed a different tool to do it, depending on where and from whom you bought them.

If we all just arbitrarily used different nuts and bolts for putting things together, we’d be facing problems with virtually everything. Plain and simple, that’s why standards are so important. Standards cross the realms of manufacturing, science and technology, and safety and security. They’re a big part of everyday life.

Standards enhance the safety of industry operations, assure quality, help keep costs down, reduce waste, and minimize confusion. They help speed acceptance and bring products to market quicker. And they avoid having to reinvent the wheel every time a product is manufactured.

A standards organization, standards body, standards developing organization (SDO), or standards setting organization (SSO) is any organization whose primary activities are developing, coordinating, promulgating, revising, amending, reissuing, interpreting, or otherwise producing technical standards that are intended to address the needs of some relatively wide base of affected adopters.

TODAY’S OIL AND NATURAL GAS INDUSTRY REACHES AROUND THE GLOBE, TOUCHING THE LIVES OF MILLIONS OF PEOPLE EVERY SINGLE DAY.
It’s an industry that relies on high-quality equipment, materials, and methods that meet the industry’s growing demands worldwide. It’s an industry that relies on standards to get the job done right.
In today’s environment of increased workload and decreased human resources, standardization has become a paramount concern of the world’s oil and natural gas companies, equipment manufacturers, and suppliers.

80% OF GLOBAL MERCHANDISE TRADE IS AFFECTED BY STANDARDS AND BY REGULATIONS THAT EMBODY STANDARDS.

THE USE OF STANDARDS ALSO HAS A PRONOUNCED VALUE FOR MANUFACTURERS ASPIRING TO WORLD MARKET STATUS.

There are many national (such as TISI – Thailand Industrial Standards Institute), international (such as ISO – International Organization for Standardization) or independent organizations (such as ASME, ASTM, IEEE etc.) who develop and publish standards for a variety of international uses.
A major independent organization in Petroleum Industry is API (American Petroleum Institute), who has been a cornerstone in establishing and maintaining standards for the worldwide oil and natural gas industry.

API Standards include manuals, standards, specifications, recommended practices, bulletins, guidelines and technical reports.

Knowledge of standards and capability to understand them is essential for Engineers all around the world. Your needs to correctly read and understand standards that incorporate the best and most current value-added practices is vital for your profession.

Since most of the Standards are written in English language it becomes obvious the essence of Technical English knowledge for an Engineer.

* * *

* * *
CONSTRUCTION METHODS AND INSTALLATION

JACKETS AND PILE FOUNDATION

Pile Foundation
The jacket foundation is provided by open-ended tubular steel piles, with diameters up to 2m. The piles are driven approximately 40 - 80 m, and in some cases 120 m deep into the seabed.

There are basically three types of pile/jacket arrangement

<table>
<thead>
<tr>
<th>Concept</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pile-through-leg</td>
<td>where the pile is installed in the corner legs of the jacket.</td>
</tr>
<tr>
<td>Skirt piles</td>
<td>through pile sleeves at the jacket-base, where the pile is installed in guides attached to the jacket leg. Skirt piles can be grouped in clusters around each of the jacket legs.</td>
</tr>
<tr>
<td>Vertical skirt piles</td>
<td>are directly installed in the pile sleeve at the jacket base; all other guides are deleted. This arrangement results in reduced structural weight and easier pile driving. In contrast inclined piles enlarge the foundation at the bottom, thus providing a stiffer structure.</td>
</tr>
</tbody>
</table>

Pile Bearing Resistance
Axial load resistance is required for bearing as well as for tension. The pile accumulates both skin friction as well as end bearing resistance.
Lateral load resistance of the pile is required for restraint of the horizontal forces. These forces lead to significant bending of the pile near to the seabed. Number, arrangement, diameter and penetration of the piles depend on the environmental loads and the soil conditions at the location.

TOPSIDES

Introduction
The major functions on the deck of an offshore platform are:
• well control
• support for well work-over equipment
• separation of gas, oil and non-transportable components in the raw product, e.g. water, parafines/waxes and sand
• support for pumps/compressors required to transport the product ashore
• power generation
• accommodation for operating and maintenance staff.
There are basically two structural types of topside, the integrated and modularized topside which are positioned either on a jacket or on a concrete gravity substructure.

Jacket-based Topsides

Concepts
There are four structural concepts in practice. They result from the lifting capacity of crane vessels and the load-out capacity at the yards:
• the single integrated deck (up to approx 100 MN)
• the split deck in two four-leg units
• the integrated deck with living quarter module
• the modularized topside consisting of module support frame (MSF) carrying a series of modules.
The figure below shows an integrated deck (though excluding the living quarters and helideck) being moved from its assembly building.
Figure 4 Typical jacket based modularized topside
Structural Design for Modularized Gravity-based Topsides
The topsides to be supported by a gravity-based substructure are in a weight range of 200 MN up to 500 MN.
The backbone of the structure is a system of heavy box-girders with a height of approximately 10 m and a width of approximately 12 - 15 m (see Figure 5).

![Figure 5: Module support frame (MSF) for a gravity based substructure (GBS)](image)

The substructure of the deck is rigidly connected to the concrete column and acts as a beam supporting the deck modules. This connection introduces wave-induced fatigue in the deck structure. A recent development, foreseen for the Norwegian Troll platform, is to provide a flexible connection between the deck and concrete column, thus eliminating fatigue in the deck [10].

EQUIPMENT AND LIVING QUARTER MODULES
Equipment modules (20-75 MN) have the form of rectangular boxes with one or two intermediate floors.
The floors are steel plate (6, 8 or 10 mm thick) for roof and lower floor, and grating for intermediate floors.
In living quarter modules (5-25 MN) all sleeping rooms require windows and several doors must be provided in the outer walls. This requirement can interfere seriously with truss arrangements. Floors are flat or stiffened plate.

Three types of structural concepts, all avoiding interior columns, can be distinguished:

- conventional trusses in the walls.
- stiffened plate walls (so called stressed skin or deck house type).
- heavy base frame (with wind bracings in the walls).

CONSTRUCTION

Introduction
The design of offshore structures has to consider various requirements of construction relating to:
1. fabrication.
2. weight.
3. load-out.
4. sea transport.
5. offshore installation.
6. module installation.
7. hook-up.
8. commissioning.

A documented construction strategy should be available during all phases of the design and the actual design development should be monitored against the construction strategy.

Construction of Jackets and Topsides

Lift Installed Jackets
The jacket is built in the vertical (smaller jackets) or horizontal position (bigger jackets) on a quay of a fabrication site.
The jacket is loaded-out and seafastened aboard a barge. At the offshore location the barge is moored alongside an offshore crane vessel.

The jacket is lifted off the barge, upended from the horizontal, and carefully set down onto the seabed. After setting down the jacket, the piles are installed into the sleeves and, driven into the seabed. Fixing the piles to the jacket completes the installation.

**Launch Installed Jackets**

The jacket is built in horizontal position. For load-out to the transport barge, the jacket is put on skids sliding on a straight track of steel beams, and pulled onto the barge.
At the offshore location the jacket is slid off the barge. It immerses deeply into the water and assumes a floating position afterwards (see Figure 6).
Two parallel heavy vertical trusses in the jacket structure are required, capable of taking the support reactions during launching. To reduce forces and moments in the jacket, rocker arms are attached to the stern of the barge. The next phase is to upright the jacket by means of controlled flooding of the buoyancy tanks and then set down onto the seabed. Self-upending jackets obtain a
vertical position after the launch on their own. Piling and pile/jacket fixing completes the installation.

**Topsides for a Gravity-Based Structure (GBS)**
The topside is assembled above the sea on a temporary support near a yard. It is then taken by a barge of such dimensions as to fit between the columns of the temporary support and between the columns of the GBS. The GBS is brought in a deep floating condition in a sheltered site (e.g. a Norwegian fjord). The barge is positioned between the columns and the GBS is then deballasted to mate with and to take over the deck from the barge. The floating GBS with deck is then towed to the offshore site and set down onto the seabed.

**Jacket Topsides**
For topsides up to approximately 120 MN, the topside may be installed in one lift. Slide 6 shows a 60 MN topside being installed by floating cranes.

![Installation of 60MN K12-BP topside by floating crane.](Image)

For the modularized topside, first the MSF will be installed, immediately followed by the modules.

**Offshore Lifting**
Lifting of heavy loads from barges (Slide 6) is one of the very important and spectacular construction activities requiring a focus on the problem when concepts are developed. Weather windows, i.e. periods of suitable weather conditions, are required for these operations.
Crane Vessel
Lifting of heavy loads offshore requires use of specialized crane vessels.

Table 1 - Major Offshore Crane Vessels

<table>
<thead>
<tr>
<th>Operator Name</th>
<th>Type</th>
<th>Lifting capacity (Tonnes)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balder</td>
<td>Semisub</td>
<td>Fix 3630 + 2720 = 6350</td>
</tr>
<tr>
<td>McDermott</td>
<td>DB50 Monohull</td>
<td>Fix 4000</td>
</tr>
<tr>
<td></td>
<td>DB102 Semisub</td>
<td>Rev 6000 + 6000 = 12000</td>
</tr>
<tr>
<td>SAIPEM</td>
<td>M7000</td>
<td>Rev 7000 + 7000 = 14000</td>
</tr>
</tbody>
</table>

Notes:
1. Rated lifting capacity in metric tonnes.
2. When the crane vessels are provided with two cranes, these cranes are situated at the vessels stem or bow at approximately 60 m distance c.t.c.
3. Rev = Load capability with fully revolving crane.
4. Fix = Load capability with crane fixed.

Sea Transport and Sea Fastening
Transportation is performed aboard a flat-top barge or, if possible, on the deck of the crane vessel.
The module requires fixing to the barge (see Figure 9) to withstand barge motions in rough seas. The sea fastening concept is determined by the positions of the framing in the module as well as of the "hard points" in the barge.

### LOAD-OUT

**Introduction**

For load-out two basic methods are applied:
- skidding
- platform trailers

**Skidding**

Skidding is a method feasible for items of any weight. The system consists of a series of steel beams, acting as track, on which a group of skids with each approximately 6 MN load capacity is arranged. Each skid is provided with a hydraulic jack to control the reaction.

**Platform Trailers**
Specialized trailer units (see Figure 10) can be combined to act as one unit for loads up to 60 - 75 MN. The wheels are individually suspended and integrated jacks allow adjustment up to 300 mm.

The load capacity over the projected ground area varies from approximately 55 to 85 kN/sq.m. The units can drive in all directions and negotiate curves.

***
DRILLING & PRODUCTION

A) DRILLING OPERATIONS

The largest and most critical investment for any oil company is that of drilling and intervening in wells. The first step in drilling operations is to review all available offset drilling data to shorten the learning and expense curves. An efficient and fully documented well design follows, and a comprehensively engineered program is drafted to ensure that the rig team has all the necessary information to complete the work safely.

The creation and life of a well can be divided into 5 stages:
• Planning
• Drilling
• Completion
• Production
• Abandonment

DRILLING
A well is created by drilling a hole between 5 to 50 inches in diameter into the earth with an oil rig that rotates a drill bit. Modern wells often have 4-7 sets of subsequently smaller-hole sizes drilled inside one another, each cemented with casing. Once the hole is drilled, a steel pipe (casing) slightly smaller than the hole is placed in the hole and secured with cement. This casing provides structural integrity for the newly drilled well bore in addition to isolating potentially dangerous high pressure zones from each other and from the surface. The outer tube, “casing”, is hence used to prevent the drilled hole from collapsing. Inside the casing a production tube is lowered as explained in detail in the next chapter.

With the high pressure zones safely isolated and the formation protected by the casing, drilling of the well can proceed deeper (into potentially more unstable and violent formations) with a smaller bit, and is also cased off with a smaller sized casing. Modern wells often have 2-5 sets of ever decreasing diameters drilled inside one another, each with a cemented casing.

COMPLETION
After drilling and casing the well must be ‘completed’. Completion is the process by which the well is prepared to produce oil or gas. In a cased-hole completion, small holes called perforations are made, by fixing explosive charges in the portion of the casing which passes through the production zone, providing a passage for the oil to flow from the surrounding rock into the production tubing. In open hole completion (an open hole completion consists of simply running the casing directly down into the formation, leaving the end of the piping open, with no protective filter), ‘sand
screens’ or a ‘gravel pack’ are often installed in the last drilled, uncased reservoir section. These maintain structural integrity of the well bore in the absence of casing, while still allowing flow from the reservoir into the well bore. Screens also control the migration of formation sands into production tubes and surface equipment. After a flow path has been established, acids and fracturing fluids may be pumped into the well to fracture, clean, or otherwise prepare and stimulate optimal production of hydrocarbons in the well bore by the reservoir rock. Finally, the area above the reservoir section of the well is isolated inside the casing and connected to the surface via the pipe of smaller diameter, namely the production tubes. This arrangement provides an extra barrier to hydrocarbon leaks as well as allowing damaged sections to be replaced.

The smaller diameter of the tubing has the added advantage of hydrocarbons being produced at a greater velocity which overcomes the hydrostatic effects of heavy fluids such as water.

In many wells, the natural pressure of the subsurface reservoir is high enough for the oil or gas to flow to the surface. However, this is not always the case, as in depleted fields where the pressure has been lowered by other producing wells, or in low permeability oil reservoirs. Installing tubing with a smaller diameter may be enough to facilitate production, but artificial lift methods may also be needed. Common solutions include down hole pumps and gas lifts. The use of artificial lift technology in a field is often termed as “secondary recovery” in the industry. In the last ten years many new systems have been introduced to the well completion field, especially in the case of horizontal wells.

PRODUCTION

The production stage is the most important stage of the life of a well, when oil and gas are produced. By this time, the oil rig and/or workover rig used to drill and complete the well have moved off the well bore, and the top is usually fitted with a collection of valves called a “Christmas Tree”. These valves regulate pressure, control flow, and allow access to the well bore, when further completion work is necessary. From the outlet valve of the Christmas Tree, the flow can be connected to a distribution network of pipelines and tanks to distribute the product to refineries, natural gas compressor stations, or oil export terminals.

As long as the pressure in the reservoir remains high enough, this Christmas Tree is all that is required for production from the well. If the pressure diminishes and the reservoir is considered economically viable, the artificial lift methods mentioned in the completions section can be employed.

Enhanced recovery methods such as water, steam, CO2 and gas injection may be used to increase reservoir pressure and provide a “sweep” effect to push hydrocarbons out of the reservoir. Such methods require the use of injection wells (often chosen from old production wells in a carefully determined pattern), and are frequently used when facing problems with reservoir pressure depletion, high oil viscosity. They can also be established early in a field’s life. In certain cases – depending on the geomechanics of the reservoir– reservoir engineers may determine that ultimate recoverable oil may be increased by applying a water
flooding strategy earlier rather than later in the field’s development. The application of such enhanced recovery techniques is often termed “tertiary recovery” in the industry.

ABANDONMENT
When a well no longer produces or produces so poorly that it is a liability to its owner, it is abandoned. In this simple process, tubing is removed from the well and sections of well-bore are filled with cement so as to isolate the flow path between gas and water zones from each other as well as from the surface. Filling the well-bore completely with concrete is unnecessary and the cost prohibitive.

TYPES OF WELLS
The drilling engineer is required to plan a variety of well types.

<table>
<thead>
<tr>
<th>Table 1–1</th>
<th>Well Type Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Well Type</strong></td>
<td><strong>Characteristics</strong></td>
</tr>
<tr>
<td>Wildcat</td>
<td>No known (or little) geological foundation for site selection.</td>
</tr>
<tr>
<td>Exploratory</td>
<td>Site selection based on seismic data, satellite surveys, etc.; no known drilling data in the prospective horizon.</td>
</tr>
<tr>
<td>Step-out</td>
<td>Delineates the reservoir’s boundaries; drilled after the exploratory discovery(s); site selection usually based on seismic data.</td>
</tr>
<tr>
<td>Infill</td>
<td>Drills the known productive portions of the reservoir; site selection usually based on patterns, drainage radius, etc.</td>
</tr>
<tr>
<td>Reentry</td>
<td>Existing well reentered to deepen, sidetrack, rework, or recomplete; various amounts of planning required, depending on purpose of reentry.</td>
</tr>
</tbody>
</table>

At a producing well site, active wells may be further categorized as:

- **Oil producers** - producing predominantly liquid hydrocarbons, mostly with some associated gas.
- **Gas producers** - producing virtually entirely gaseous hydrocarbons.
- **Water injectors** - where water is injected into the formation either to maintain reservoir pressure or simply to dispose of water produced at the same time as the hydrocarbons, because even after treatment it would be too oily to dump overboard and too saline to be considered clean for offloading into a fresh water source, in the case of onshore wells. Frequently, water injection is an integral part of reservoir management and produced water disposal.
- **Aquifer producers** - producing reservoir water for re-injection to manage pressure. In effect this is moving reservoir water from a less to a more useful site.
- **Gas injectors** - where gas is often injected into the reservoir as a means of disposal or storage for later production, but also as a means to maintaining reservoir pressure.
Abnormal pressures affect the well plan in many areas, including:

- Casing and Tubing design
- Mud weight and type selection
- Casing setting depth selection
- Cement planning

In addition, the following problems must be considered as a result of high formation pressures:

- Kicks and blowouts
- Differential pressure pipe sticking
- Lost circulation from mud weight

Because of the difficulties associated with high-pressure exploratory well planning, most design criteria, publications, and studies have been devoted to this area; the amount of effort expended is justified. Unfortunately, the drilling engineer still must define for himself the planning parameters that can be relaxed or modified when drilling normal pressure holes or well types such as step-outs or infills.

**Well Drilling**

Once the site has been selected, it must be surveyed to determine its boundaries, and environmental impact studies may be carried out. Lease agreements, titles and right-of-way accesses for the place must be obtained and evaluated legally. For the offshore sites, legal jurisdiction must be determined.

**Setting Up the Rig**

Sea-based oil platforms and oil drilling rigs are some of the largest moveable man-made structures in the world. Below is a figure of a typical drilling rig.
Main system and drilling rigs include:

- Large diesel engines - burn diesel fuel oil to provide the main source of power or Gas Turbine driven generators
- Electrical generators - to provide electrical power.
- Mechanical system - driven by electric motors.
- Hoisting system - used for lifting heavy loads; consists of a mechanical winch with a large steel cable spool, a block-and-tackle pulley and a receiving storage reel for the cable.
- Rotary Table - part of the drilling apparatus Rotating equipment - used for rotary drilling.
- Swivel - large handle that holds the weight of the drill string; allows the string to rotate and makes a pressure tight seal on the hole.
- Kelly - 4 or 6 sided pipe that transfers rotary motion to the turntable and drill string.
• Top Drive – Rotates the drill string either by means of an electrical or hydraulic motor. Replaces the rotary table and the 4 or 6 sided kelly bushing. This is the modern and most common drilling system used today.

• Drill string - consists of a drill pipe made up of connected sections about 10 m each and drill collars (a heavier pipe with a larger diameter that fits around the drill pipe and places weight on the drill bit).

• Drill bit(s) – at the end of the drill that actually chisels the rock; come in many shapes and materials (tungsten carbide steel, diamond) and are specialized for various drilling tasks and adapted to specific rock properties.

• Circulation system pumps drilling mud (e.g. a mixture of water, clay, weighting material and chemicals, used to lift drill cuttings from the drill bit to the surface) under pressure through the drill pipes and drill collars

• Pump - sucks mud from the mud pits and pumps it into the drilling apparatus.

• Pipes and hoses - connect pump to drilling apparatus.

• Mud-return line - returns mud from hole.

• Shale shaker - shaker/sieve that separates rock cuttings from the mud.

• Shale slide - conveys cuttings to transport skips or overboard for disposal.

• Reserve pit - collects drill cuttings separated from the mud.

• Mud pits - where drilling mud is mixed and recycled.

• Mud-mixing hopper - where new mud is mixed and sent to the mud pits.

• Derrick - support structure that holds the drilling apparatus.

• Blowout preventer – a system of high-pressure valves. Located under the rotary table/diverter or on the sea floor, it seals the high-pressure drill lines and relieves pressure when necessary to prevent a blowout (uncontrolled gush of gas or oil to the surface, often associated with fire).
PERSONNEL
Personnel required for operating and overseeing drilling and completion operations as well as a short description of duties are listed below:

• **Company Representative:** a Company Man is a representative for the oil company. Other terms that may be used are: Drilling Foreman, Drilling Engineer, Company Consultant, or Rig Site Leader. The company man is in direct charge of most operations pertaining to the actual drilling and integrity of the well bore. In the offshore oil and gas business he usually reports to the drilling Superintendent onshore.

• **OIM (Oilrig Installation Manager):** the OIM is the most senior member of management offshore for the drilling contractor. His main responsibility is the safe operation of the offshore installation.

• **Tool pusher:** the tool pusher is the person responsible for drilling operations on the drilling rig. Tool pushers are in charge of keeping the rig supplied with all the necessary tools and equipment, supplies, etc. They work closely with the OIM and Company Representative with regards to the actual drilling of the well.

• **Driller:** The driller is a team leader in charge of drilling the well bore and operating the hoisting equipment. The Driller is in charge of his drill crew, and runs the rig itself. He is responsible for interpreting the signals the well sends regarding pressure of gas and fluids. In an emergency situation he is also responsible for taking the correct counter measures to stop an uncontrolled well control situation from emerging. The driller will watch for gas levels, the flow of drilling mud and other information. While tripping out, the driller will run the floor and work the rig.

• **Assistant Driller:** His general responsibility is to assist the driller by keeping records and paperwork up to date. Training and instructing the floor hands and newly hired personnel. Over time this may allow the assistant driller to qualify for a position as driller.

• **Roustabout:** A new entrant starts as a roustabout. No formal academic qualifications are needed, but many employers want people with some relevant experience. Applicants must usually pass a medical before working offshore. Roustabouts, who show ability, can advance in the career path and may be assistant driller and driller.

• **PRS Operator:** this is a somewhat new position at some automated rigs. PRS stands for Pipe Racking System. This is an automated system that allows the drill pipe to be racked by a man stationed in the room alongside the driller. It also eliminates the need for the derrickman to go aloft on the derrick to guide the drill pipe into the wellhead.

• **Derrickman:** the derrickman reports to the assistant driller or to the Driller when required. The name Derrickman comes from the position that he normally occupies.
which is at the top of the derrick. From this position he guides the strands of drill pipe (typically 25-30 m long) into the wellhead at the top of the derrick while tripping out the hole. When tripping out the hole he pulls the pipe out of the fingers and guides it into the top drive or the travelling block. Traditionally the derrickman works closely with the mud engineer when not tripping out pipe since he is not needed in the derrick. In this capacity it is his responsibility to monitor the mud weight and density, to add chemicals to the mud to maintain its properties as well as monitor the mud level in the mud pits to assist in well control.

Depending on country and operator other terms may be used for the drilling and completion personnel.

Drilling the Well

Once the site has been surveyed and the rig positioned over the area of interest, a drilling template is placed onto the seabed. This is a metal structure with a conical pipe arrangement placed where the wells will be drilled. The drilling template is secured into the seabed with piles. Next, a conductor hole is either drilled or driven to the required depth. The crew then drills the main portion of the well. The first part of the hole is larger and shorter than the main portion and is lined with a large diameter conductor pipe.

Sometimes, if a survey shows the presence of a structure which potentially may contain oil and gas, an exploratory well is drilled.

The next stage is to drill appraisal wells to find out how much oil and gas are present, and whether it is worth developing the field.

To drill the well, the following steps are taken:

• The drill bit, aided by rotary torque or mud motor and the compressive weight of drill collars above it, breaks up the earth.
• Drilling mud (also known as “drilling fluid”) is pumped down inside the drill pipe and exits at the drill bit where it helps to break up the rock, controls formation pressure, as well as cleaning, cooling and lubricating the bit.
• The generated rock “cuttings” are swept up by the drilling mud as it circulates back to surface outside the drill pipe. They go over “shakers” which shake out the cuttings over screens allowing the cleaned mud to return back into the pits. Watching for abnormalities in the returning cuttings and volume of returning fluid are imperative to catch “kicks” early. A “kick” refers to a situation where the pressure below the bit is higher than the hydrostatic pressure applied by the column of drilling fluid. When this happens gas and mud gushes up uncontrollably.
• The pipe or drill string to which the bit is attached is gradually lengthened as the well gets deeper by joining 10-20 m lengths of threaded drill pipe at the surface. 3 joints (treble) combined equal 1 stand. Some smaller rigs only use 2-joint (double) stands while newer rigs can handle stands of 4 joints (fourable).

The drilling rig contains all necessary equipment to circulate the drilling fluid, hoist and turn the pipe, control down-hole pressures and remove cuttings from the drilling fluid. It also generates on site power for these operations.

There are 5 basic steps to drilling the hole:
1. Place the drill bit, collar and drill pipe in the hole.
2. Attach the Kelly or Top-drive and begin drilling.
3. As drilling progresses, circulate mud through the pipe and out of the bit to float the cuttings out of the hole.
4. Add new sections (joints) of drill pipes as the hole goes deeper.
5. Remove (trip out) the drill pipe, collar and bit when the required depth is reached or drill bit fails.

The casing crew puts the casing pipe in the hole. The cement crew pumps cement down the casing pipe using a bottom plug, cement slurry, a top plug and drill mud. The pressure from the drill mud causes the cement slurry to move through the casing out through the bottom of the well. The slurry then backtracks up around the casing to fill the void between the outside of the casing and the hole. Finally, the cement is allowed to harden and then tested for hardness, alignment and tightness. Drilling continues in stages: Drilling, running and cementing new casings, then drilling again.

When rock cuttings from the mud reveal oil in the reservoir rock, the final depth may have been reached. At this point, drillers remove the drilling apparatus from the hole and perform several tests to confirm this finding:
• Well logging - lowering electrical and gas sensors into the hole to take measurements of the rock formations there
• Drill-stem testing - lowering a device into the hole to measure pressures, which will reveal whether a reservoir rock has been reached
• Core samples - taking samples of rock to look for characteristics of a reservoir rock
Once drillers have reached the final depth, the crew completes the well to allow oil to flow into the casing in a controlled manner. First they lower a perforating gun into the well down to the production depth. The gun has explosive charges which perforate holes in the casing through which oil can flow. After the casing has been perforated, they run a small-diameter pipe (tubing) into the hole as a conduit for oil and gas to flow up the well.

A device called a packer is run down the outside the tubing. When the packer reaches the production level, it is expanded to form a seal around the outside of the tubing. Finally, a multi-valved structure called a Christmas Tree is connected to the top of the tubing and fastened to the top of the casing. The choke valve on the Christmas Tree allows the flow of oil from the well to be controlled. Once the well is completed, flow of oil into the well must be initiated.

For limestone reservoir rock, acid is sometimes pumped down the well and out the perforations. The acid dissolves the limestone creating channels through which oil can flow into the well. For sandstone reservoir rock, a specially blended fluid containing proppants (sand, walnut shells, aluminum pellets) is pumped down the well and out through the perforations. The pressure from this fluid creates small fractures in the sandstone which in turn allow oil to flow into the well, while the proppants hold these fractures open. Once the oil is flowing, the oil rig is removed from the site, and production equipment is set up to extract oil from the well.

**Drilling Bits**

The drilling part that actually chisels away at soil, rock and other materials, as a well is being dug, is called a drill bit and is an essential tool in the drilling of a well. In recent years, technological advances have made such tools more efficient, longer lasting and less expensive. A drill bit is edged with diamonds or carbide to make the cutters extremely hard. Mud circulates through the bit.
Drilling fluids, including the various mixtures known as drilling mud, do the following essential jobs in oil and gas wells:

- Lubricate the drill bit, bearings, mud pump and drill pipe, particularly as it wears against the sides of the well when drilling deviated wells.
- Clean and cool the drill bit as it cuts into the rock.
- Lift cuttings to the surface and allow cuttings to drop out into the mud pit or shakers to prevent them recirculating.
- Regulate the chemical and physical characteristics of the mixture arriving back at the drilling rig.
- Carry cement and other materials to where they are needed in the well.
- Provide information to the drillers about what is happening downhole - by monitoring the behaviour, flow-rate, pressure and composition of the drilling fluid.
- Maintain well pressure and lubricate the borehole wall to control cave-ins and wash-outs.
- Prevent well blow-outs - by including very heavy minerals such as bentonite to counteract the pressure in the hole.

The main classification scheme used broadly separates the mud into 3 categories based on the main component that makes up the mud:

- Water Based Mud (WBM). This can be sub divided into Dispersed and Non-Dispersed.
- Non Aqueous or more commonly ‘Oil Based Mud’ (OBM) this also includes synthetic oils (SBM).
- Gaseous or Pneumatic mud.

Over the years individual drilling companies and their expert drillers have devised proprietary formulations to deal with specific types of drilling jobs.

**Horizontal Drilling**
Not all oil deposits are readily accessible to a traditional vertical well. In this situation surface drilling equipment is offset from the oil deposit. At the outset of the drilling process, the well is drilled vertically, and then a few degrees at a time it turns in whichever direction is needed to hit the reservoir. Horizontal drilling itself has been around for some time, but approximately 10 years ago it regained popularity in its use to increase production from narrow, fractured formations.

When a vertical well is drilled through a narrow pay zone, its exposure to the pay zone is limited, but if the well is horizontal and runs in the pay zone it allows for a much better performance of the well.

In 1987, Maersk Oil in Denmark drilled the world’s first horizontal well equipped with a cemented liner and multiple hydraulically induced, sand propped fractures for drainage and productivity enhancement.

A horizontal drilling record was set by Maersk Oil Qatar in 2004, when a horizontal well drilled in the Al Shaheen Field reached a total depth of 9.4 km with a horizontal section of 8.1 km.

Well Completion

Once the design well depth is reached, the formation must be tested and evaluated to determine whether the well should be completed for production, or plugged and abandoned.

To complete the well production, casing is installed and cemented, and the drilling rig is dismantled and moved to another site. Well completion activities include:

- Conducting Drill Stem Test
- Setting Production Casing
- Installing Production Tubing
- Initiating Production Flow
- Installing Pumping Units
- Servicing as required after start of production

Conducting Drill Stem Test

To determine the potential of a formation, the operator may order a Drill Stem Test (DST). The DST crew sets up the test tool at the bottom of the drill stem, then lowers it to the bottom of the hole.
Weight applied to the test tool expands a hard rubber seal called a packer. Opening the tool ports allows the formation pressure to be tested. This process enables workers to determine the potential of the well.

**Setting Production Casing**
Production casing is the final casing in a well. It can be established from the bottom to the top of the well. This casing is set in place in the same way as other casings, and then cemented in place.

**Installing Production Tubing**
A well is usually produced through tubing inserted down the production casing. Oil and gas are produced more effectively through this smaller-diameter tubing than through large-diameter production casing. Joints of tubing are connected to couplings to make up a tubing string. Tubing is run into the well in much the same way as casing, but tubing is smaller in diameter and is removable.

The steps for this activity are:
- Tubing elevators are used to lift tubing from the rack to the rig floor.
- The joint is stabbed into the string that is suspended in the well with air slips.
- Power tongs are used to make-up tubing.
- This process is repeated until tubing installation is complete.
- The tubing hanger is installed at the wellhead.

New technology allows tubing to be manufactured in a continuous coil, without joints. Coiled tubing is inserted into the well down the production casing without the need for tongs, slips, or elevators and takes considerably less time to run.

**Starting Production Flow**
Production flow is started by washing in the well and setting the packer. Washing refers to pumping water or brine(salt solution) into the well to flush out the drilling fluid. Usually this is enough to get the well flowing. If not, the well may need to be unloaded. This means swabbing the well to remove some of the brine. If this does not work, flow may alternatively be started by pumping high pressure gas into the well before installing the packer. If the well does not flow on its own, well stimulation or artificial lift may need to be applied.

**Servicing**
Servicing operations assume that the well has been completed and initial production has begun. All servicing activity requires specialized equipment. The equipment is transported to the well and rigged up.

Servicing is done by specialized crews and includes:
- Transporting Rig and Rigging Up
- General and Special Services
- Workover

**Transporting Rig and Rigging Up**
Transporting and rigging up the equipment is the first step in well servicing operations. After these steps, servicing activities commence.
**General and Special Services**
Wells often need maintenance or servicing of on-surface or downhole equipment. Working on an existing well to restore or increase oil and gas production is an important part of today’s petroleum industry. A well that is not producing to its full potential may require service or workover. Special services are operations that use specialized equipment and workers who perform support well drilling and servicing operations. Coordination between all personnel is critical for onsite safety. Therefore, all special services operations should conduct a pre-job safety meeting that includes all personnel on the job site.

**Workover**
Workover activities include one or more of a variety of remedial operations on a producing well to try to increase production.

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**TYPICAL CHRISTMAS TREE CONFIGURATION (with Glossary)**

Wellhead and Christmas tree is the main equipment for oil production, water injection and downhole operation. It is installed on the casing head to seal the annular space between casing and tubing, control wellhead pressure, adjust well flow rate and transport oil to pipeline.

![Diagram of Christmas tree configuration](image)

*Source: Schlumberger Oilfield Glossary Online*
SOME CONCEPTS OF FISHING AND MILLING OPERATIONS

A “fishing” job is an unwelcome but often necessary procedure in both drilling and workover operations. It is expensive. It usually is not in the budget, and the operator must see that it is performed in the most expeditious manner.

“Fishing” is the term used for procedures to correct downhole problems in an oil or gas well such as stuck pipe or drill collars, recovery of pipe twisted off or otherwise lost downhole, removal of loose junk, and the recovery or removal of wireline that has parted or become stuck.

When any of these conditions develops, all progress in the drilling, workover, or completion ceases and fishing operations must be successfully completed before normal operations can resume.

Fishing is not considered to be a usual or common practice, but it is probably required to some degree in about one of every five wells drilled and up to four out of five wells that are worked over. Since the cost of fishing, including the rig time used, can be considerable, care and judgment must be exercised. Fishing tools and practices have been developed over the years making possible the correction of almost any downhole problem. However, the cost may be prohibitive, and in some cases, even initial fishing operations should not be conducted. In view of the high cost of rig operation plus the cost of the special services involved in fishing, proper judgment must be exercised and decisions must be made based on all the information available.

Fishing is not an exact science, and many times there is more than one way to approach the problem. However, there is probably a best way if all factors are considered. Personnel of fishing tool companies have valuable experience gained by performing this work constantly, where operating personnel are only exposed to these problems occasionally. Planning a fishing job is one of the most important phases, and costs can be reduced by adequate planning. Discussions should be held with all personnel involved, such as fishing tool operators or supervisors, mud company personnel, rig personnel, electric wireline company representatives (where applicable), and any others who might become involved. It is much cheaper to discover that a certain procedure will not work before doing it than after a misrun with the subsequent expense.

Economics of Fishing – To fish or not to fish?
Fishing should be an economical solution to the problem in the well. Obviously, a shallow hole with little rig time and equipment invested can justify only the cheapest fishing. When there is a large investment in the hole and substantial capital equipment to be recovered, more time and expense can be feasibly committed. There are studies, papers, formulas, and models that help in the economic decision of “to fish or not to fish, and if so, for how long?” All have merit, but so many factors affect the decision that converting them into a standard formula or pattern is almost impossible.

Probability factors are useful in determining the time to be spent on a fishing job. These percentages must be derived from similar situations, however, as there are
no two fishing jobs exactly alike. Decision making with the associated costs should be established for drilling and workover programs where there are multiple wells and similar situations. Good judgment, a careful analysis of the problem, and then the skilled application of the decision, insofar as the rig and tools are concerned, is the best solution.

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B) PRODUCTION OF OIL AND GAS

How are Oil and Natural Gas produced?
Before a well can produce oil or gas, the borehole must be stabilized with casing, which is a length of pipe cemented in place. A small diameter tubing string is centered in the well bore and held in place with packers. It enables the hydrocarbons to be brought from the reservoir to the surface. Due to underground forces reservoirs typically have an elevated pressure. To equalize the pressure and avoid blowouts of oil and gas, a series of valves and equipment are installed at the top of the well. This “Christmas tree”, as it is sometimes called, regulates the flow of hydrocarbons out of the well. Early in its production life, underground pressure often pushes the hydrocarbons all the way up the well bore to the surface like a carbonated soft drink that has been shaken. Depending on reservoir conditions, this “natural flow” may continue for many years. When the pressure differential is insufficient for the oil to flow naturally, artificial lift may be used to bring the oil up to the surface. The offshore most common process is the artificial lift by means of gas lift.

As a field ages, the company may choose one of the production recovery techniques, where an external fluid such as water or gas is injected into the reservoir through injection wells. Usually the injection wells are wells in the field that are converted from production wells to injection wells.

In the so-called “waterflooding” technique, some of these wells are used to inject water (often produced water from the field) into the reservoir. This water tends to push the oil out of the pores in the rock toward the producing well. Waterflooding will often increase production from a field.

In the second production recovery technique, some of or all gas from the production wells (or imported from another platform) may be re-injected into the reservoir (the gas cap) through the gas injection wells to sustain a high reservoir pressure.

In more advanced cases, the company may use more sophisticated techniques, collectively referred to as Enhanced Oil Recovery (EOR). Depending on reservoir conditions, various substances may be injected into the reservoir to extract more oil from the pore spaces and increase production. These substances can be steam, nitrogen, carbon dioxide or surfactants (soap).

Throughout their productive life, most oil wells produce oil, gas, and water. This mixture is separated at the surface. Initially, the mixture coming from the reservoir may be mostly oil with a small amount of water. Over time, the proportion of water increases and it may be reinjected into the reservoir either as part of a water flooding project or for disposal. In the latter case the water is returned to the subsurface. Natural gas wells do not usually produce oil, but occasionally produce a small amount of liquid hydrocarbons. These natural gas liquids are removed in the field or at a gas processing plant that removes other impurities as well. Natural gas liquids often have significant value as raw material for the petrochemical industry. These wells often produce water as well, but volumes are much lower when compared to oil wells.
Once produced, oil may be stored in a tank and later transported by ship to a site where it will be sold or enter the transportation system. More often, however, it goes from the separation facilities at the wellhead direct into a small pipeline and from there into a larger one. Pipelines are frequently used to bring production from offshore wells to shore. They may also transfer oil from a producing field to a tanker loading area for shipping or from a port area to a refinery to be processed into petrol, diesel fuel, jet fuel, and many other products.

Natural gas is almost always transported through pipelines. Because of difficulties in transferring it from where it is found to where potential consumers are, years ago, the gas would have been wasted (flared) as an unwanted by-product of oil production. However, now industry recognizes the value of clean-burning natural gas and is working on improved technologies to get it from the reservoir to the consumer. Once the individual well streams are brought into the main production facilities over a network of gathering pipelines and manifold systems, another phase of the production process will start. Some of the main offshore installations and processes are summarised in figure below.
Separation Process

Crude oil usually consists of different components in 2 or 3 different phases, namely liquid, gas and solid. The industry uses several separation mechanisms, such as separation utilizing by gravity or centrifugal forces as well as electric and/or magnetic fields, to separate these from one another. Separation by gravity is mostly used in the petroleum industry to separate crude oil into oil, water and gas. Separators with different configurations such as vertical, horizontal and/or spherical are used in this type of separation. The purpose is to separate gas from liquid with a minimum of liquid transfer in the gas stream or liquid from gas with a minimum of gas bubbles entrapped in the liquid. The oil and gas treatment industry requires a combination of the above, meaning that the gas separated has to be free of any water and oil, and the oil separated, free from any water and gas. Cyclones, the principal type of gas-solids separators, using centrifugal force, are widely used. They are basically simple in construction and can be operated at high temperatures and pressures. Hydro-cyclones are used for liquid-liquid separation. It is a centrifugal device with a stationary wall, the centrifugal force being generated by the movement of the liquid. It is suitable in waste water treatment. The water treatment unit includes a degassing vessel, used to remove gas from water, as gas bubbles can carry some of the remaining oil from the water.

Separator
A separator is a vessel used in the field to remove well-stream liquid(s) from gas components. The separator may be either 2-phase or 3-phase. 2-phase separators remove the totality of the liquid from the gas, while 3-phase separators in addition remove free water from the hydrocarbon liquid.

An oil and gas separator generally includes the following essential components and features:
In most oil and gas surface production equipment systems, the oil and gas separator is the first vessel the well fluid flows through after it leaves the producing well.
However, other equipment – such as scrubbers\textsuperscript{7} and water knockouts\textsuperscript{8} - may be installed upstream of the separator.

**Pumps**
The liquids used in the chemical industries differ considerably in their physical and chemical properties. Selection of a pump for a specific service requires knowledge of the liquid to be handled, the total dynamic head required, the suction and discharge heads, and in most cases, the temperature, viscosity, vapor pressure and density of the fluid. Special attention will need to be given to those cases where the liquid contains solids. Pumps fall into 3 categories: positive displacement, kinetic (centrifugal), and jet (eductor), their names describing the method by which liquid is displaced.

**Compressor**
A compressor is a device that transfers energy to a gaseous fluid, the purpose being to raise the pressure of the fluid e.g. where it is the prime mover of the fluid through the process. Compressors are driven by gas turbines or electrical motors. Often several stages in the same train are driven by the same motor or turbine. The main purposes of gas compression offshore are for:
- Gas export
- Gas injection to well
- Gas lift
- Fuel gas
The compression process includes a large section of associated equipments such as scrubbers (removing liquid droplets), heat exchangers and lube oil treatment etc. Several types of compressors are used for gas compression, each with different characteristics such as operating power, speed, pressure and volume. The most basic and well-known types of compressors are the positive displacement and the dynamics compressors.

**Valves**

\textsuperscript{7} A scrubber is a type of separator that has been designed to handle flow streams with unusually high gas-to-liquid ratios. These are commonly used in conjunction with dehydrators, extraction plants, instruments, or compressors as protection from entrained liquids.

\textsuperscript{8} A knockout is a type of separator falling into 1 of 2 categories: free water or total liquid knockouts. The free water knockout is a vessel used to separate free water from a flow stream of gas, oil, and water. The gas and oil usually leave the vessel through the same outlet to be processed by other equipment. Water is removed for disposal.
Valves are the components in a fluid flow or pressure systems that regulate either the flow or the pressure of the fluid. Their duty may involve stopping and starting flow, controlling flow rate, diverting flow, preventing back flow, controlling pressure, or relieving pressure.

Valves can be operated and adjusted in their either manually or automatically. Manual operation includes the operation of the valve by means of a manually controlled power operator. The manual valves are the manually operated valves for stopping and starting flow, controlling flow rate, and diverting flow; and the automatically operated valves for preventing back flow and relieving pressure.

The way the closure member moves onto the seat gives a particular group or type of valve a typical flow-control characteristic. This flow control characteristic can be used to establish a preliminary chart for the selection of valves.

Check valves are divided into several groups according to the way the closure member moves onto the seat. The basic duty of these valves is to prevent back flow. Pressure relief valves are divided into 2 major groups: direct-acting pressure relief valves that are actuated direct by the pressure of the system fluid, and pilot-operated pressure relief valves in which a pilot controls the opening and closing of the main valve in response to the system pressure.

Pilot-operated pressure relief valves may be provided with a pilot that controls the opening and closing of the main valve direct by means of an internal mechanism. In an alternative type of pilot-operated pressure relief valve, the pilot controls the opening or closing of the main valve indirect by means of the fluid being discharged from the pilot.

Rupture discs are non-reclosing pressure relief devices that may be used alone or in conjunction with pressure relief valves.

**Control valves**

Control valves are valves used to control process conditions such as flow, pressure, temperature, and liquid level by fully or partially opening or closing in response to signals received from controllers that compare a “set point” to a “process variable” whose value is provided by sensors that monitor changes in such conditions. The opening and/or closing of control valves is done by means of electrical, hydraulic or pneumatic systems. Positioners are used to control the opening or closing of the actuator based on electric or pneumatic signals. The most common signals for industry are 4-20 mA signals.

The most common and versatile types of control valves are sliding stem globe and angle valves. Their popularity derives from rugged construction and the many options available that make them suitable for a variety of process applications, including severe service.

Control valve bodies may be categorized as below: [Fisher, Control valve handbook, 4th ed.]
- Angle valves
- Angle seat piston valves
- Globe valves
• Rotary valves

**Heat Exchangers**
The heat exchanger is one of the most important units in the oil industry. For safety reasons or to achieve a specific required operative condition (temperature) the fluid needs to be heated or cooled. It is also of great importance in achieving an optimal separation process. The fluid temperature must be fixed due to the thermodynamic calculation results to reduce fluid viscosity. The fluid itself needs to be cooled after the compressing process.

**Selection**
The selection process usually includes a number of factors, all of which are related to the heat transfer application. These factors include, but are not limited to, the items listed here:
- Thermal and hydraulic requirements
- Material compatibility
- Operational maintenance
- Environmental, health, and safety consideration and regulation
- Availability
- Expenses

Any heat exchanger selected must be able to provide a specified heat transfer, often between a fixed inlet and outlet temperature, while maintaining a pressure drop across the exchanger that is within the allowable limits dictated by process requirements or economy. The exchanger should be able to withstand stresses due to fluid pressure and temperature differences. The material or materials selected for the exchanger must be able to provide protection against excessive corrosion. The propensity for fouling (clogging) in the exchanger must be evaluated to assess the requirements for periodic cleaning.

The exchanger must meet all the safety codes. Potential toxicity levels of all fluids must be assessed and appropriate types of heat exchangers selected to eliminate or at least minimize human injury and environmental costs in the event of an accidental leak or failure of the exchanger. Finally, to meet construction deadlines and project budgets, the design engineer may have to select a heat exchanger based on a standard design used by the producer to attain these parameters.

**Types**
A typical heat exchanger, usually for high-pressure applications, is the shell-and-tube heat exchanger, consisting of a series of finned tubes, through which one of the fluids runs. The second fluid runs over the finned tubes to be heated or cooled.

Another type of heat exchanger is the plate heat exchanger. One section is composed of multiple, thin, slightly separated plates that have a very large surface area and the other of fluid flow passages which allows heat transfer. This stacked-plate arrangement can be more effective, in a given space, than the shell-and-tube heat exchanger.
Advances in gasket and brazing technology have made the plate type heat exchanger increasingly practical. Other types of heat exchanger are the regenerative heat exchanger\(^9\) and dynamic heat exchanger\(^10\)

**Control Systems and Safety**

A control system is an interconnection of components forming a system configuration that will provide a desired system response. We need to control many parameters to get the required results. For this purpose we need to control pressure, temperature, flow and the level of the liquid inside the separators. The process at the platform deals with high pressures, explosive gasses, flammable liquids or oil that requires specific safety considerations. Due to these factors a good safety system needs to be installed to reduce hazards. The computerized emergency shutdown system (ESD) is the most important element in the safety system. Control, in one form or another, is an essential part of any industrial operation. In all processes it is necessary to keep flows, pressures, temperatures, compositions, etc. within certain limits for safety reasons or as a required specification. This is most often done by measuring the process/controlled variable, comparing it to the desired value (set point) for the controlled variable and adjusting another variable (manipulated variable) which has a direct effect on the controlled variable. In order to design a system so that it operates not only automatically but also efficiently, it is necessary to obtain both steady and dynamic (unsteady) state relationships between the particular variables integrated. Automatic operation is highly desirable, as manual control would necessitate continuous monitoring of the controlled variable by a human operator.

**Some Concepts of Computer Control System**

Supervisory Control and Data Acquisition, or SCADA control system is a computerized control system. It can control and monitor all the processes in a greater process such as an offshore platform. The SCADA control system is divided into two subsystems:

1. Process Control System, (PCS): This represents the main controlling computer that gets information from all the processes in operation on the platform. At the same time it will take appropriate action and intervene when necessary. Units called Remote Terminal Units or (RTU’s) are responsible for transferring the information (signals) between the PCS and the controlling and measuring equipment on the plant. The RTU’s software contains a database, control functions, logic functions and alarm/event treatment.

\(^9\) In this type of Heat Exchanger he heat from a process is used to warm the fluids to be used in the process, and the same type of fluid is used on both sides of the heat exchanger.

\(^10\) This is mainly used for heating or cooling high viscosity products, in crystallization processes and in evaporation and high fouling applications.
2. Data Acquisition System, (DAS): It receives data coming from the process control system (PCS) and interprets it, so any developments (variations/discrepancies) in the system will be shown in the control room. In both systems there is a master PCS/DAS and a slave PCS/DAS for back-up, so no data will be lost if the master fails. There is also a report printer and an event printer in addition to a hard copy printer which is linked to all computers through a switchboard for printing visual displays, providing supervisors and operators with an overview of operations.
PLATFORM DECOMMISSIONING

We have seen the many different types of offshore installations, from fixed steel platforms and large concrete gravity structures, to a variety of floating production systems and subsea completions.

Many of these offshore oil and gas facilities are now reaching the end of their productive phase, and the questions relating to shutting down production, decommissioning the production facilities and removing the redundant structures are becoming an important issues for consideration.

It is likely that more than 7,000 offshore oil and gas installations which are in place worldwide will be decommissioned in the coming years and decades. Furthermore, several thousand kilometers of pipelines will probably need to be removed, trenched or covered.

One of the main difficulties with decommissioning is finding the right balance between:

- Technical Feasibility
- Environmental Protection
- Health and Safety
- Cost
- Public Opinion

The process of decommissioning is very strictly regulated by international, regional and national legislation. The options available for decommissioning will depend on the location of the offshore facility and subsequent legislations. One of the most important steps in the decommissioning process is planning ahead.

**Possible Decommissioning Options**
The topsides of all installations must be removed to shore, without exception.

For structures considered ‘small’ (i.e. those with substructures weighing less than 10,000 ton) complete removal is the only permitted option. The best option is then down to evaluating the various methods for carrying out the removal, balancing the same set of criteria.

For structures that are brought back to shore (either as a whole or in pieces), different disposal options must then be evaluated. The waste hierarchy dictates that there is a preference for reuse (either within or outside the oil and gas industry), followed by recycling and finally disposal, if neither of the other two options are possible.
For the large structures (i.e. all steel or concrete installations with substructures weighing more than 10,000 t) a number of options are possible and must be evaluated balancing all the above listed criteria:

• Complete removal
• Partial removal leaving 55 m clear water column for navigational safety.\(^{11}\)
• Leave in place (for concrete gravity based installations only).
• Disposal at deep sea site following removal from original site (for concrete gravity based installations only).

Criteria for Decommissioning Solution
When considering the environmental impacts of a given option, it is necessary to assess the wider effects on the land, sea and air of bringing all or parts of the structure to shore. A number of environmental-impact factors may be evaluated:

• The amount of energy used to remove a structure and take it back to shore
• The emissions to the atmosphere during all the phases of the decommissioning
• Waste streams from all phases of the decommissioning of a structure, which must be traced and accounted for
• The environmental effects on other users of the sea and the local populations onshore
• The environmental effects on the marine fauna and flora

To date most decommissioning has relied on heavy lift vessels which take the structure apart offshore piece by piece. However, new technologies, which could lift whole topsides off in one go and possibly the whole of the substructures, are being jointly developed by marine contractors and the oil and gas industry. As with all businesses, the onus is on the operator to find the most cost-effective option which does not compromise the safety of workers or the environment. At present the costs for decommissioning structures are relatively high since experience is still limited to a small number of shallow water structures. The health and safety of the workers is of paramount importance, and every effort is made to ensure that all phases are carried out to the highest industry safety standards. The work offshore is inherently more dangerous as it is the least predictable due to the weather, the sea movement and the equipment being used.

Technical Challenges
The technical challenges faced in decommissioning an offshore oil and gas facility are equal to, and in some respects, more complex than those overcome in the initial construction and installation phase.

\(^{11}\) For steel structures the cutoff point would be at the top of the ‘footings’; For concrete gravity structures the cutoff point is usually determined by the construction of the installation
Whereas the industry has considerable worldwide experience in removing steel structures, particular challenges are presented by some of the larger deep water structures.

Health and Safety Challenges
Decommissioning and removal of a complex offshore oil and gas facility is a complex and potentially risky operation. Any proposed decommissioning operation must seek to minimize the associated hazards and risks to personnel to a level that is as low as reasonably practicable. Such operations will be subject to detailed safety analysis and summarized in the abandonment safety case approved by the appropriate regulatory authorities.

Environmental Challenges
When undertaking and planning decommissioning, account has to be taken of the environmental impact of each phase of the operation. Results of the various options available will be compared to identify the option of least detriment to the environment.

Economic Challenges
There are many economic decisions involved in planning a decommissioning operation. From defining the optimum time to shut down a producing facility and ensuring adequate financial security is in place to meet decommissioning liabilities, through to selecting the decommissioning option of least cost, which is compatible with technical feasibility, least risk to personnel and least impact on the environment.

Construction Challenges
The process of decommissioning offshore oil and gas facilities raises many complex issues and choices. Because of these complexities and their inter-relation, it is essential that there is fully transparent and well informed debate between owners, government and all interested parties in society to define consensus solutions. Decommissioning strategies are not developed in an ad hoc fashion. The oil and gas industry is highly regulated through each phase of its development from exploration, building and installing processing facilities, operations and decommissioning. The freedom of National States to define their own abandonment regulatory regimes is constrained by a global framework of conventions, guidelines, and regional protocols, which together define international law.
SUB-SEA PIPELINES

Introduction
Within industry, piping is defined as a system of pipes used to convey media from one location to another. The engineering discipline of “piping design” studies the best and most efficient way of transporting the medium to where it is needed. Piping design includes considerations of diameters, lengths, materials as well as in-line components (i.e. fittings, valves, and other devices). Further considerations must be given to instrumentation used for measurements and control of the pressure, flow rate, temperature and composition of the media. Piping systems are documented in Piping and Instrumentation Diagrams (P&ID’s).

Industrial process piping and the accompanying in-line components can be manufactured from various materials such as glass, steel, aluminum, plastic and concrete. Some of the more exotic materials of construction are titanium, chrome-molybdenum and various steel alloys.

Piping Primary Function
The primary function of piping is to transport media from one location to another. Also in relation to piping, it is necessary to mention pressure vessels. Pressure vessels, in opposition to piping, are used mainly to store and process media. Piping can also be used as a pressure vessel, but transport is the primary function. In piping permitted stresses are categorized differently than those for pressure vessels. In piping one talks about sustained and expansion stresses, whereas in pressure vessels one talks about primary and secondary stresses. While the word “piping” generally speaking refers to in-plant piping such as process piping, which is used inside a plant facility, the word “pipe-line” refers to a pipe running over a long distance and transporting liquids or gases. Downstream pipelines often extend into process facilities (e.g. process plants and refineries).

It is important to distinguish between piping and pipelines since they usually are subjected to different codes.

Piping Criteria
When analyzing piping mechanics, the following parameters need to be considered:
• The appropriate code that applies to the system.
• The design pressure and temperature.
• The type of material. This includes protecting the material from critical temperatures, either high or low.
• The pipe size and wall thickness.
• The piping geometry.
• The movement of anchors and restraints.
• The stresses permitted for the design conditions set by the appropriate code.

12 A 3” ISO flange will NOT fit on a 3” API Pipeline.
• The upper and lower limit values of forces and moments on equipment nozzles set by the standardization organizations or by the equipment manufacturers.

Pipe Design Requirements
The primary function of a pipeline is to transport media safely and reliably for the duration of its life. The service conditions for pipelines are related to substances with elevated pressure, flowing at temperatures that will vary along the route from a typically high inlet temperature to temperatures that may be critically low. In gas pipelines low temperatures may cause the formation of hydrates, while in oil pipelines waxing and viscosity problems may arise.

The functional or operational requirements basically concern the operation of the pipeline. The requirements cover definitions of the system’s ability to transport a specified media quantity within a specific temperature range. The requirements also relate to the service and maintenance of the pipeline system. Other requirements may arise from safety assessment or operator practice, and may imply the introduction of subsea isolation valves, monitoring systems, diver less access et al. Functional requirements also include the requirements facilitating inspection access, normally pig launchers and receivers. For pipelines ending on manned platforms or terminals, integration with fire fighting and other safety systems falls under the heading of functional requirements.

Pipeline Size Determination
The pipeline diameter is determined on the basis of the main operational parameters for the pipeline system, such as:
• Flowrate
• Expected system availability 13
• Requirements for delivery pressure
• Properties of the transported medium

The optimum pipeline dimension is based on the ‘lifetime’ evaluation of the system, taking into account the capital cost for the establishment of compressor/pumps, the pipeline itself, receiving facilities, as well as the operational and maintenance cost of the system.

An economic model for the pipeline system is often used to calculate different economic key parameters such as: net present value, unit transportation cost, etc.

An important part of the optimization process including the requirements for compression or pumping are flow calculations. In the initial phase the flow calculations may be performed on an overall level without detailed modeling of the thermodynamic conditions along the pipeline. However, such modeling may eventually be required, because parameters other than the pressure drop may be important factors for the dimension of the pipeline.

13 E.g. tolerated uptime and downtime
Installation

Marine pipeline installation comprises many activities including fabrication of the pipe joints, bends and components through to preparation of the pipeline for commissioning. The principal exercise is the joining of the individual pipe joints into a continuous pipe string. This may take place concurrently with the installation on the seabed by lay barge, or it may be carried out onshore in preparation for installation by reeling, towing, pulling or directional drilling. To construct the complete pipeline it may be necessary to perform offshore tie-ins to other pipe strings or to risers. These connections may be carried out on the seabed or above water.

As an example I wish to mention that in the North Sea most pipelines are trenched and backfilled leaving the pipeline approximately 1.5 m below the seabed. Large diameter pipelines are usually left on the seabed if they are found to be able to withstand common fishing gear interaction.

In areas with difficult seabed conditions the pipeline must be controlled by anchors on the seabed.

Pipelines close to installations and crossings are usually protected by concrete mattresses, rocks or other protective structures in steel, concrete or composites.

Once the pipeline is installed on the seabed it is connected to installations by spools. Spools are usually Z-shaped in order to absorb the thermal expansion from the pipeline.

Before the pipeline is handed over to production it must be commissioned by cleaning and pressure testing according to the applied code and requirements.
THE FUTURE OF OFFSHORE

The Oil and Gas Industry has experienced dynamic swings in recent years. The industry had been experienced a significant resurgence in investment coinciding with the run up in crude oil which peaked at 145 $ per barrel in mid 2008. This was then tempered with the onset of the financial crisis and ensuing global recession which gained momentum in the last quarter of 2008, and is continuing till today.14

With market confidence slowly restored the price recovered to somewhat 75 $ per barrel in 2009 and steadily increased to about 100 $ at the end of 2011, to then move at around 90 $.

Today, oil and gas business is faced with volatile oil and gas prices which shall compensate uncertain high risk of exploration disaster such as the fire of West Atlas in North West Australia and recent accident of the Deep Horizon in the Gulf of Mexico.

Similar risk with lower extent of loss is also faced by small players which develop marginal oil and gas fields. As marginal field development requires minimal investment commonly resulting fast capital return. It has become highly desired option for oil and gas investors.

To minimize the investment and operation cost of this kind oil and gas field development is very important as the oil and gas resource is economically limited. All associated cost component in Capital Expenditure (CAPEX) and Operational Expenditure (OPEX) are consequently minimized with limited economy with safety and serviceability requirements.

The currently available technology is still costly, as the technology was developed for large offshore platforms. Structural engineering, material and fabrication cost for the minimum offshore platforms can accordingly be optimized. However, current installation technology such as transportation by barge or self-floating; lifting by derrick barge cranes or jack up rigs; self-elevating installation may not be suitable and requires innovative changes specifically suitable for the platforms.

Minimum offshore structures have been known for optimizing the size and weight leading to the cheap development cost. Minimum offshore platform is an offshore structure whose size and weight are leading to minimal forces which optimized the facilities. The minimum platform size and weight have many advantages in such a way directly impact to load – out, transportation and installation method.

14 From its peak in 2008, the oil price collapsed more than 70% and ended 2008 at approximately 40 $ per barrel
The smaller and lighter platform may eliminate the requirement of expensive offshore derrick barge. There is also potential for simplified fabrication work and minimal CAPEX and OPEX.

The aspects considered in the development of new concepts for minimum offshore structures can be summarized as follows:

- Optimization of structural weight (Impact to load out, transportation and installation).
- Minimization of process equipments.
- Minimization of fabrication works.
- Offshore time reduction for installation.
- Minimization of CAPEX and OPEX.

**Minimum Offshore Platform Concepts**

Minimum offshore platform concept has been adopted since last decade. *Albaugh et al. (2001)* conducted a global review to classify eight (8) main groups of minimal offshore fixed platform and deck for marginal fields based on the structural configuration. What is illustrated below a Tripod Model Configuration.

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**Tripod Model of Minimum Offshore Platform**
I make a reference here to a study which focus on minimum offshore structure to be installed at shallow water depth with three (3) different water depths of 15m, 25m and 35m in reference to Lowest Astronomical Tide (LAT) in the Gulf of Thailand.\footnote{Cost and practical: Based Concept for Innovative Design of Minimum Offshore Structures, J.Buacharoen, A thesis for the degree of Master of Engineering in Offshore Technology and Management - Asian Institute of Technology , School of Engineering and Technology, 2010}

The platform design utilizes a minimum wellhead platform for marginal field in shallow water in the Gulf of Thailand. Some key features of this platform are as follow:

1. Topside has two (2) levels of cellar deck and upper deck providing total area about 125 sq.m. - Height between 2 floors is 4.40 m.
2. Platform access will be by boat (no helipad).
3. Maximum eight (8) single wells with dry Christmas tree.
4. One (1) small vent boom.
5. One (1) small pedestal crane with maximum vertical capacity of 10.5 ton.
6. For simplified design, assuming the blanket live load 490 kg/mq is adopted. This load case will be distributed on both upper deck and cellar deck for necessary equipments.

7. In order to reduce the structural weight, grade 42 yield strength of tubular steel would be used.

The study concludes that such minimum platform model developed in such a way as to meet the minimum structures definition for marginal field development in the Gulf of Thailand (GOT) is a valuable considerations because its unit cost per weight is low, it is a viable solution for an unmanned platform and has an optimal structural design as lifting and in-place case has a considerable cost saving.

* * * *

CONCLUSIONS

At the conclusion of this lesson, I wish to thank Prof. Amphol and Prof. Puldpong of the C.O.E Offshore Engineering Group for having offered me this opportunity to introduce the Offshore Industry. I hope the students find these subject captivating and I wish all the success for their future career in Oil & Gas.

Giorgio Segurini
APPENDIX 1 – OIL PRICE CHARTS

APPENDIX 2 – GLOBAL OIL PRODUCTION

Source: Guardian, UK Newspaper, 15.6.2010 (BP Statistics)
APPENDIX 3 – ASIA OIL AND GAS INVESTMENTS

Asian outbound oil and gas investment (excluding China)
(total reported deal value: 1Q06-2Q11)

Source: Ernst & Young analysis of data from IHS Herold, Inc.
APPENDIX 4 – LIFE TIME CYCLE OF EXPLORATION & PRODUCTION

Source: SHELL Alsaka, Oil & Gas Offshore Production, Brochure 2010
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