Engineering for Oil and Gas Exploration

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DEPARTMENT OF OCEAN ENGINEERING
INDIAN INSTITUTE OF TECHNOLOGY MADRAS

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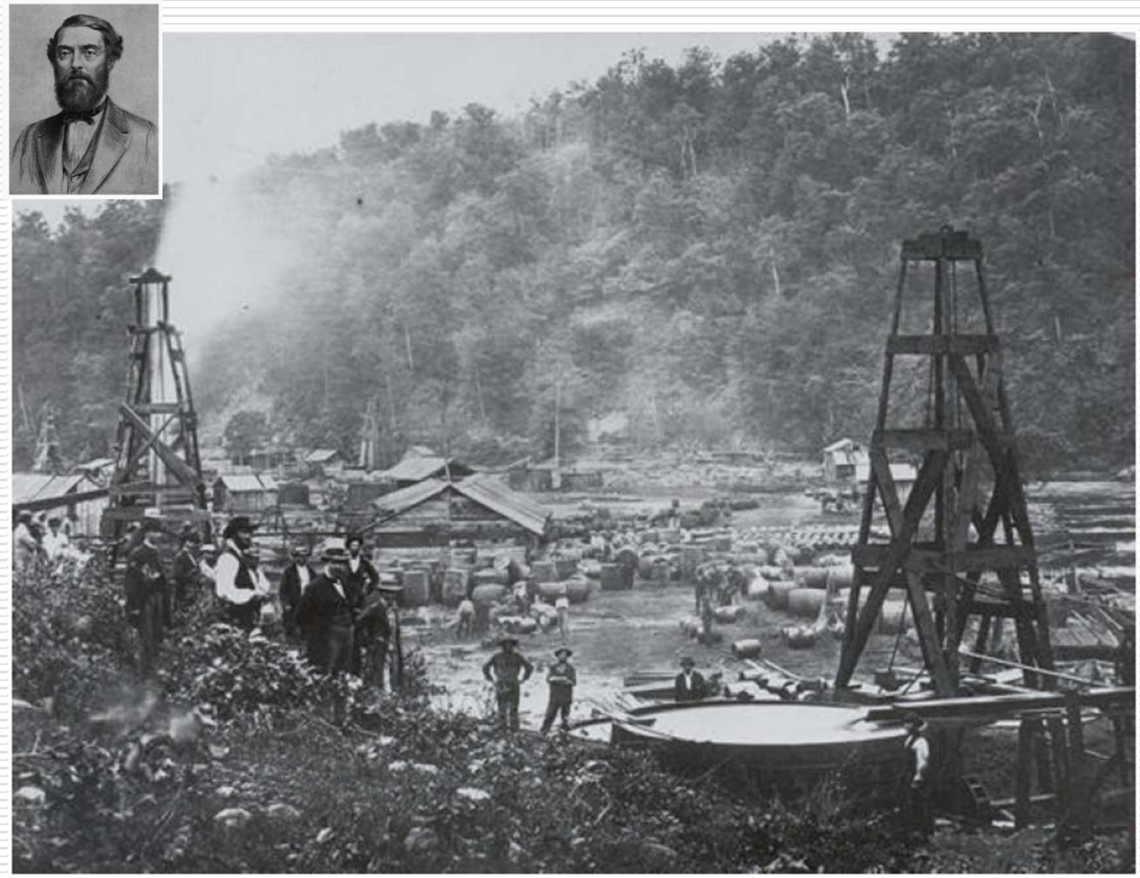
FIRST OIL EXPLORATION

Edwin Drake



First oil well was drilled in 1859 by Edwin Drake.

Use of contemporary equipment, collected in storage drums can be seen from the picture.

First one to use driven pipe in to the ground to bring oil to the surface.

Employed by Seneca oil company, oil was struck at 69.5m.

Today, the modern technology used for drilling, storage and transportation is very much part of hydrocarbon exploration.

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OIL WELLS

Oil wells in early 60's were primarily shallow depth and require pumping or other means of bringing oil to the surface.

Donkey pumps or sucker rod pumps were used to bring oil the oil.

Free flowing oil wells came in to existence as the drill depth exceeded several hundred meters as the pressure is high enough for the oil to flow up and reach the surface.

Artificial or Enhanced Oil Recovery (EOR) methods or used in wells with low pressure due to continuous exploration for a long time.

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OFFSHORE PLATFORMS

Offshore platforms became integral part of oil and gas exploration to support the drilling and production facilities in offshore miles away from land.

Offshore platforms concept has been developed keeping in view of the technology on drilling and production on land.

Hence the offshore oil and gas exploration primarily stems on to a suitable supporting structure in shallow and deep water either using fixed structure or using floating structure.

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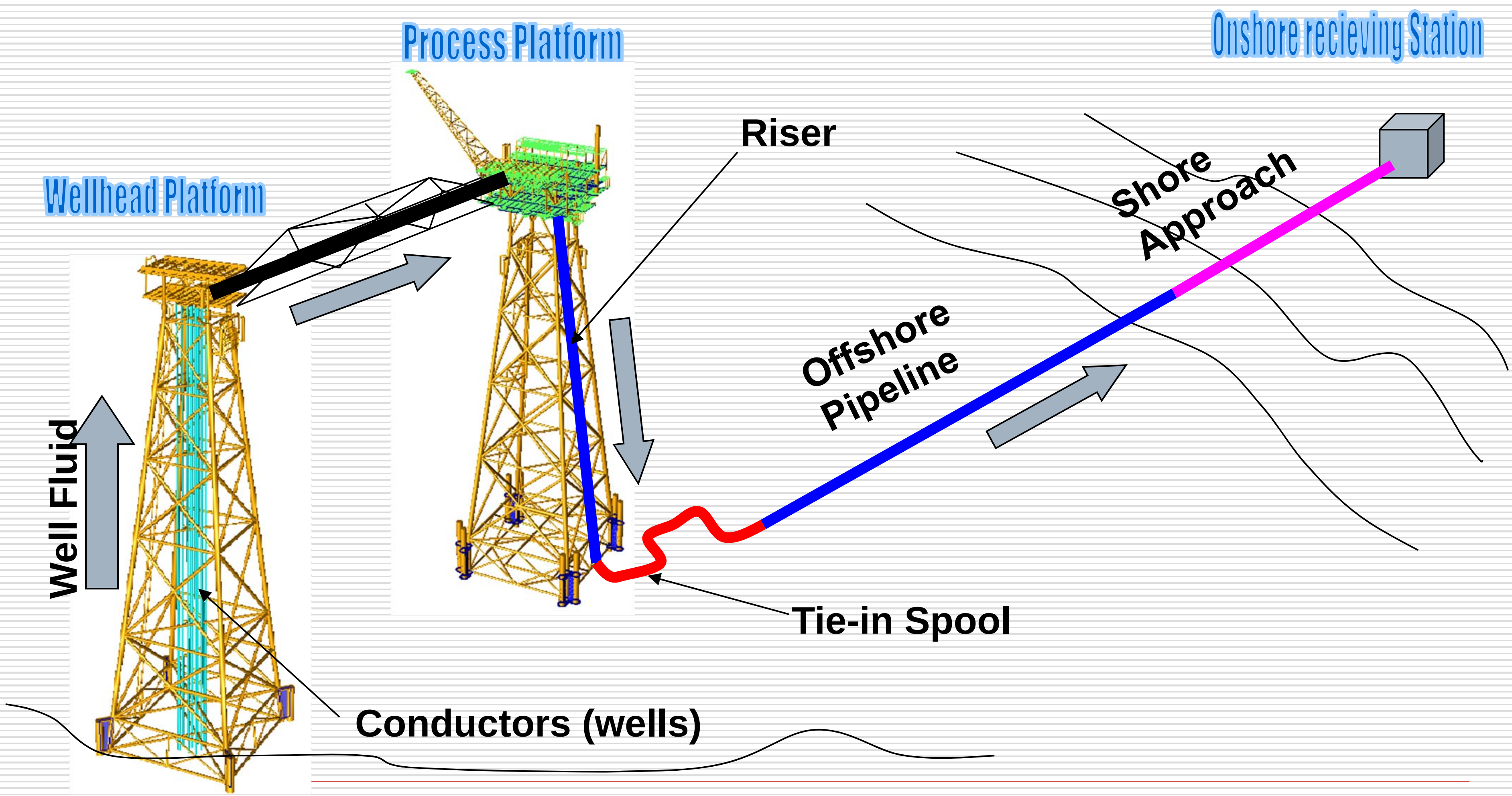
Hydrocarbon Production and Transportation



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Hydrocarbon Production and Transportation

- **Wellhead Platform**
  - Structure supports the drilling rig
  - Facilitate the drilling through conductors which protects the drill string from external environment
  - Conductor is also used to bring the oil above water through the flow lines.
- **Process Platform**
  - Primarily to remove unwanted large volume impurities present in the fluid brought from the reservoir.
  - Additional processing to condition the fluid for transportation is carried out
- **Subsea Pipelines**
  - Transportation of hydrocarbon in the form crude oil to transport to onshore for further refinement

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Wells and Manifold

Usually each wellhead platform will be installed with more than one well and all the wells will be manifolded and connected to the header for further processing.

Typical wellhead or christmas tree is shown in pictures.

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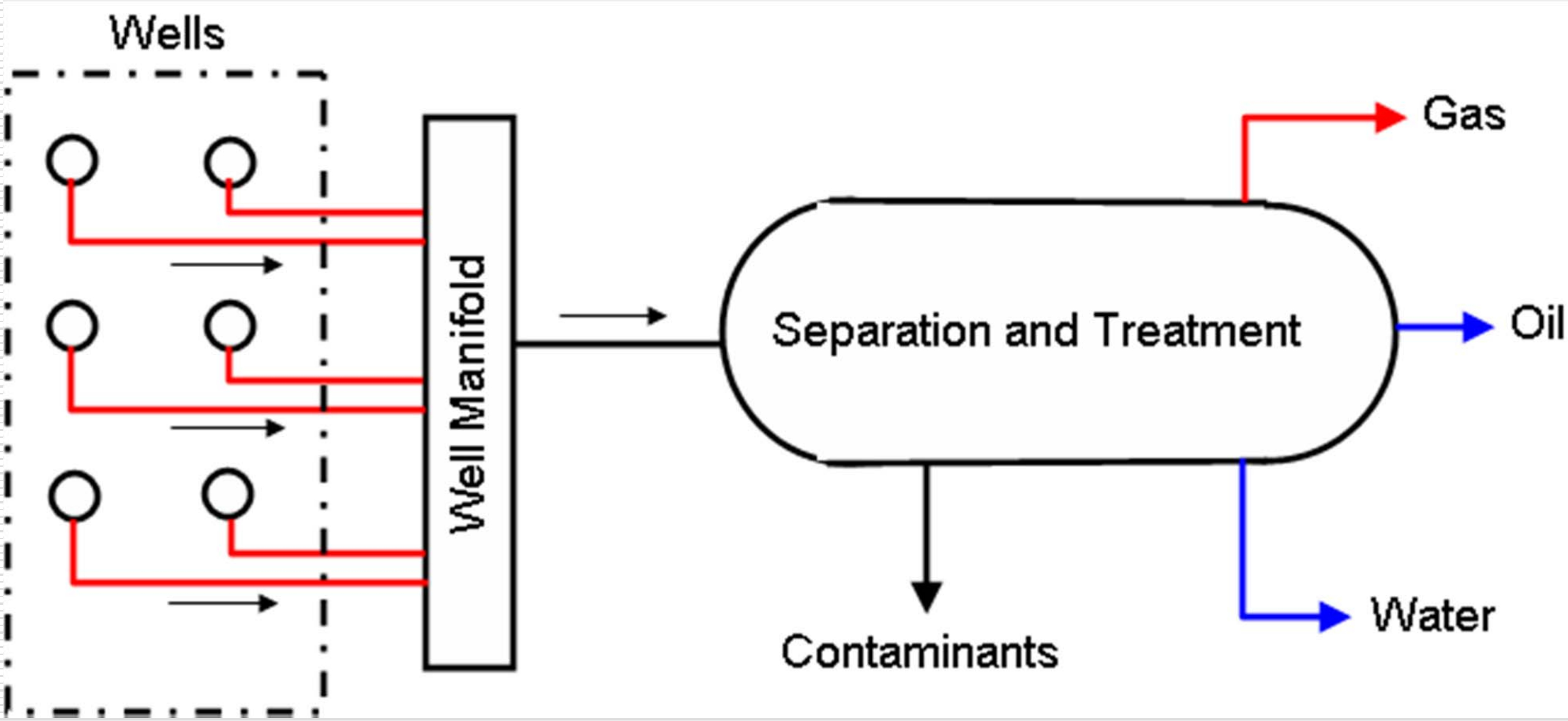
OIL AND GAS PRODUCTION SYSTEM SCHEMATIC



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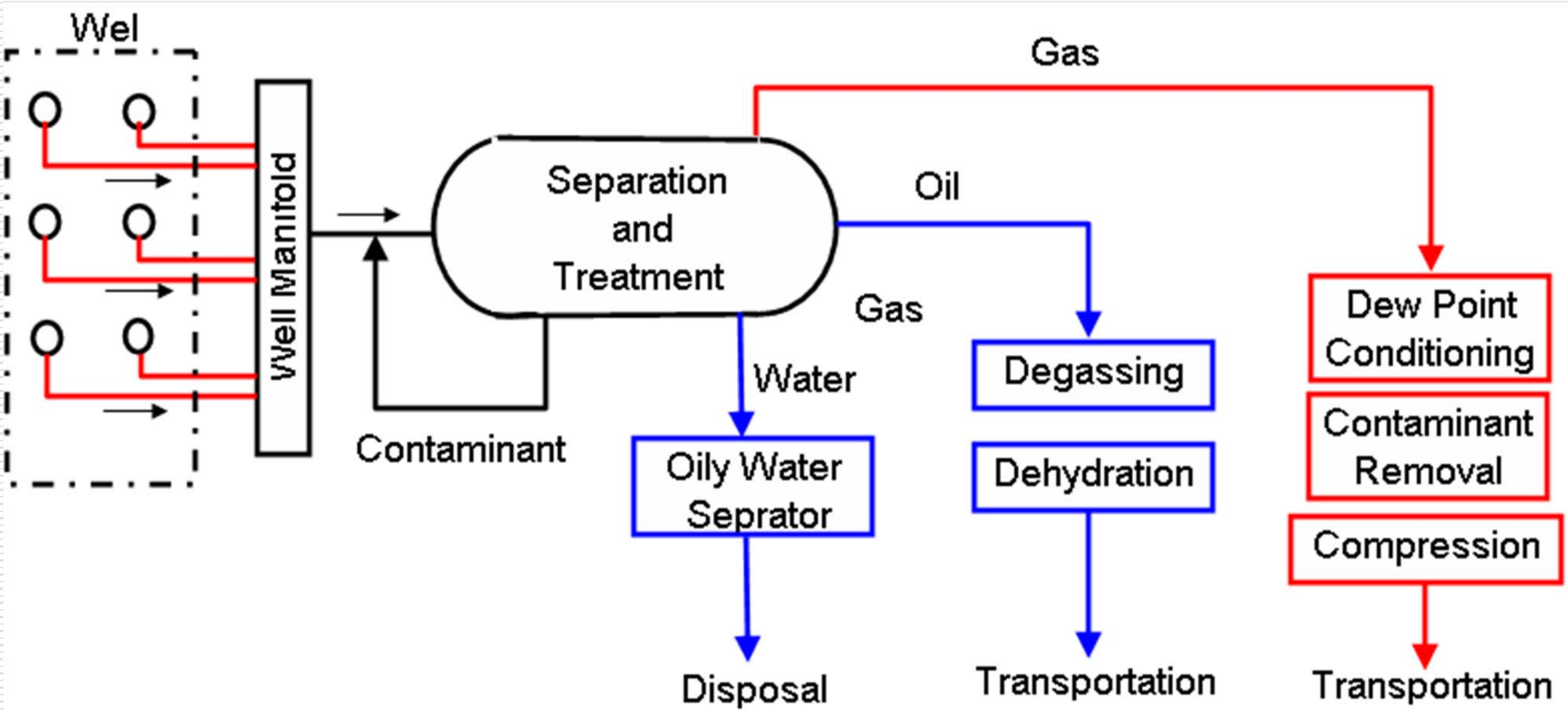
PROCESS FLOW SCHEMATIC



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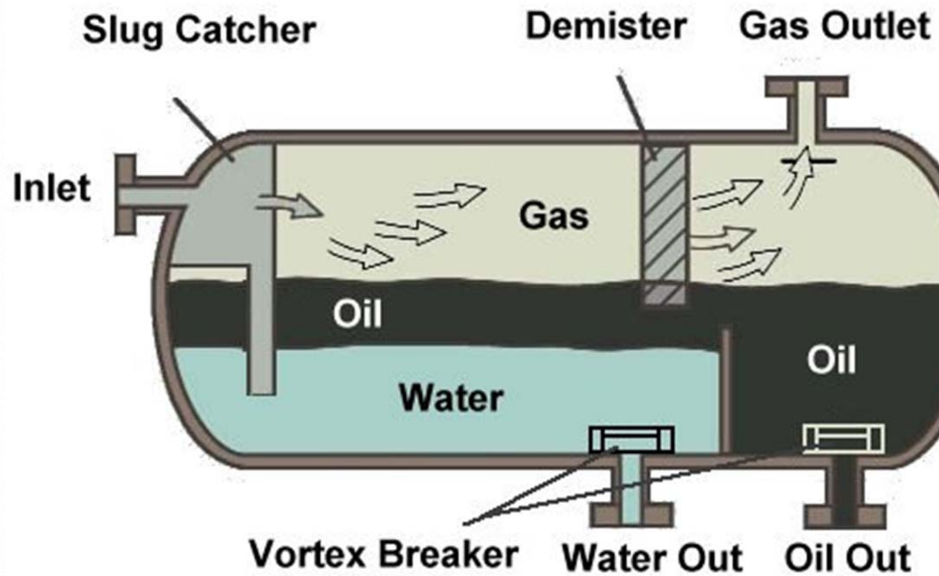
Separator

Separator is a pressure vessel that separates three phase fluid in to Gas, Water and Oil at high pressure and temperature.



Separation can be carried out in stages, Single Stage or Multistage.

First and Second Stage Separation is high pressure while the Third stage separation is low pressure.

In addition to the Separator, typical production process will have Desander, Desalter, Coalescer, water treatment package, hydrocylcone etc.

The produced oil is then exported and the produced water may be disposed off to the sea.

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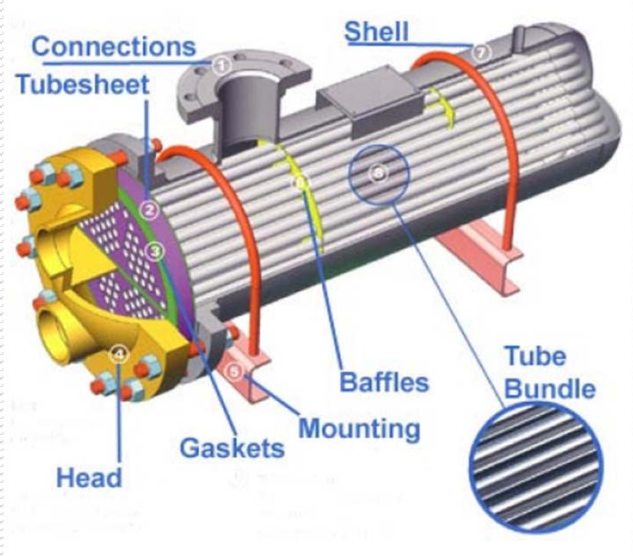
Gas Treatment and Compression

Heat Exchangers are used to cool the gas coming out from the separator. Shell and Tube heat exchangers are commonly used in the industry.

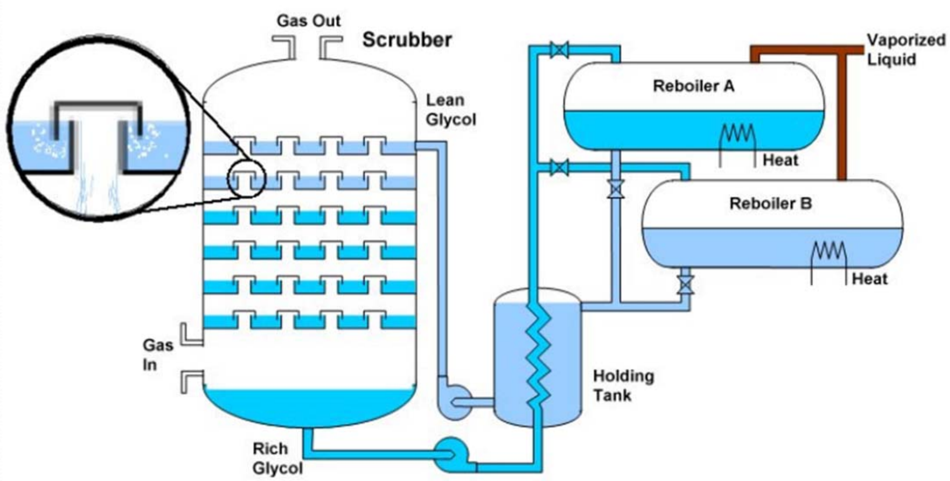


The cooled gas may contain moisture or liquid droplets and the same shall be removed. **Scrubber and re-boiler** is used to remove such droplets before the gas is then sent to the compressor.

Gas compression is required to send out the gas to the onshore.

This can be achieved by again single or multi-stage compression using Low pressure or High Pressure compressors.

Compressors can be screw type or axial compressors.



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OIL AND GAS PROJECT SEGMENTS

The overall oil and gas project can be classified into following three segments from drilling to final product at refinary

- **Upstream Production**
  - Reservoir assessment and Drilling
  - Oil, water and gas separation from 3 phase fluid
  - Heating, compression and pumping
- **Transportation**
  - Transporting Crude oil and natural gas to land
- **Downstream Refining**
  - oil refinery, which converts crude oil into high-octane motor fuel (gasoline/petrol), diesel oil, liquefied petroleum gases (LPG), jet aircraft fuel, kerosene, heating fuel oils, lubricating oils, asphalt and petroleum coke;
  - natural gas processing plant, which purifies and converts raw natural gas into residential, commercial and industrial fuel gas, and also recovers natural gas liquids (NGL) such as ethane, propane, butanes and pentanes;

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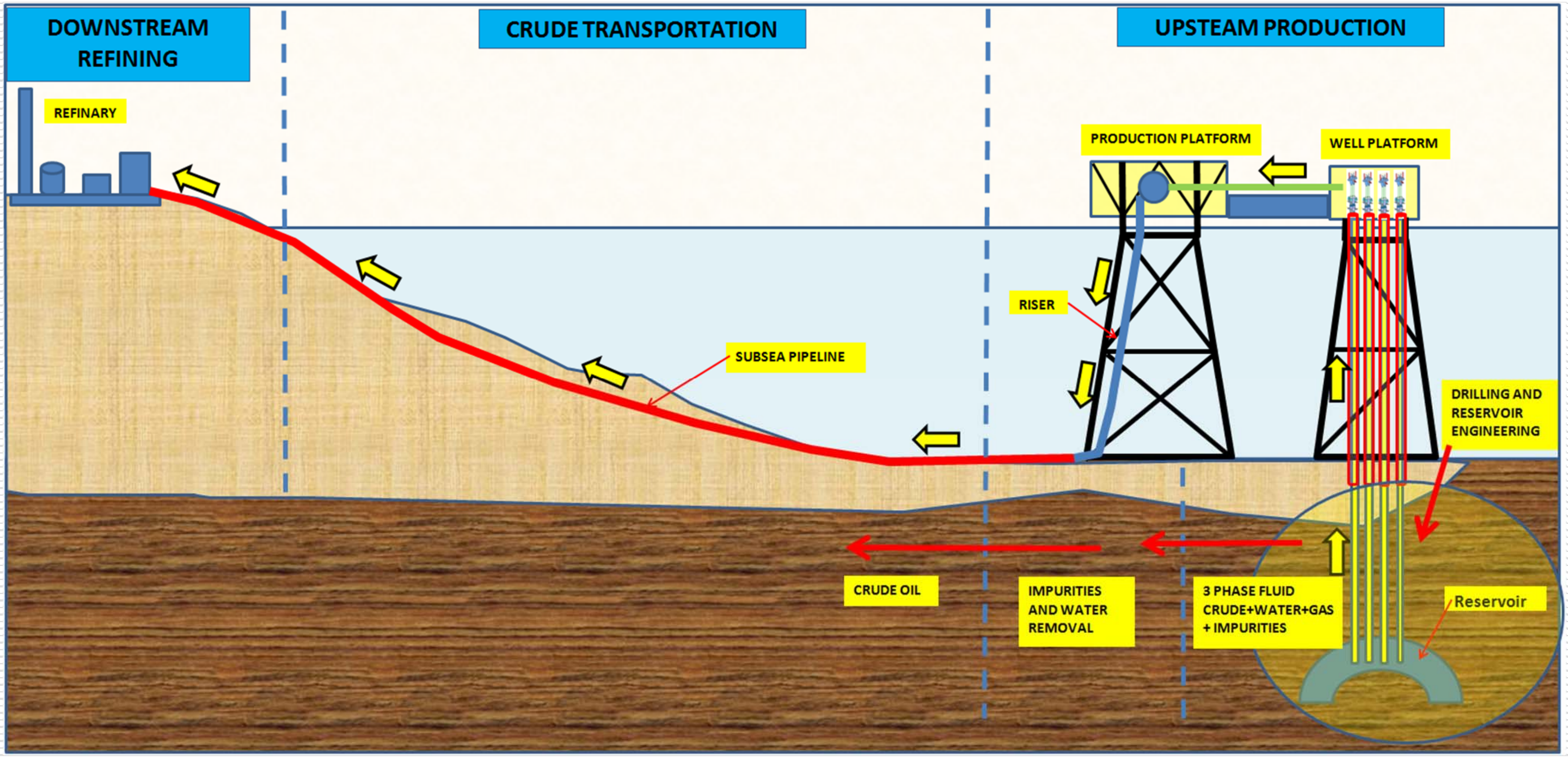
OIL AND GAS PROJECT SEGMENTS



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SUBSEA ENGINEERING

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SUBSEA ENGINEERING

The location of exploration and exploitation extends in to deep sea areas, the water depth and the environmental conditions becomes extremely difficult to design and work with.

Alternate ideas were always on the look out and one such is to install these exploration and exploitation equipment on the seabed it self thus avoiding large structures either fixed or floating.

These ideas of change includes

- Subsea well completion
- Subsea production
- Subsea gathering

The design activities shall be supported by sound engineering as we are also dealing with high pressure and low temperature, though the effect of sea wave has been reduced considerably at the sea bed.

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SUBSEA ENGINEERING

Subsea Engineering is vast field covering subsea well development, reservoir management, risers and pipelines, subsea structures, etc

- **Well Development**
  - Drilling and well completion.
- **Pipelines and Risers**
  - Rigid Pipe lines, Flexibles, Jumpers and Risers
- **Subsea Structures**
  - Subsea Wellhead Manifold, Pipeline End manifold (PLEM), Riser Supports;

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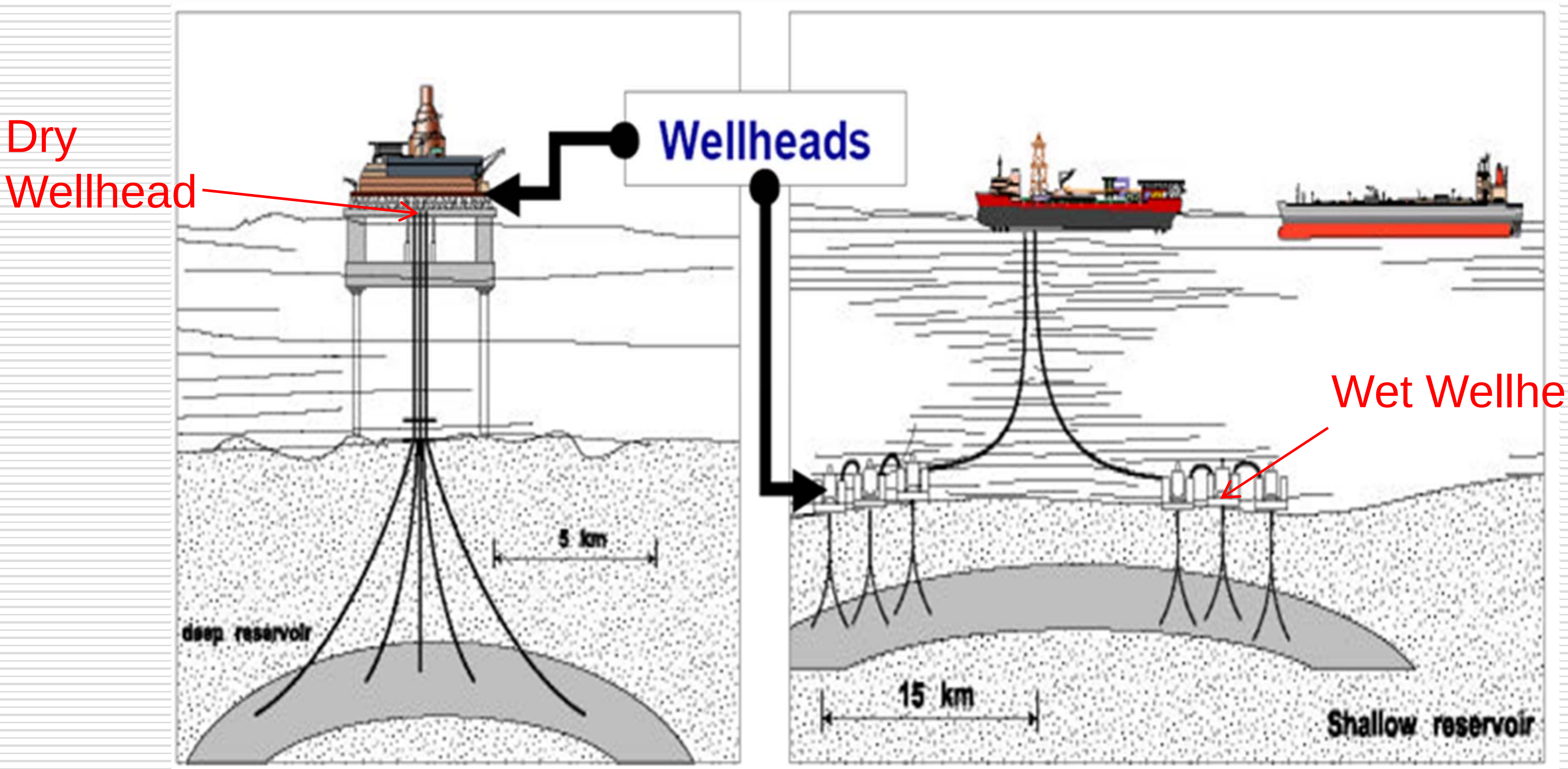
WELLHEAD – DRY OR WET ?

Wellheads located above water in a topside is called Dry wellhead or Dry Tree and the wellhead located below water at the seabed is called wet tree.



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DRY TREE CONCEPTS

Dry tree concepts are common in fixed platforms and also in tension leg platforms where the vertical movement is not appreciable.

- **Well Development**
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- **Pipelines and Risers**
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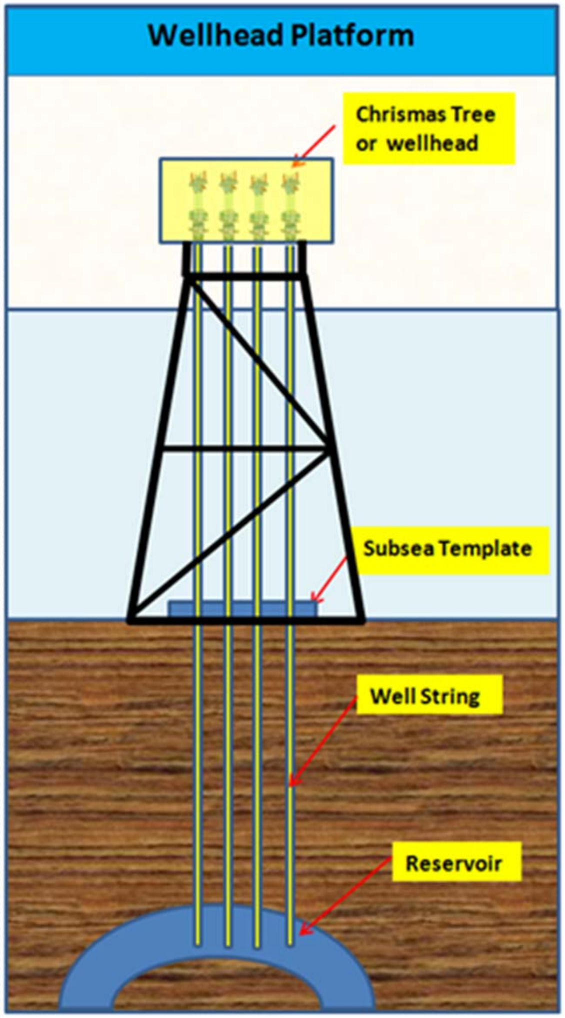

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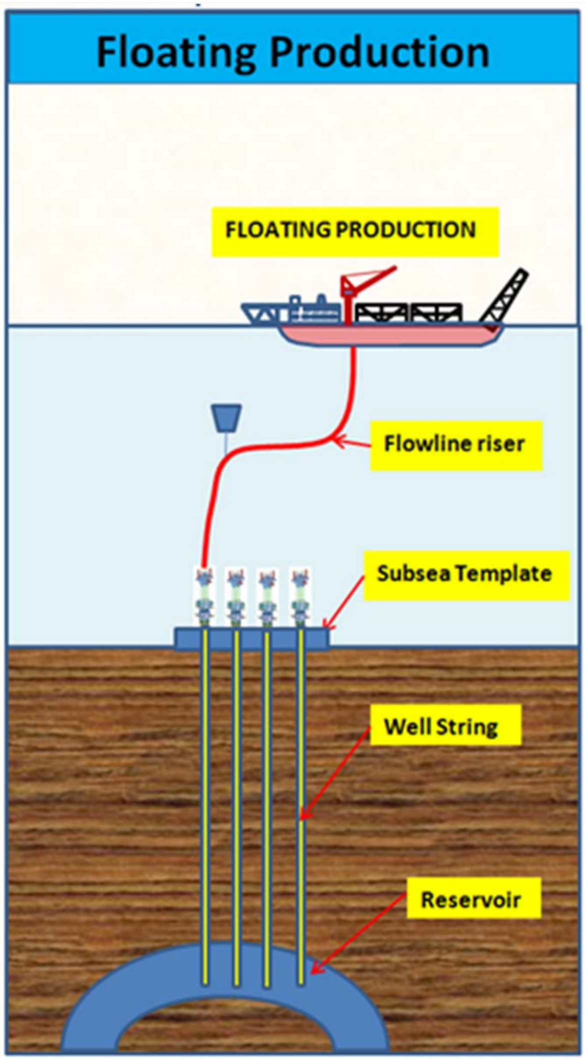
WET TREE CONCEPTS

Wet tree concepts are common in floating platforms such as Spar, FPSO and other systems.

- **Well Development**
  - Drilling and well completion.
- **Pipelines and Risers**
  - Rigid Pipe lines, Flexibles, Jumpers and Risers
- **Subsea Structures**
  - Subsea Wellhead Manifold, Pipeline End manifold (PLEM), Riser Supports;



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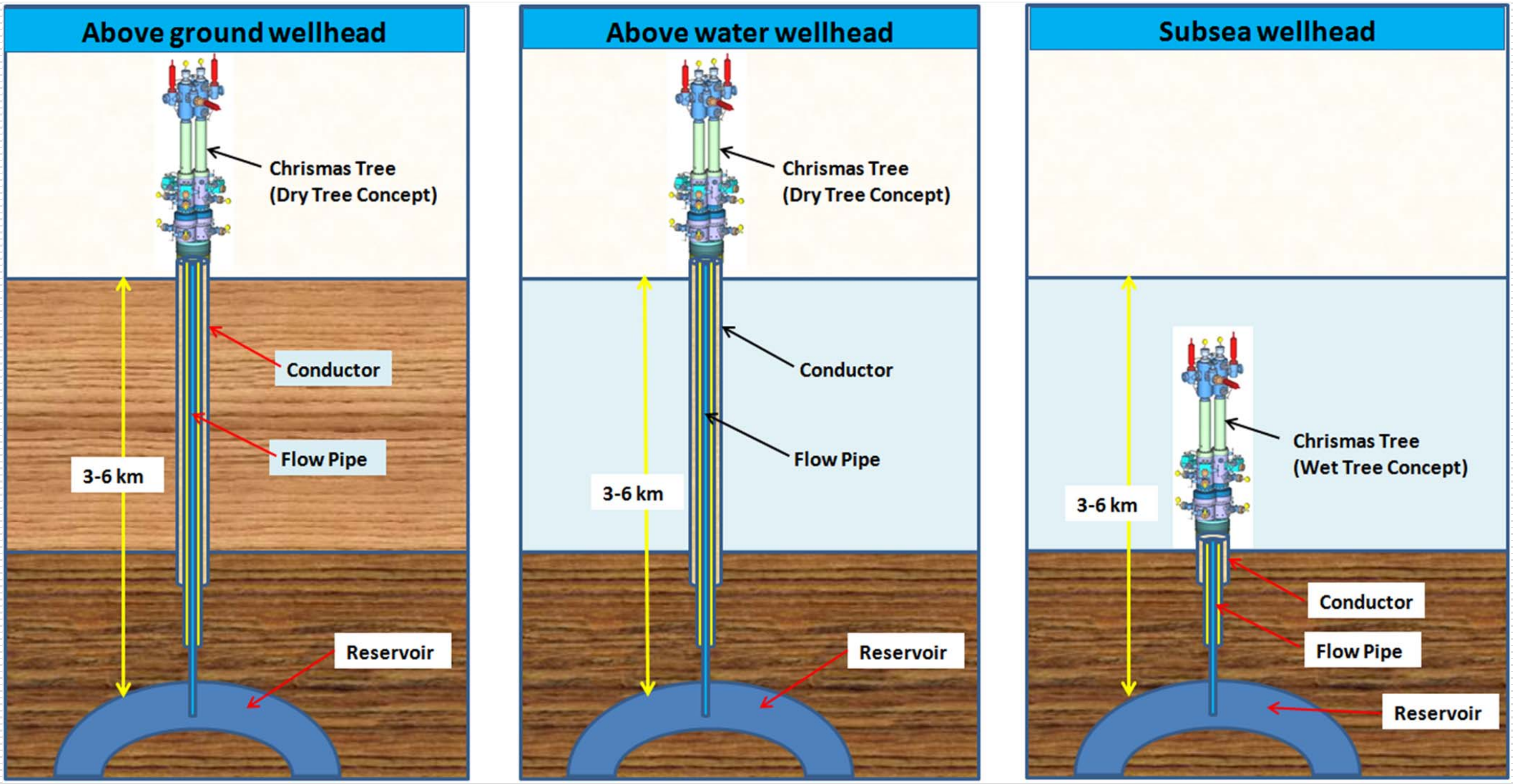
DRY AND WET TREE CONCEPTS



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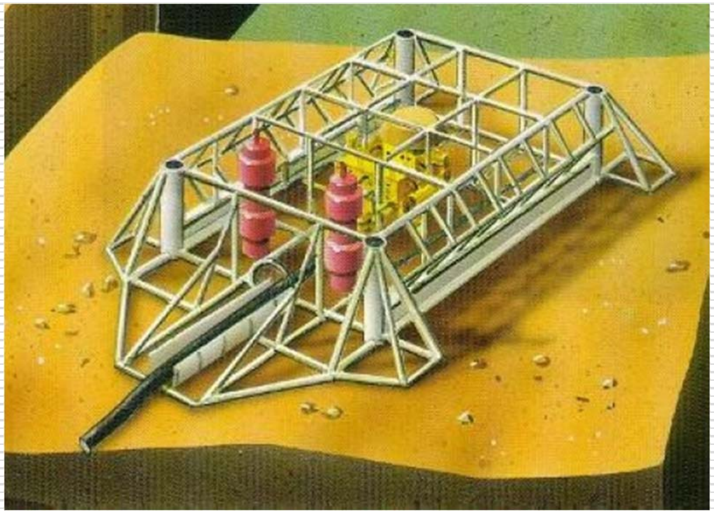
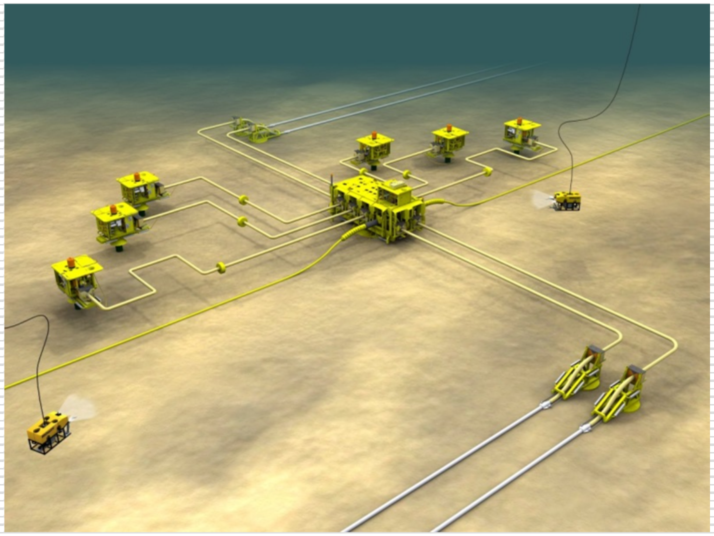
SUBSEA STRUCTURES AND FLOW LINES



The subsea wells include a wellhead and its connection to the manifold for gathering the flow and sending the fluid to the nearest production platform or pipeline for transport.

Subsea structures are required to support the following.



- Subsea wellhead
- Gathering manifold
- Pipeline junction
- Pipeline end Manifold
- Pipeline Valve manifold
- Production skids
- Pipeline jumpers

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SURVEY AND IDENTIFICATION

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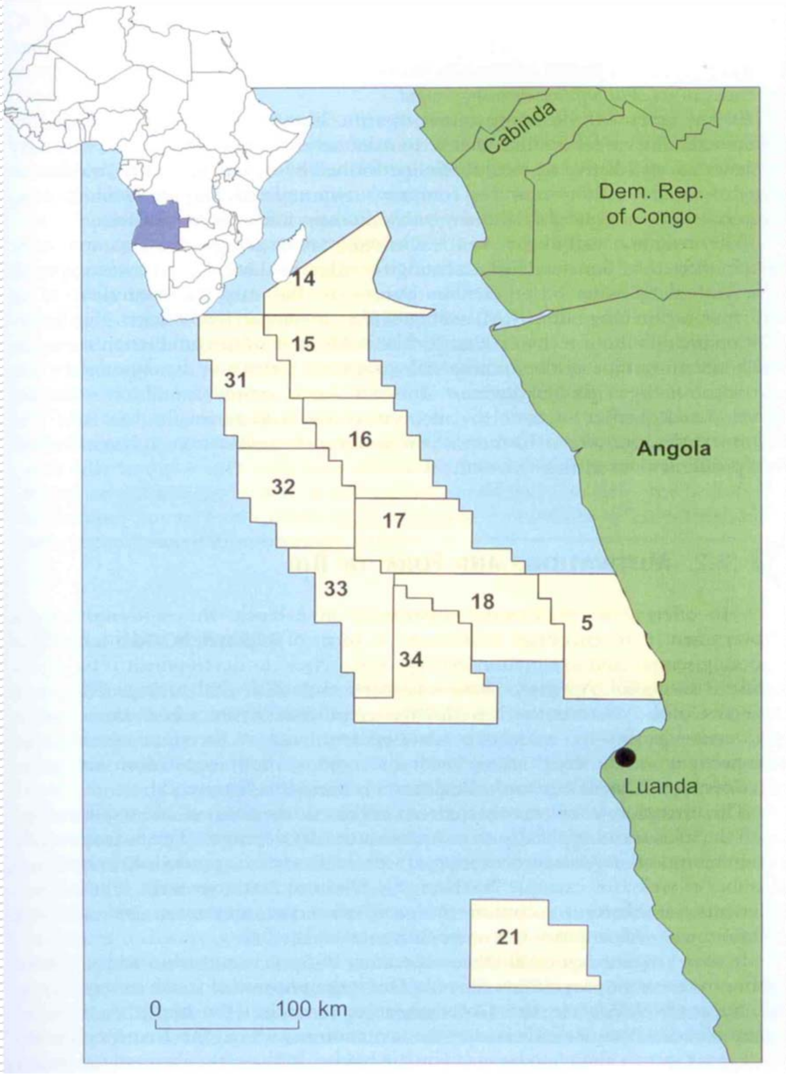
GEOPHYSICAL SURVEY METHODS

Geophysical survey methods are used to search for potential hydrocarbon accumulations. Following methods are commonly used.

- **Gravity Methods**
- **Magnetic Methods**
- **Electro Magnetic Methods**
- **Acoustic Methods**



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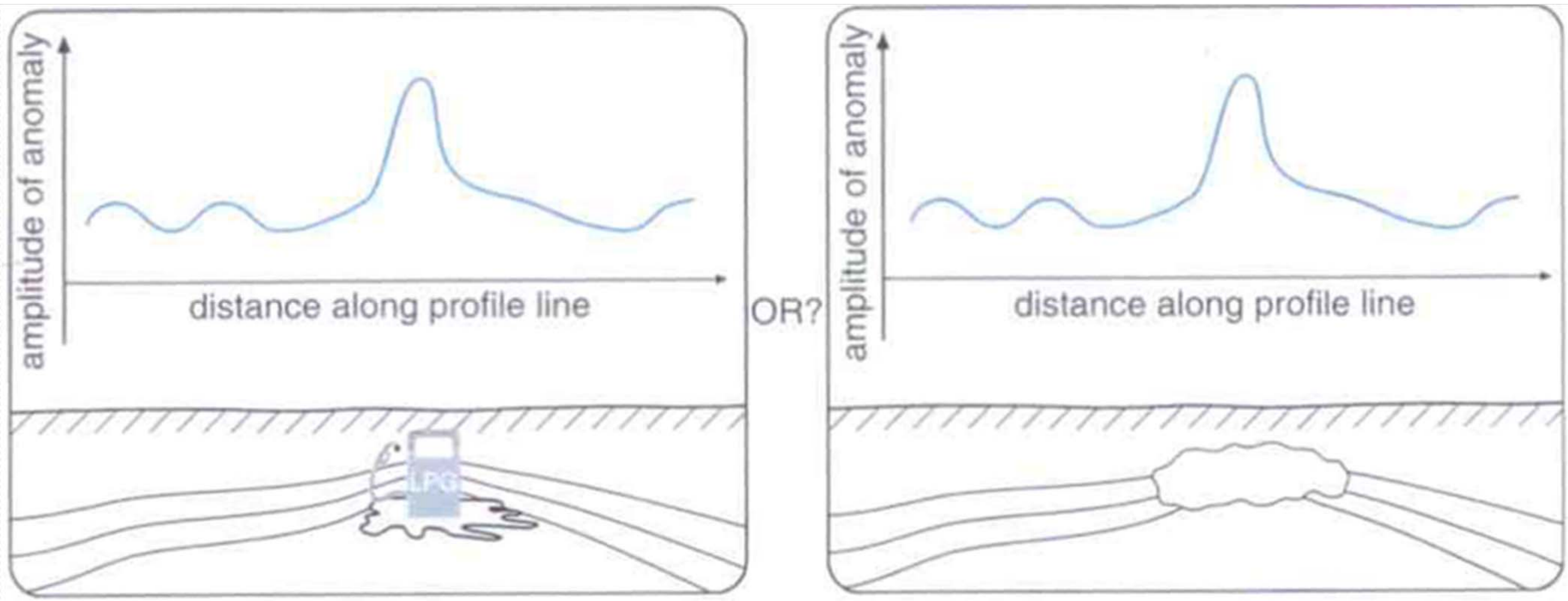
ALTERNATIVE INTERPRETIONS OF THE SAME ANOMALY RESPONSE



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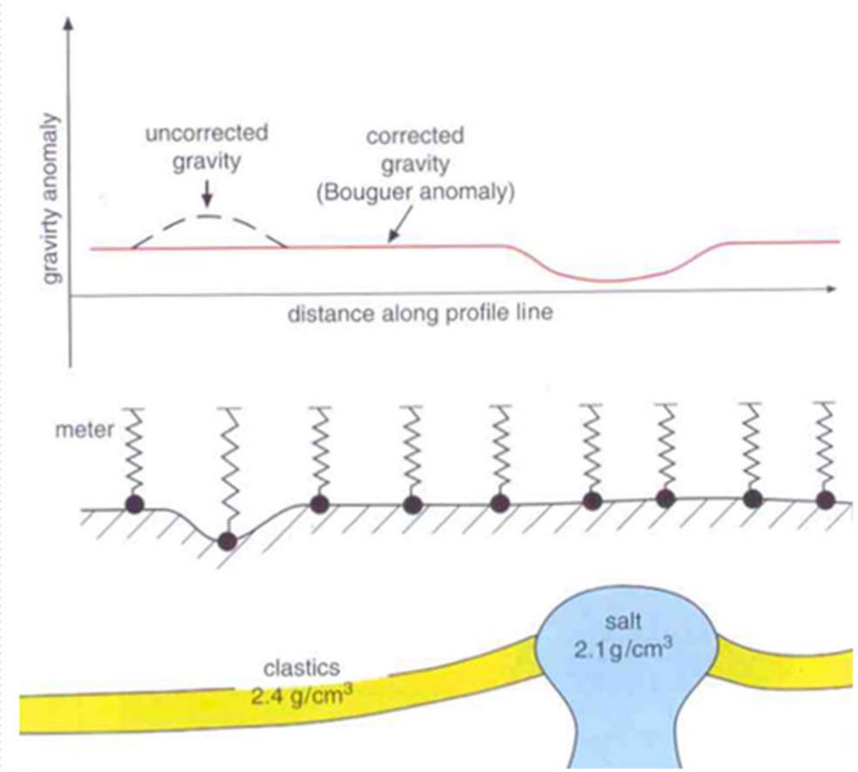
GRAVITY METHOD

Gravity method measures the small variations of the earth's gravity field caused by density variations in geological structures. sophisticated spring balance designed to be responsive over a wide range of values is used.

Fluctuations in gravity field give rise to changes in the spring length. Corrections for latitude position (Bouguer Correction) will be done prior to use. Most applications use airborne devices from aircraft or satellite.



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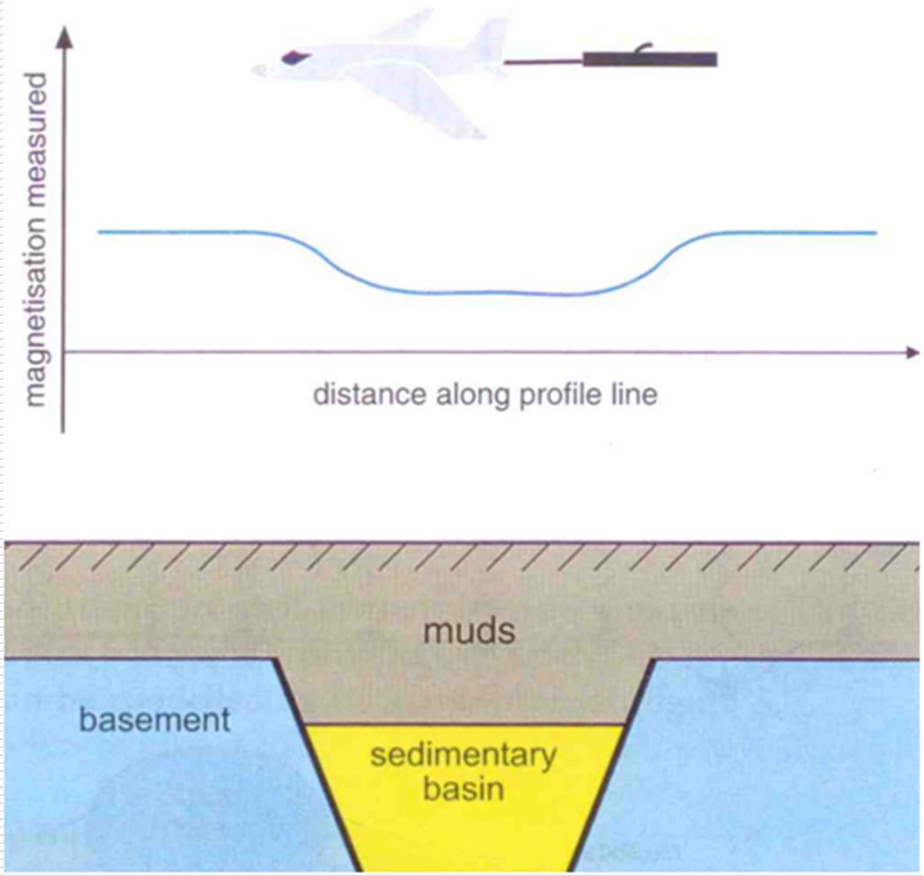
MAGENETIC METHOD

Magnetic method detects changes in earth's magnetic field caused by variations in the magnetic properties of rocks.

Basement and igneous rocks are relatively highly magnetic. If they are close to the surface they give rise to anomalies with a short wave length and high amplitude.

Most applications use airborne devices from aircraft or satellite which permits rapid surveying and mapping large areas quickly



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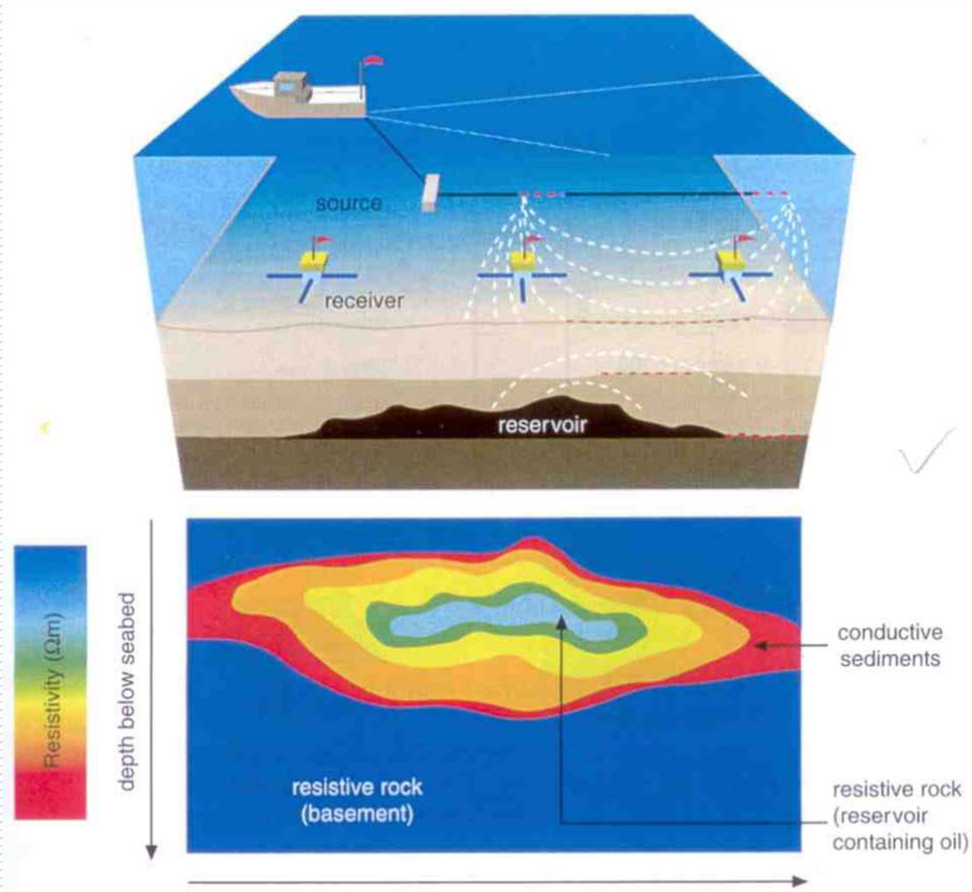
ELECTRO-MAGENETIC METHOD

Controlled Source Electro-Magnetic (CSEM) surveying or seabed logging is a remote sensing technique which uses very low frequency electro-magnetic signals emitted from a source near the seabed.

Receivers are placed on the seabed at regular intervals and register anomalies and distortions in the electro-magnetic signal generated by resistive bodies such as reservoirs saturated with hydrocarbons.



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ACOUSTIC METHOD (SEISMIC METHOD)

Seismic Survey involve generating sound waves which propagate through the earth's rocks down to reservoir targets.

The waves are reflected to the surface, where they are registered in receivers, recorded and stored for processing. The resulting data make up an acoustic image of the subsurface which is interpreted by geophysics and geologists.

Seismic surveying is used in

- *exploration* for delineating structural and stratigraphic traps.
- *field appraisal* and development for estimating reserves and drawing up FDPs.
- *production* for reservoir surveillance such as observing the movement of reservoir fluids in response to production

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PRINCIPLES OF SEISMIC SURVEY

Sound waves are generated at the surface (onshore) or under water (offshore) and travel through the earth's subsurface. The waves are reflected back to the surface at the interface between two rock units where is an appreciate change in 'acoustic impendence' (AI) across that interface. AI is the product of the density of the rock formation and the velocity of the wave through that particular rock (seismic velocity).

'Convolution' is the process by which a wave is modified as a result of passing through a filter. The earth can be which a wave is modified as a result of passing waveform characteristics of the down-going wave (amplitude, phase, frequency). In schematic form the earth can be represented either as AI log in represented in the time domain. When the wave passes through the rocks its shape changes to produce a wiggle trace that is a function of the original source wavelet and the earth's properties.

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SEISMIC DATA ACQUISITION SURVEY VESSELS AT SEA

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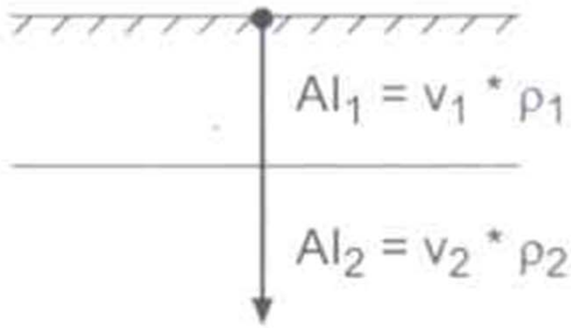
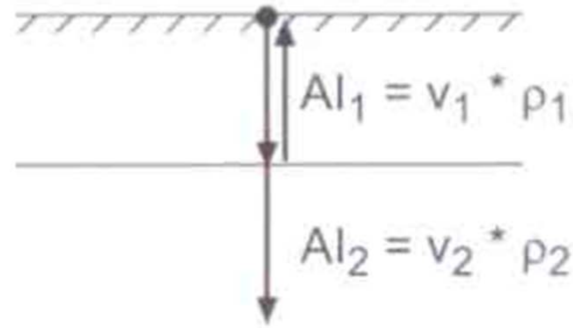
CHANGES IN ACOUSTIC IMPEDANCE (AI) GIVE RISE TO REFLECTED SEISMIC WAVES



(a) $AI_1 = AI_2$

If there is no change in acoustic impedance across the interface, the seismic wave will pass through the boundary without reflection.

AI = acoustic impedance
v = seismic velocity
ρ = density



(b) $AI_1 \neq AI_2$

If there is a change in acoustic impedance across the boundary, a seismic reflection occurs at the interface. The wave continues to propogate down through the following layers albeit with reduced energy.

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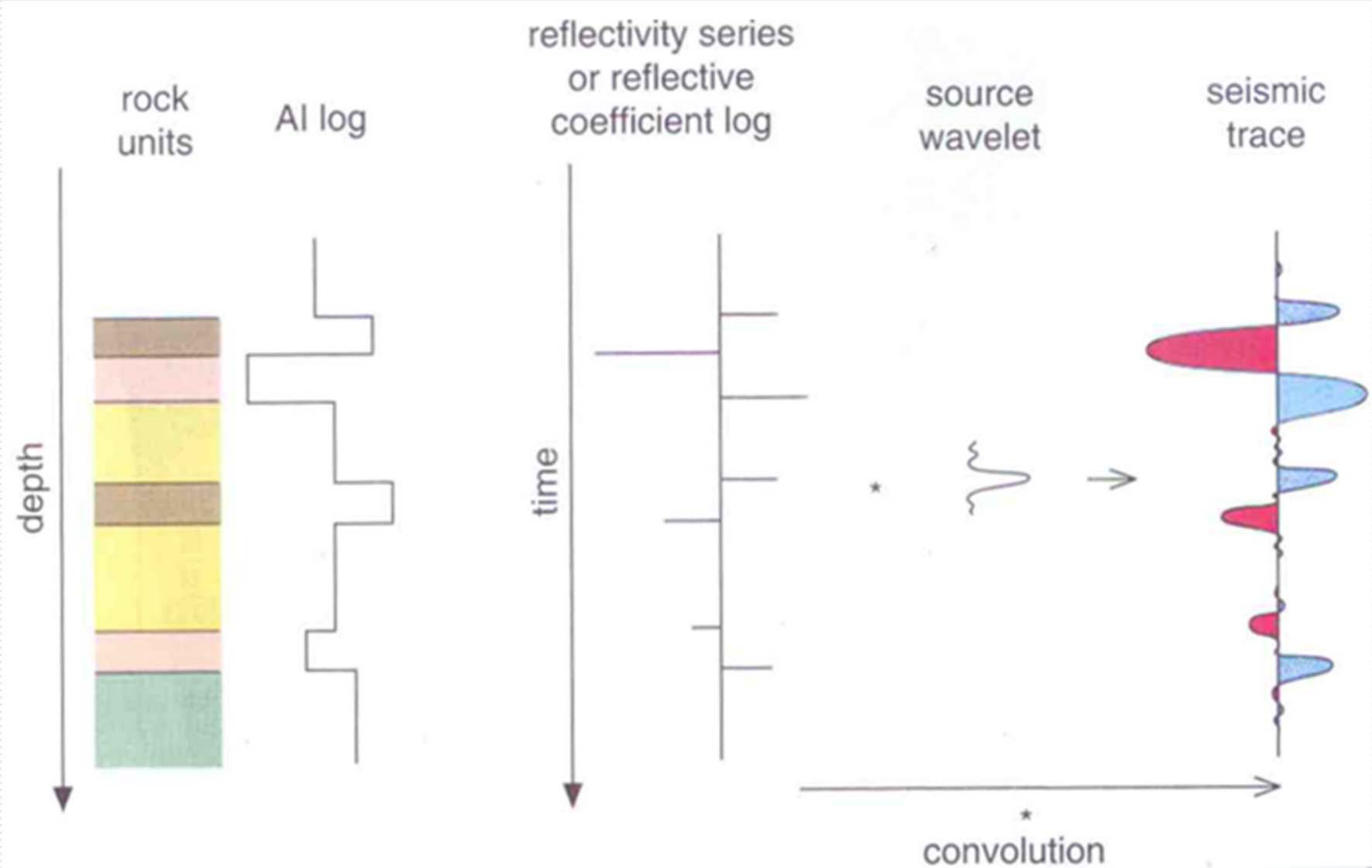
CONVOLUTION OF REFLECTED SEISMIC WAVE



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DRILLING AND WELL COMPLETION

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WELL PLANNING

The drilling of a well involves a major investment, ranging from a few million US$ for an onshore well to 100 million US$ plus for a deepwater exploration well.

Well engineering is aimed at minimizing the value of this investment by employing the most appropriate technology and business process, to drill a 'fit for purpose' well, at the minimum cost, without compromising safety or environmental standards.

Successful drilling engineering requires the integration of many disciplines and skills. Successful drilling projects will require extensive planning. Usually, well are drilled with one, or a combination, of the following objectives.

- to gather information
- to produce hydrocarbons
- to inject gas or water to maintain reservoir pressure or sweep out oil
- to dispose of water, drill cuttings or CO_2 (sequestration)

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RIG TYPES AND RIG SELECTION

The type of rig which will be selected depends upon a number of parameter in particular.

- cost and availability
- water depth of location (offshore)
- mobility/transportability (onshore)
- depth of target zone and expected formation pressures
- prevailing weather/metocean conditions in the area of operation
- experience of the drilling crew (in particular the safety record)

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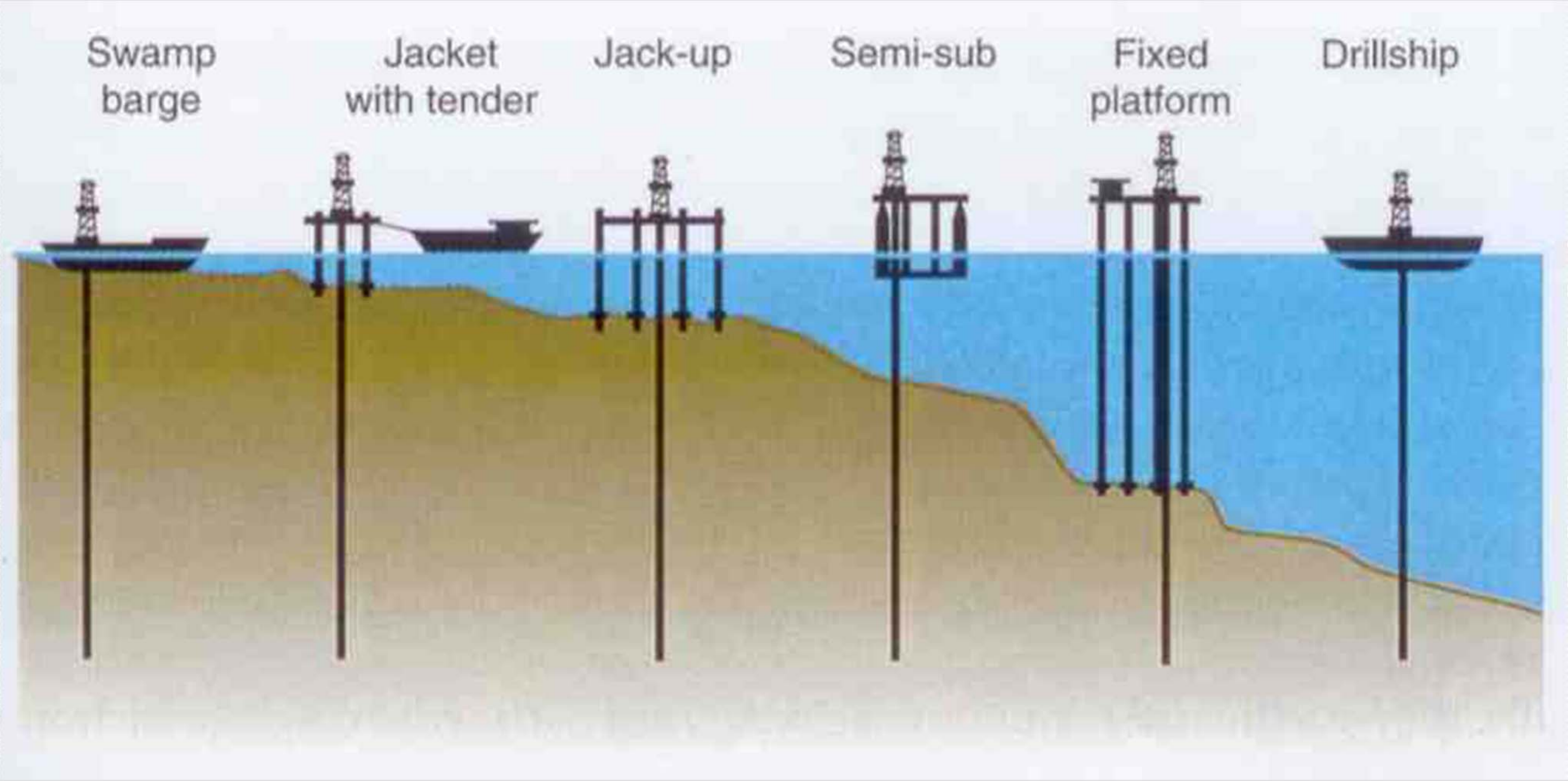
OFFSHORE RIG TYPES



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JACKUP RIG FOR DRILLING (EXPLORATORY)

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Jackup Drilling over existing template structure

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SEMI-SUBMERSIBLE RIG (COURTESY OF STENA DRILLING)

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DRILL SHIP 'TRANSOCEAN ENTERPRISE'

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TENDER ASSISTED DRILLING

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DECK MOUNTED DRILLING RIG

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DRILLING METHODS

Top Hole Drilling (THD) method is used is very common in both onshore and offshore.

This method involves drilling of large diameter hole using large drill bits. Usually the first will be done after driving a top section of pipe and drilling will be done through the pipe.

Subsequent sections of drill strings will be cemented sequentially.

Directional Drilling (DD) usually done with *rotary steerable system.* A downhole steering and control unit is located in the near-bit assembly.

Mud-turbine and mud motor is also used in directional drilling.

Horizontal Drilling (HD) is used when the reservoir fluids spread over a large area. Horizontal well may provide optimum trajectory. Usually, curved transition from vertical to horizontal will be employed. When the horizontal reach is more than four time the vertical is then called **Extended Reach Drilling (ERD)**

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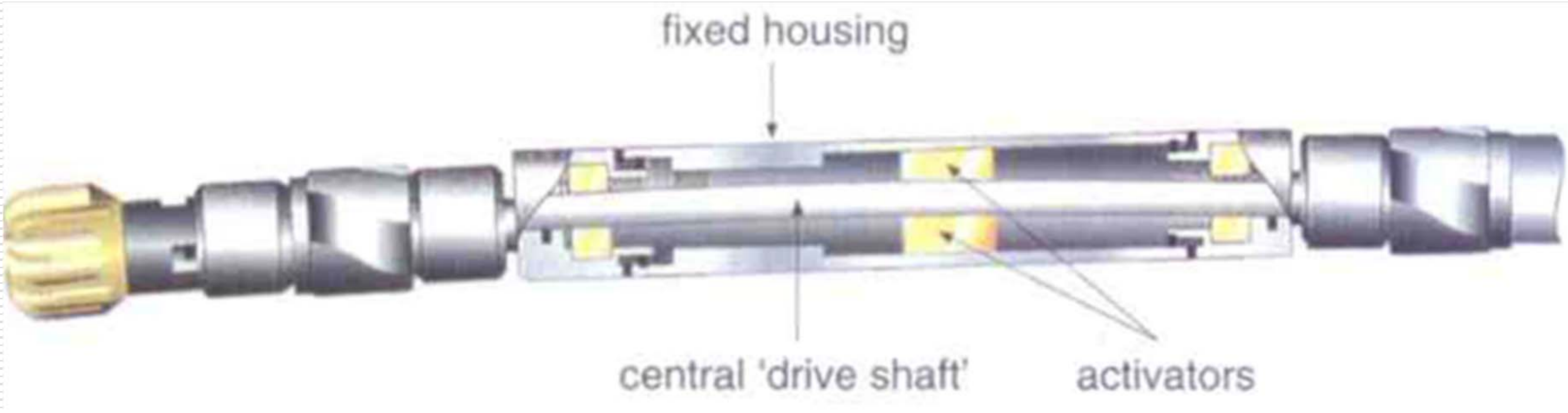
ROTARY STEERABLE SYSTEM



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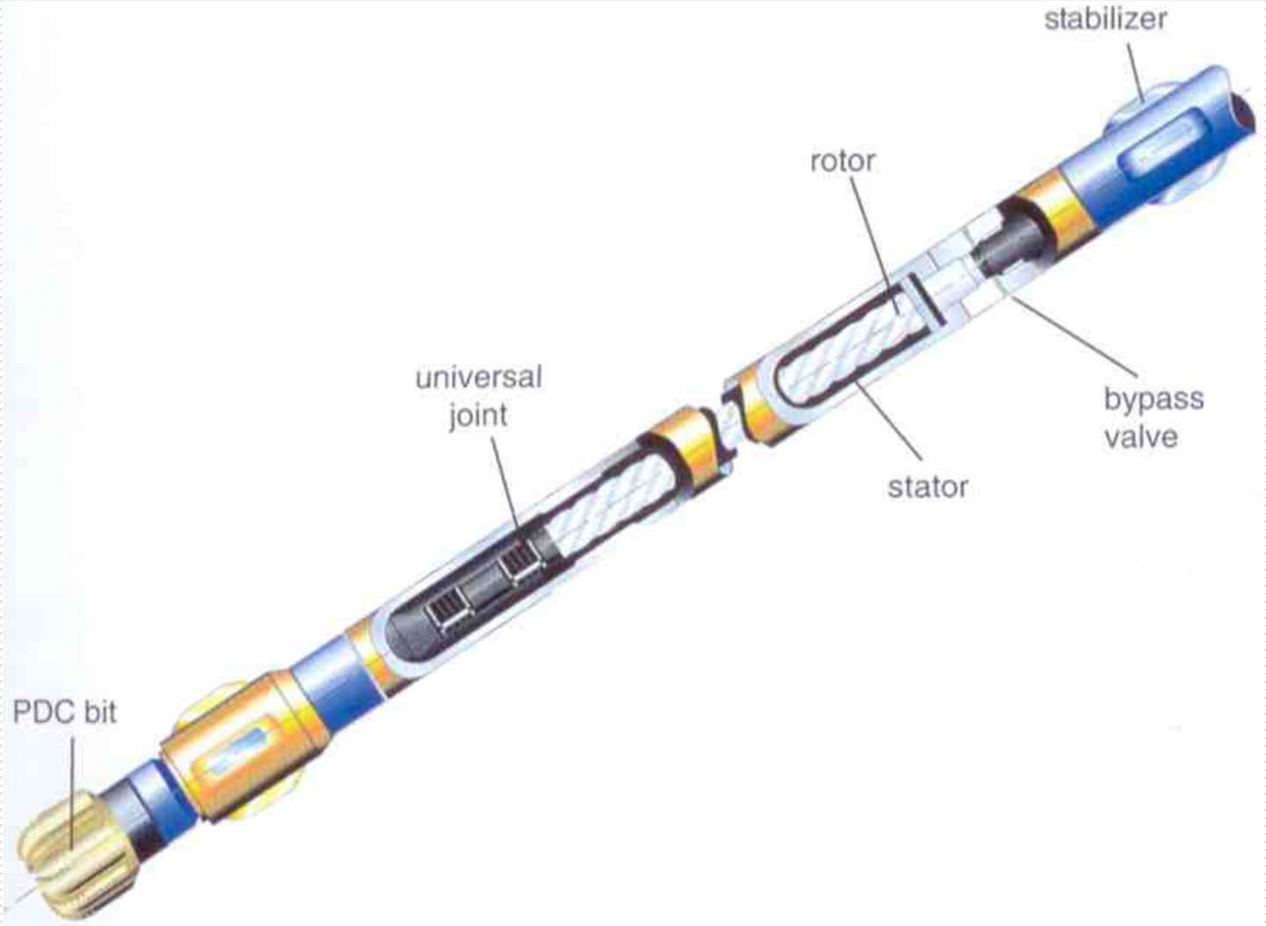
DRILLHEAD STRING



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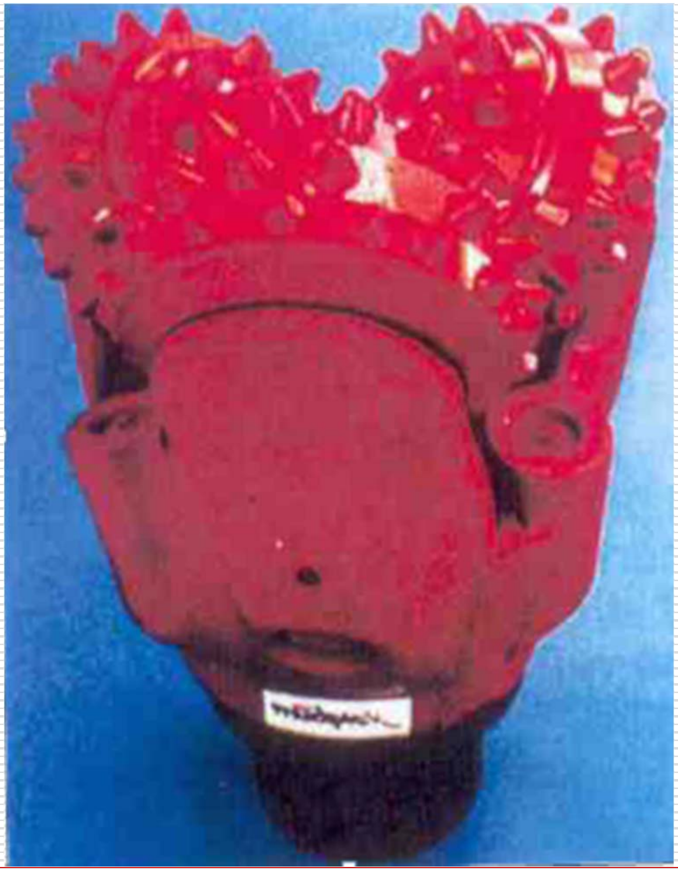
DRILL BITS

The most frequently used bit types are the roller cone or rock bit and the Polycrystalline Diamond Compact bit or PDC bit.



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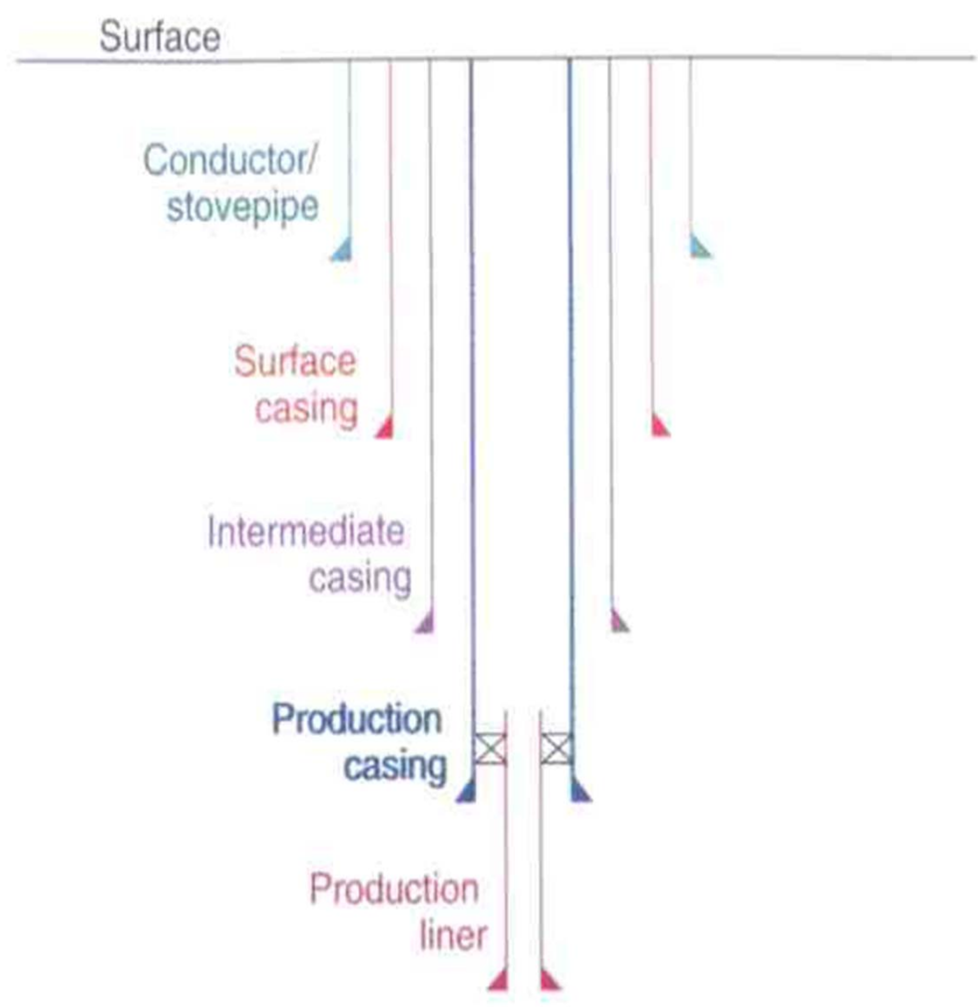
TYPICAL CASING SCHEME

Sets of casing is installed into the ground and their corresponding depth is indicated.

- Conductor Casing – 70m
- Surface Casing – 100-400m
- Intermediate casing – 1000m
- Production casing – 2000-3000m
- Production liner – 4000-6000m

The annulus space between the casings will be cemented to contain the flow as well as to achieve the strength against the earth pressure.

The method of installation and explained in subsequent discussion.



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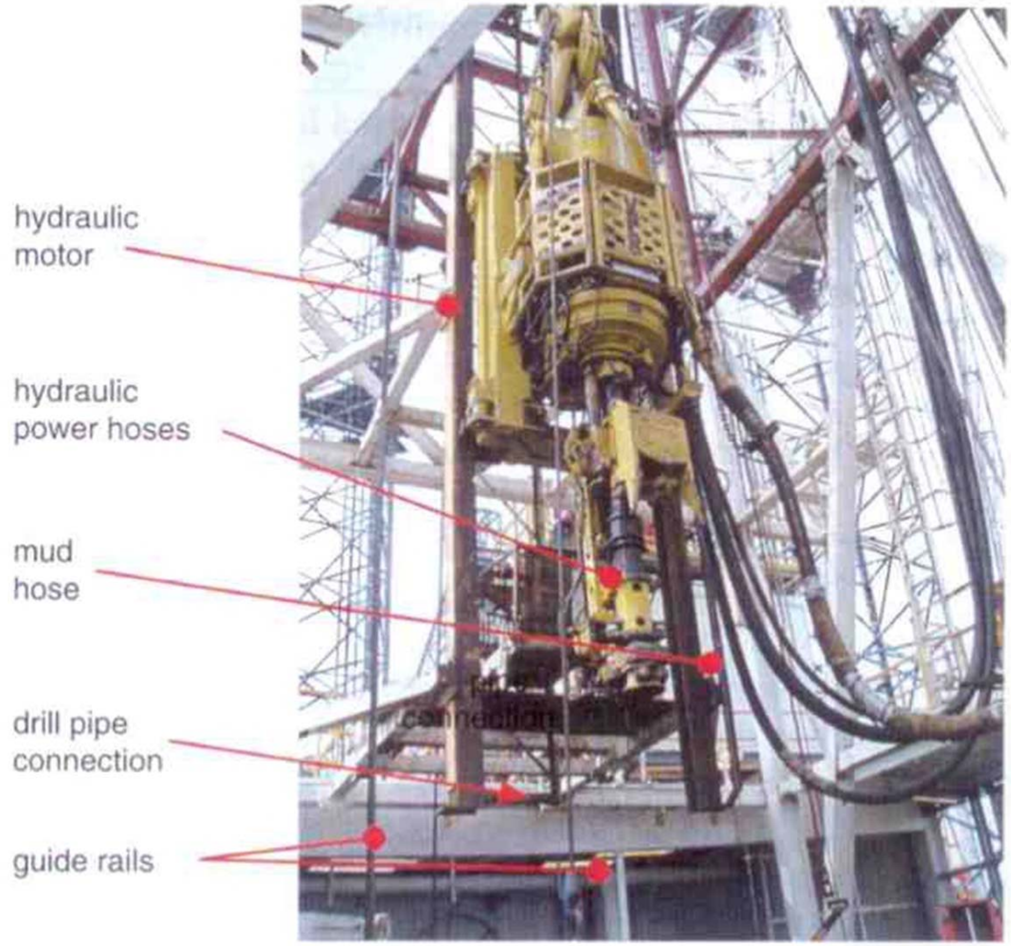
TOP DRIVE SYSTEM

Top drive is normally positioned on top of the drill floor. This will be hanging from the drill tower using the hanger system so that the same can be moved up or down during the drilling process.

The coupling between the top drive and the drill string segment will be based on quick connect disconnect method.

The drive will transmit the torque to the drill string which rotates the drill string and drill down.

Drill strings are added in segments of 12m in length.



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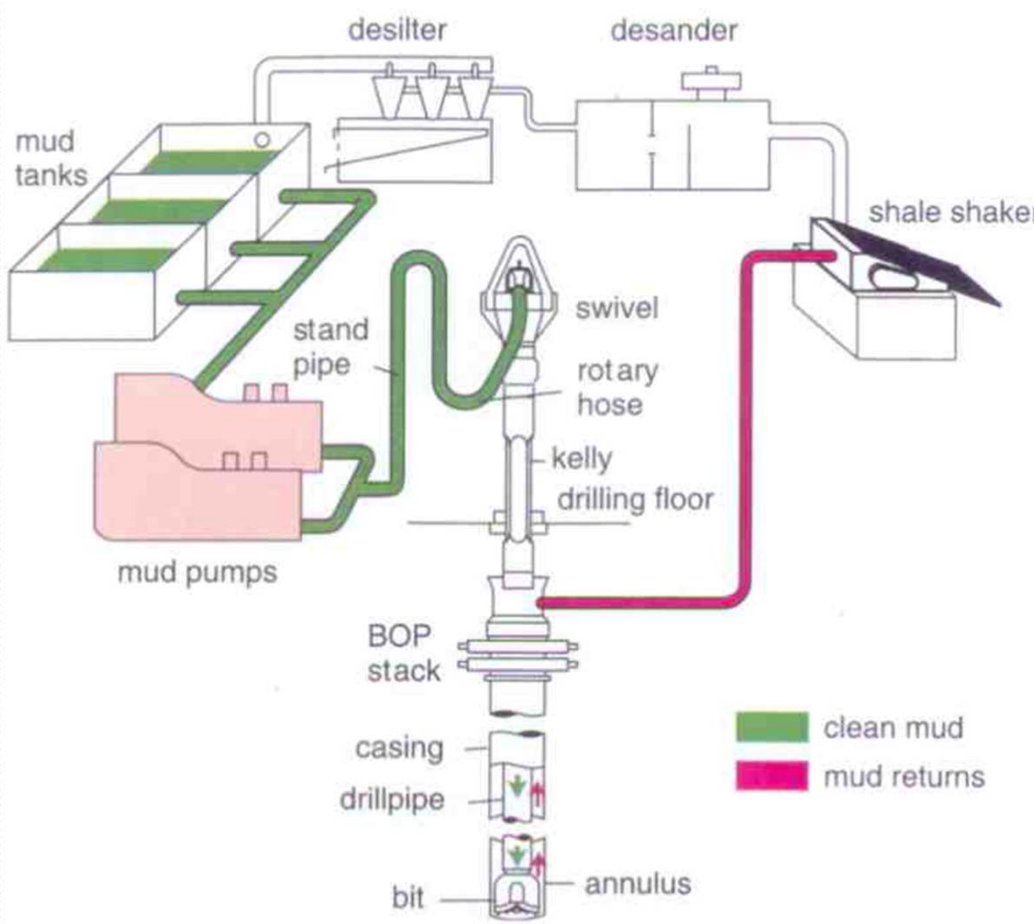
MUD CIRCULATION SYSTEM

During drilling by rotary drill bit, the tip of the drill bit will be heated and the temperature can raise to 1000 degrees and hence the same needs to be cooled down.

Hence to reduce the heat, cooling fluid is supplied through the drill tube and circulated continuously during the drilling.

Drill fluid or Drill mud is prepared in specific viscosity, density and temperature using cement and water. The return fluid will be reconditioned after the removal of debris and recirculated.



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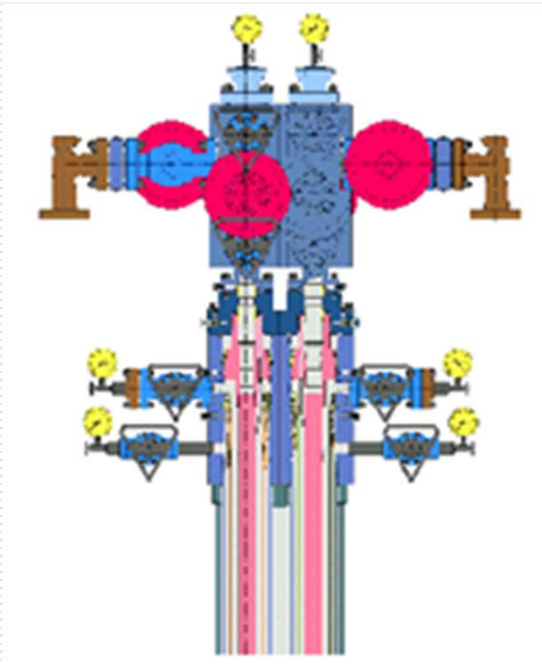
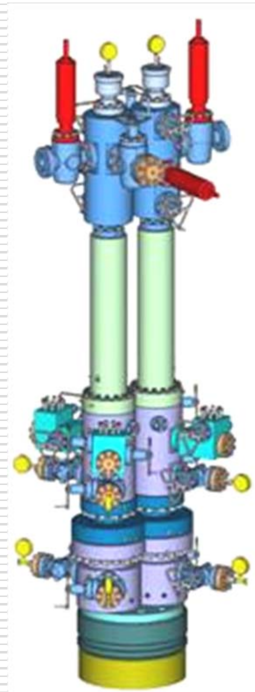
DRY TYPE CHRISTMAS TREES

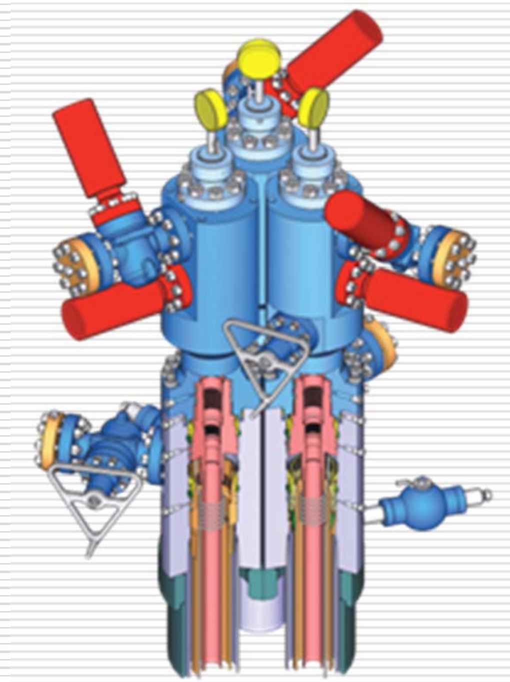
Dry type wellheads can accommodate single, double or triple wellheads.



Dual Well



Dual Well



Triple Well

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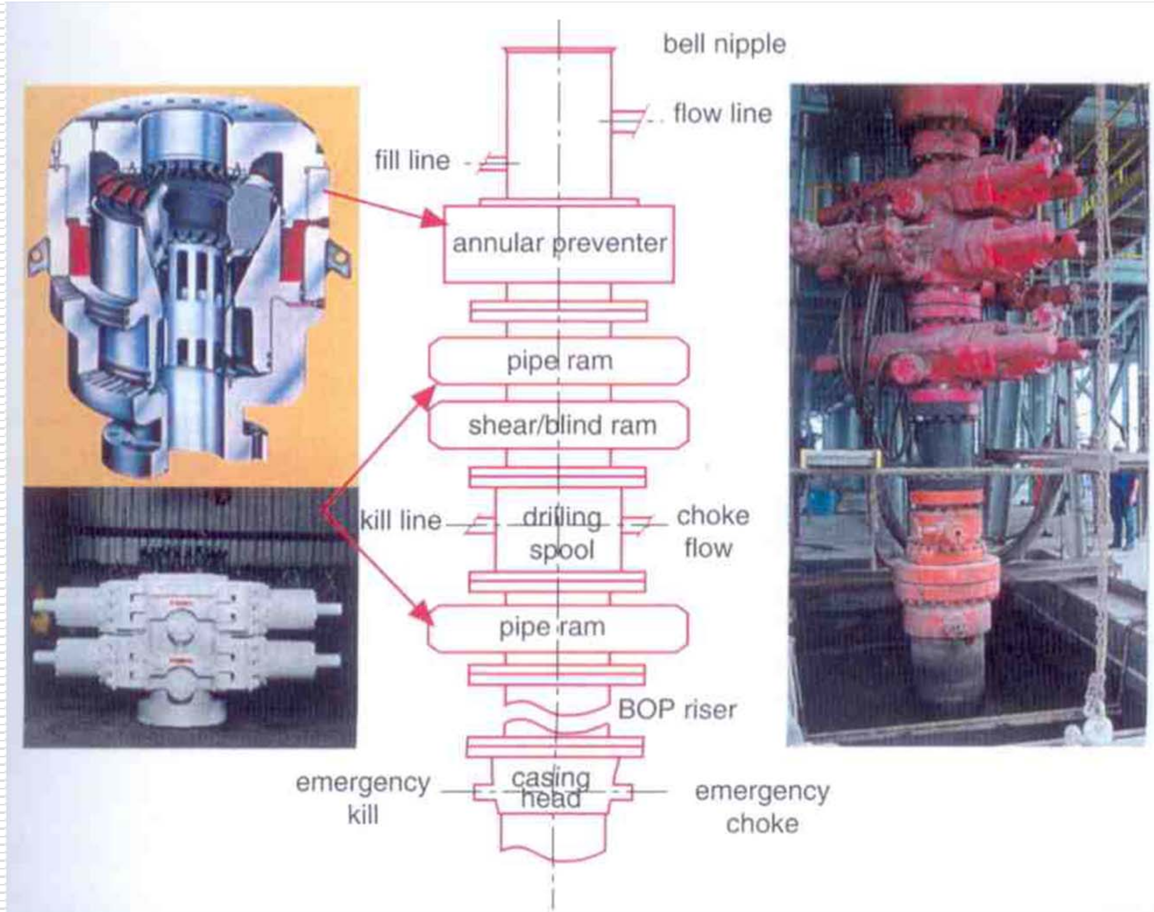
BLOW OUT PREVENTER (BOP)

A **blowout preventer** is a large, specialized valve or similar mechanical device, usually installed redundantly in stacks, used to seal, control and monitor oil and gas wells.

Blowout preventers were developed to cope with extreme erratic pressures and uncontrolled flow (formation kick) emanating from a well reservoir during drilling.

Kicks can lead to a potentially catastrophic event known as a blowout.



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SUBSEA WELL HEAD

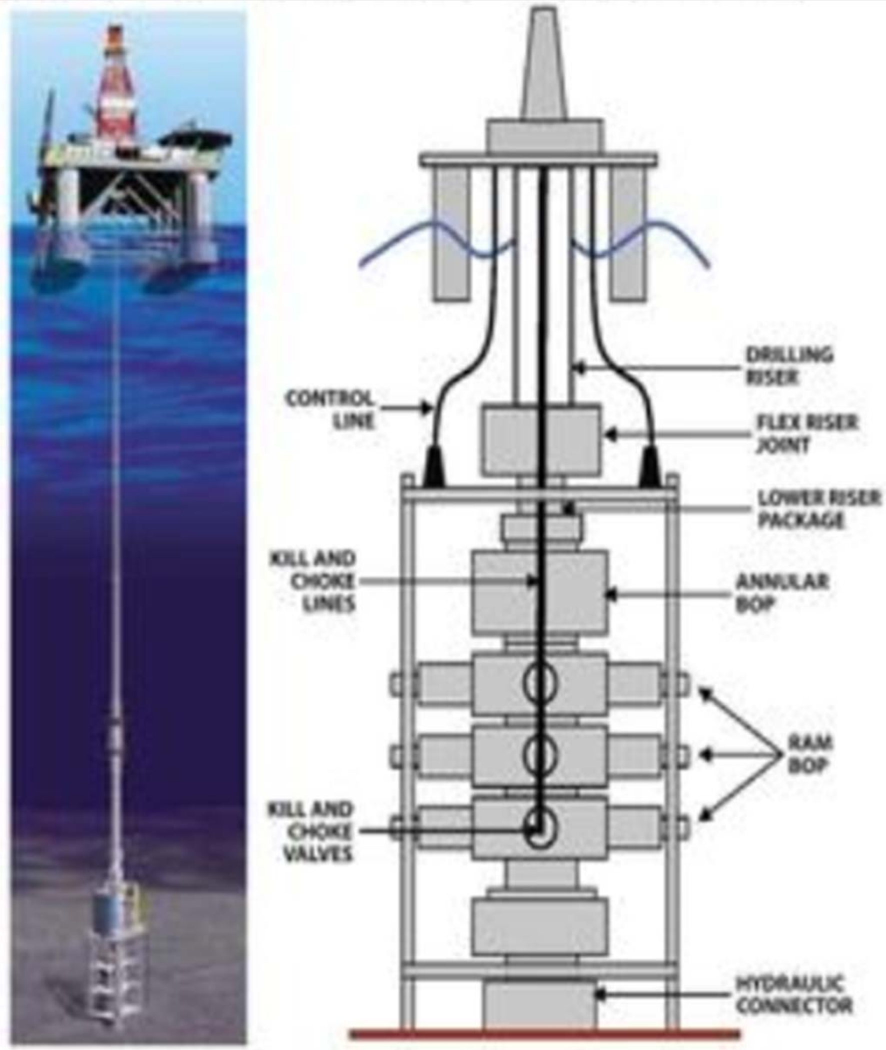
Subsea well head and BOP for a deep water drilling is shown in figure below.

The drilling is carried out from a semi-submersible drilling rig and top tensioned riser system.

Usually, subsea BOPs will have Ram type BOP followed by Annular BOP on top.

The BOPs and valves will be controlled from the surface using control lines (hydraulic tubing).

The whole assembly is mounted on a wellhead head using hydraulic connector.



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BP HORIZON BOP FAILURE

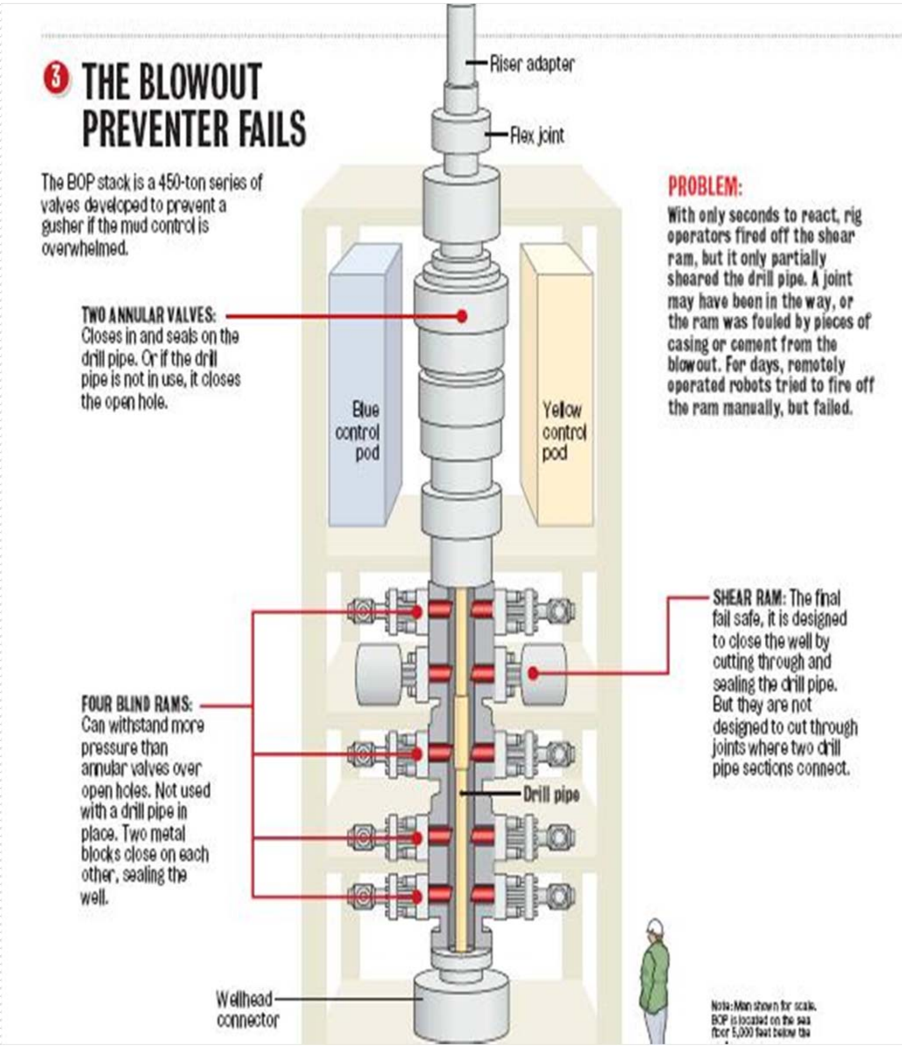
The BP Horizon drilling accident in 2009, caused a huge oil pollution due to failure of ram BOP failure.

Large amount of methane gas gushed out to the surface and followed by fire and explosion made the rig to sink.

Attempt to close during the initial period failed though several attempts were made using ROV (Remotely Operated Vehicle).

Later, the well was closed using a alternate side well and the bottom of the well was cemented by pumping in grout.

Still the main cause of the failure is not known clearly.



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TYPES OF WELLS

- **PRODUCTION WELLS**
  - **FREE FLOWING WELL**

    A free flowing well has enough down hole pressure (100 PSI) for the fluid to come up to the surface.
  - **LIFTED WELL**

    If the formation pressure is too low and water or gas injection cannot maintain the pressure then the well must be artificially lifted.
- **INJECTION WELLS**
  - **WATER INJECTION WELLS**

    Water is injected into the reservoir to maintain hydrostatic pressure of the reservoir and force the oil to move towards the well
  - **GAS INJECTION WELLS**

    Similar to water, but instead of water, gas is injected in to increase the reservoir pressure

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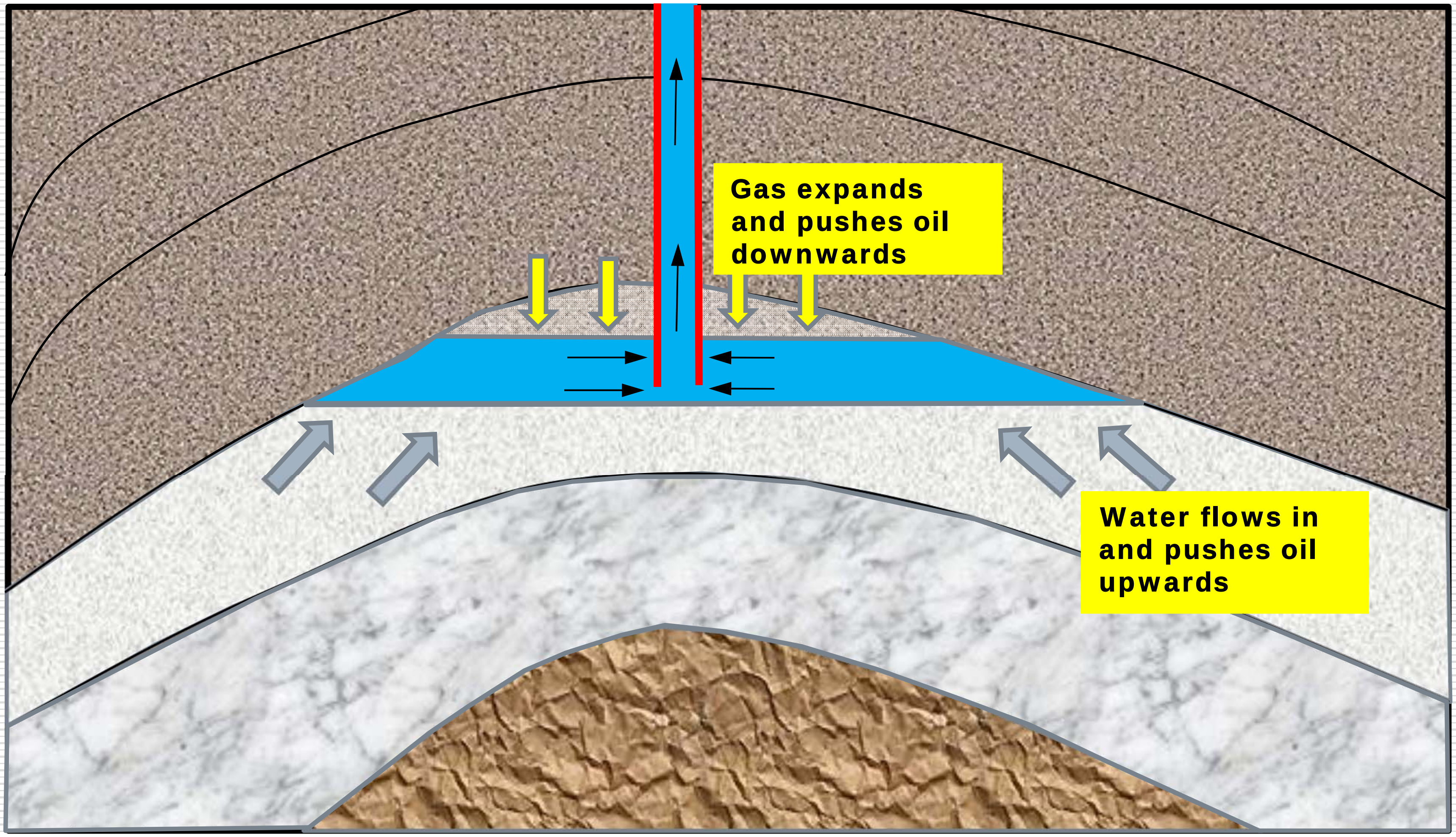
TYPES OF WELLS



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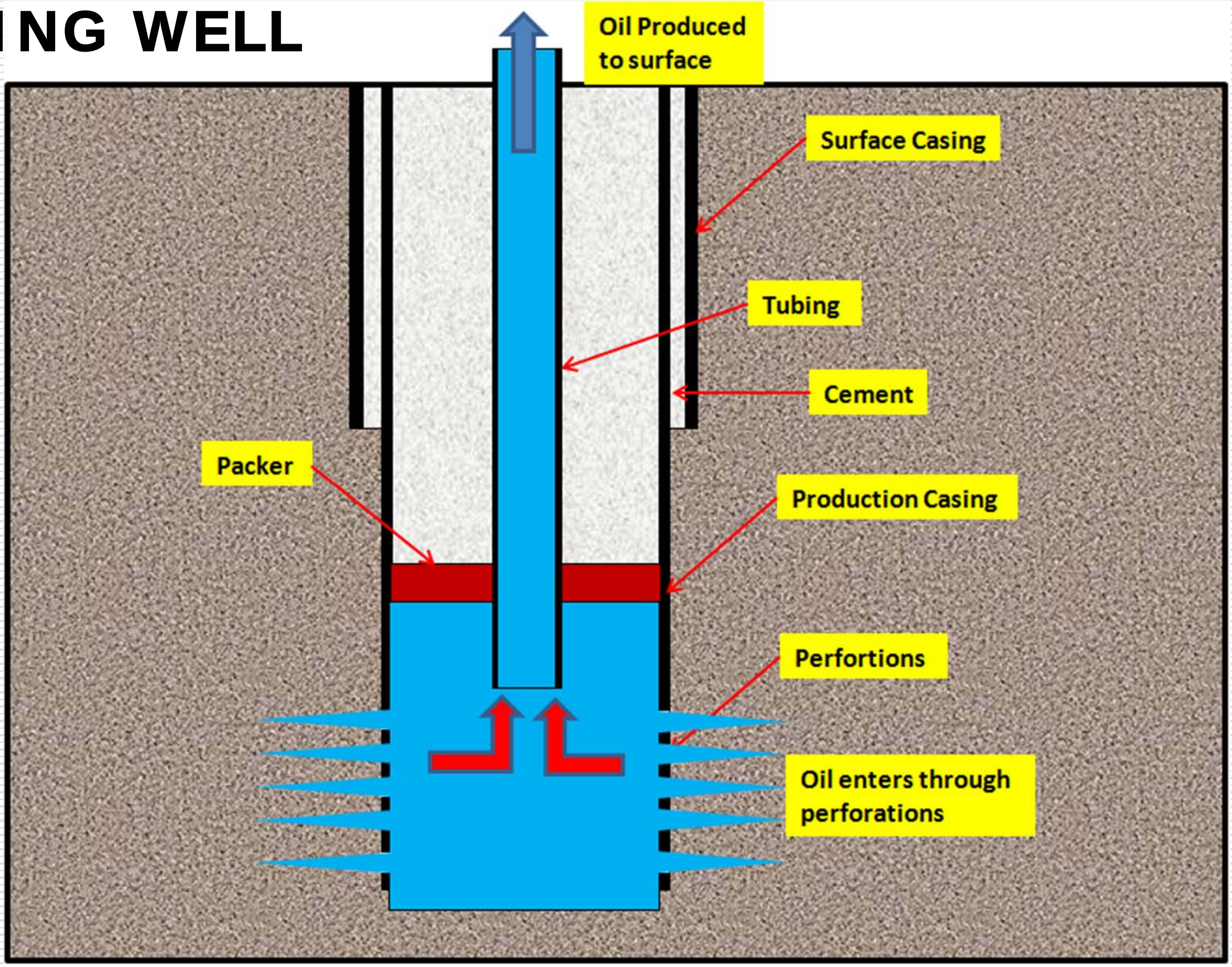
THE FLOWING WELL



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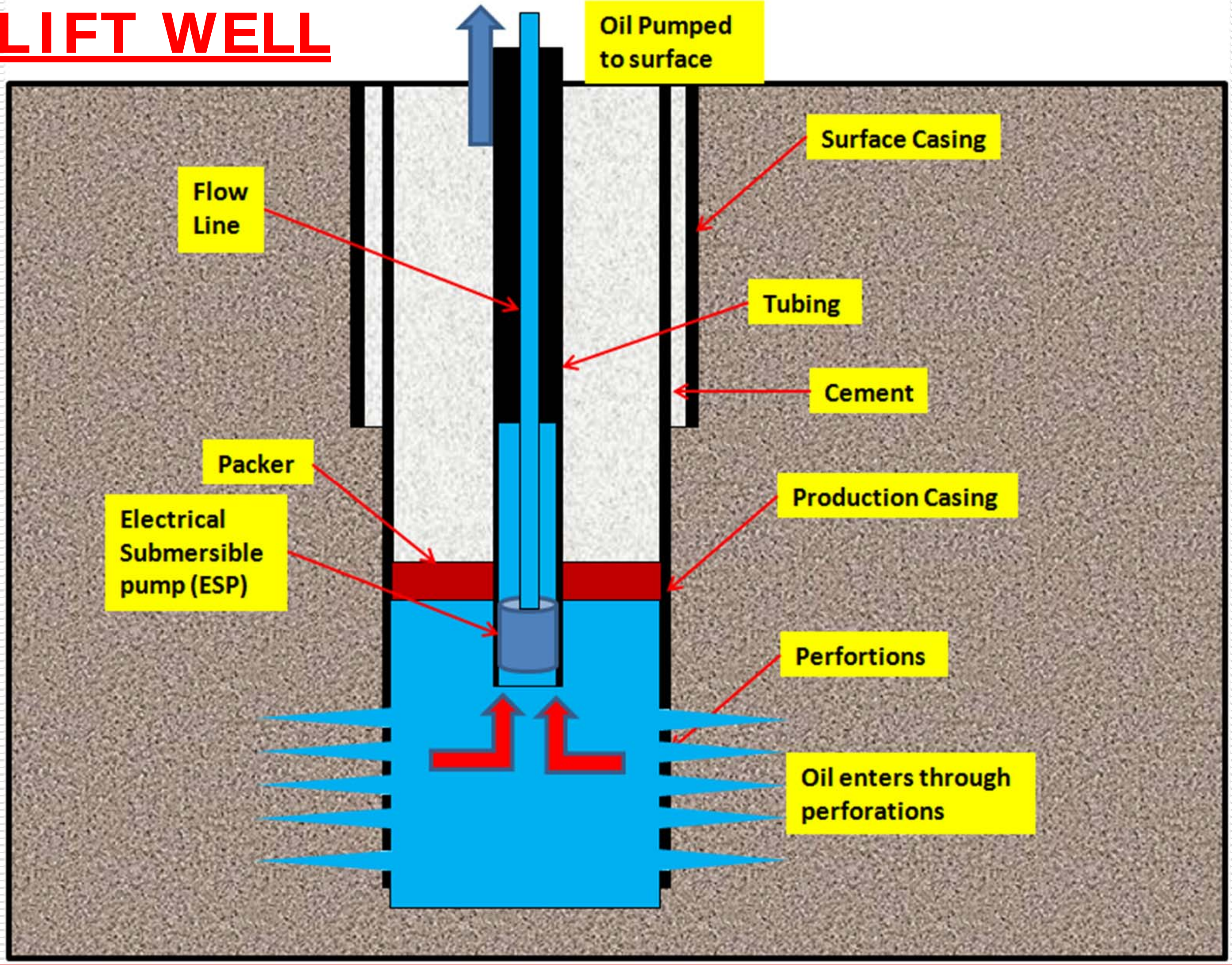
THE ESP LIFT WELL



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WELL CASINGS

There are five different types of well casing. They include:

- CONDUCTOR CASING
- SURFACE CASING
- INTERMEDIATE CASING
- PRODUCTION CASING
- TUBING

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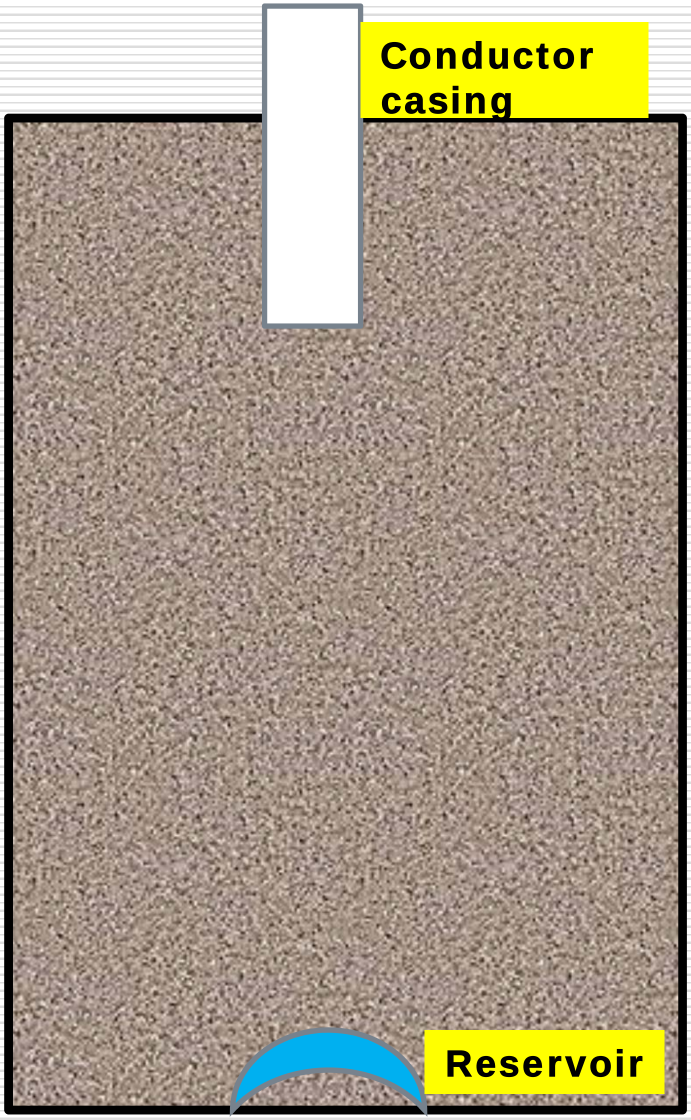
CONDUCTOR CASINGS

Conductor casing, which is usually no more than 50 to 70 m long, is installed before main drilling to prevent the top of the well from caving in and to help in the process of circulating the drilling fluid up from the bottom of the well.

Typical conductor casing diameter varies from 20” to 30” (508mm to 762mm)



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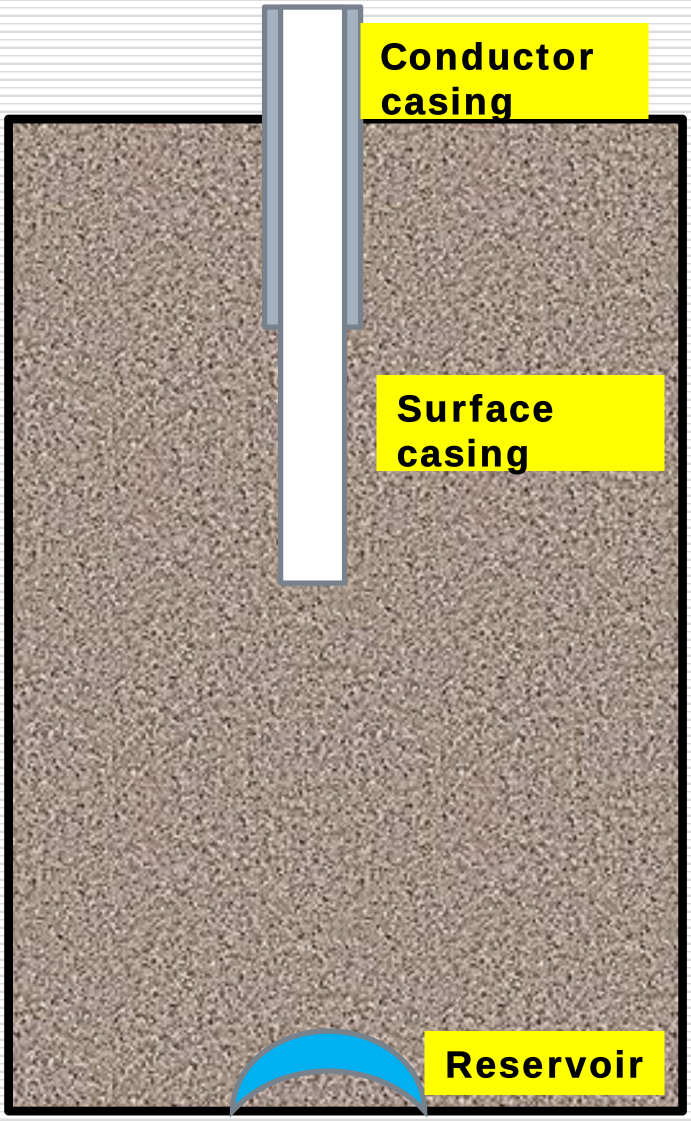
SURFACE CASINGS

Surface casing is the next type of casing to be installed. It can be anywhere from **100 to 400** meters long, and is smaller in diameter than the conductor casing and fits inside the conductor casing. The primary purpose of surface casing is to protect fresh water deposits near the surface of the well from being contaminated by leaking hydrocarbons or salt water from deeper underground. It also serves as a conduit for drilling mud returning to the surface, and helps protect the drill hole from being damaged during drilling.



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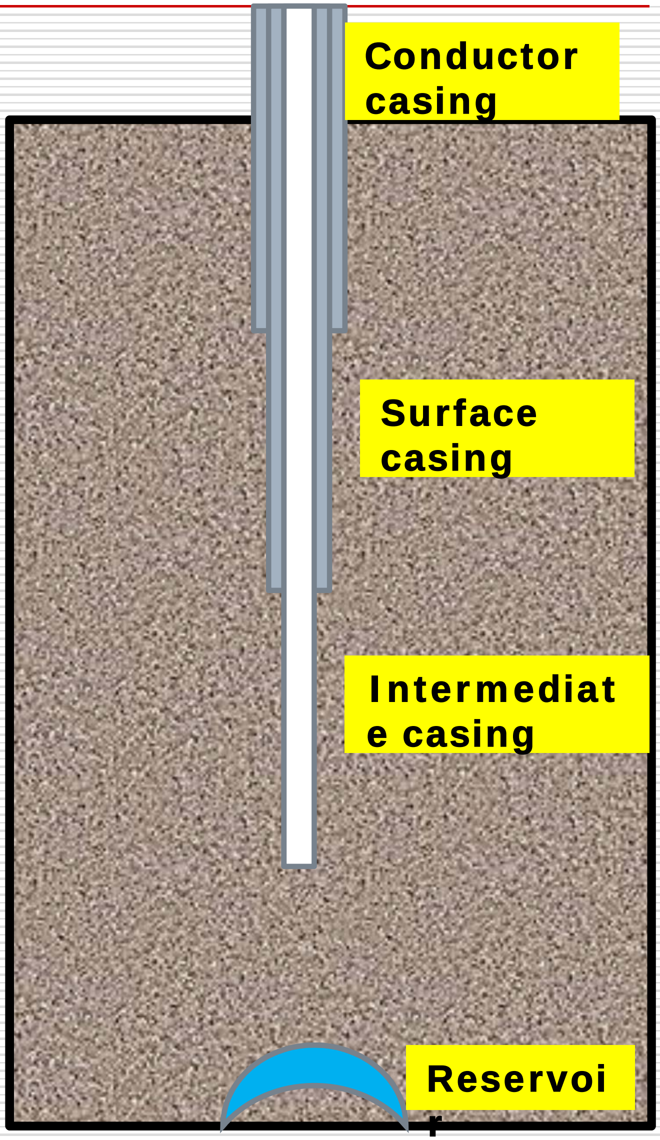
INTERMEDIATE CASINGS

Intermediate casing is usually the longest section of casing found in a well. The primary purpose of intermediate casing is to minimize the hazards that come along with subsurface formations that may affect the well. These include abnormal underground pressure zones, underground shales, and formations that might otherwise contaminate the well, such as underground salt water deposits. Liner stings are sometimes used instead of intermediate casing Liner strings are usually just attached to the previous casing with 'hangers', instead of being cemented into place and is thus less permanent.



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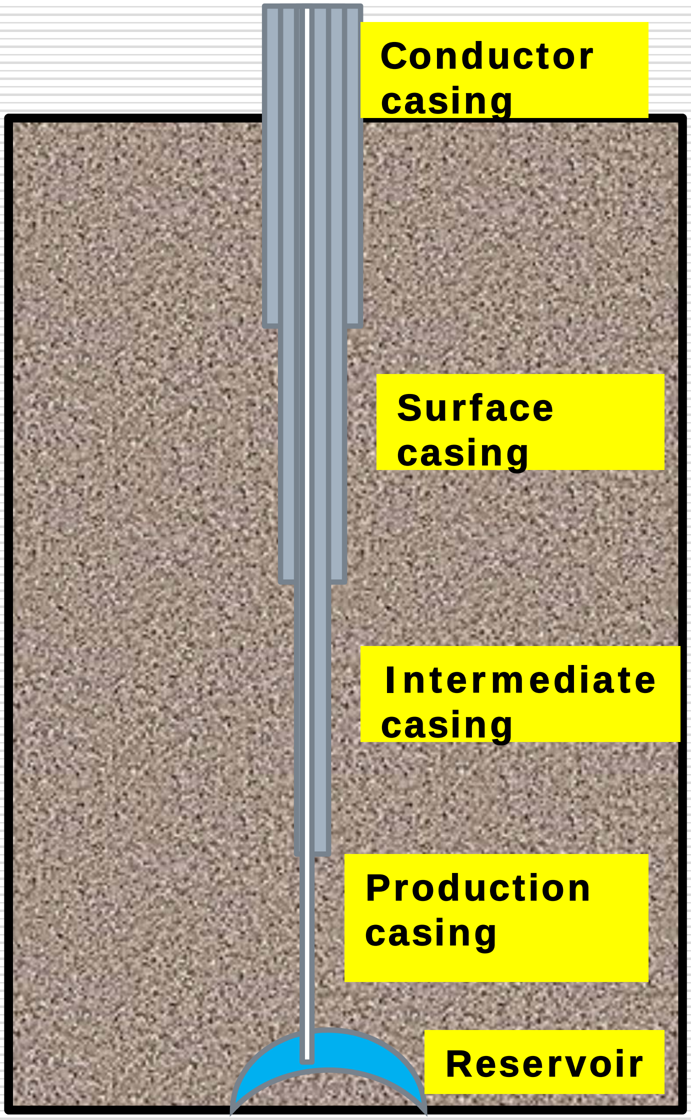
PRODUCTION CASINGS

Production casing, alternatively called the ‘Oil string’, is installed last and is the deepest section of casing in a well. This is the casing that provides formation. The size of the production casing depends on a number of considerations, including the lifting equipment to be used, the number of completions required, and the possibility of deepening the well at a later time. For example, if it is expected that the well will be deepened at a later date, then the production casing must be wide enough to allow the passage of a drill bit later on. It is also instrumental in preventing blowouts, allowing the formation to be ‘sealed’ from the top should dangerous pressure levels be reached.



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TUBING OR FLOWLINE

Once the casing is installed, **tubing** is inserted inside the casing, from the opening well at the top, to the formation at the bottom. The hydrocarbons that are extracted run up this tubing to the surface.

The production casing is typically 5 to 28cm (2-11 in) with most production wells being 6 in or more. Production depends on reservoir, barrels per day. (5000 bpd is about 555 liters/minute).

A **packer** is used between casing and tubing at the bottom of the well.

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BASICS OF OFFSHORE STRUCTURES

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Contents

- Classification of offshore structures
  - Fixed Structures
  - Floating Structures
  - Gravity Structures
- Fixed Structures
  - Jacket Templates
  - Compliant Towers
  - Jackups
- Floating Structures
  - Tension Leg Platforms
  - Semi-submersibles
  - Spars
  - Truss Spars
  - FPSOs
  - Articulated Towers
- Gravity Structures
- Subsea Structures
- Conceptualization
  - Loading on Foundations
  - Load Transfer concept
  - Design Spiral
- Fabrication & Installation
  - Fabrication
  - Loadout
  - Transportation
  - Launching
  - Lifting
  - Upending
- Analysis and Design
  - Analysis methods
  - Design methods (LRFD & WSD)
  - Tubular members
  - Tubular Connections
  - Codes and Standards

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Can be classified into three broad categories based on their foundation concepts

- **Bottom Fixed Structures**
  - Jacket or Template type structures
  - Compliant Structures
  - Semi-fixed Structures (Jackups)
- **Floating Structures (Buoyant but Moored)**
  - Tension Leg Platforms
  - Semi-submersible
  - Articulated Towers
  - FPSO's
- **Gravity Based Structures**
  - **Concrete Gravity Base Structure**
  - **Steel Gravity Base Structure**
- **Subsea Structures**
  - **Gravity Templates Structure**
  - **Piled Templates Structure (PLEM)**
  - **Pipeline End Manifold (PLEM)**
  - **Well Template**

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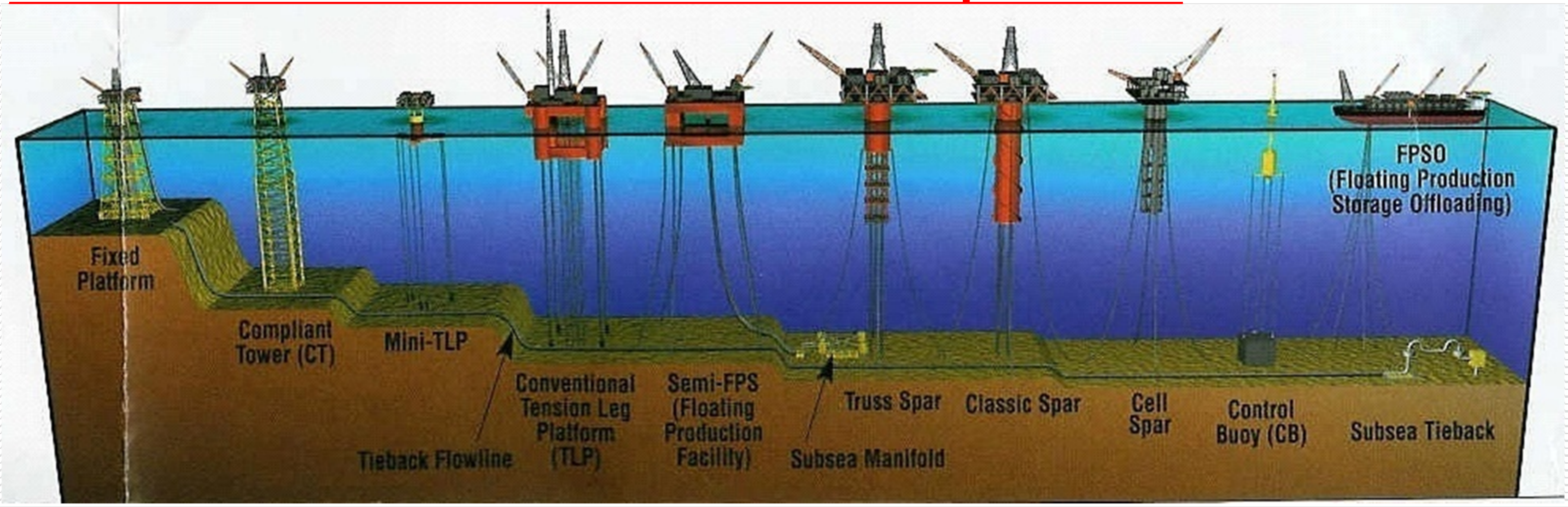
Offshore Structures for Oil and Gas Exploration



Spectrum of **offshore structures** concepts developed over the last century. These concepts range from fixed and floating structures.

Fixed structures are those resting on seabed with pile foundations transferring all gravity and environmental loads to seabed.

Floating structures are those floating on water with gravity loads supported by buoyancy and the environmental loads transferred to seabed by mooring system and anchor foundations.

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FIXED STRUCTURES

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Fixed Platforms

- Wellhead Platforms
  - Generally 4 legged or Tripods (3 legged)
  - Supports minimum topside
  - Supports Well conductors sizes ranging from 16” to 30”
  - In Persian Gulf, typical water depths around 30-70m, most jacket installed by lifting with weight ranging from 600T to 2000 T
- Process Platforms
  - Generally 8 legged or 6 legged
  - Large topsides either installed by modular lifts or float-over
  - Large 8 legged Jackets weight vary from 4000T to 6000 T depending on water depth
  - South China Sea water depth ranging from 90m to 120m

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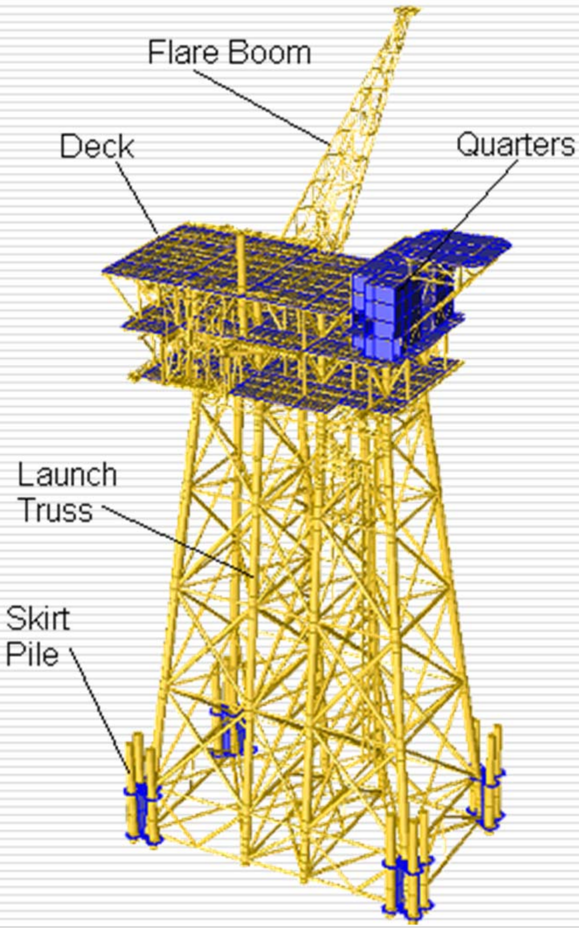
A fixed Offshore Platform

An offshore platform for drilling and production of oil and gas interconnected by a bridge.



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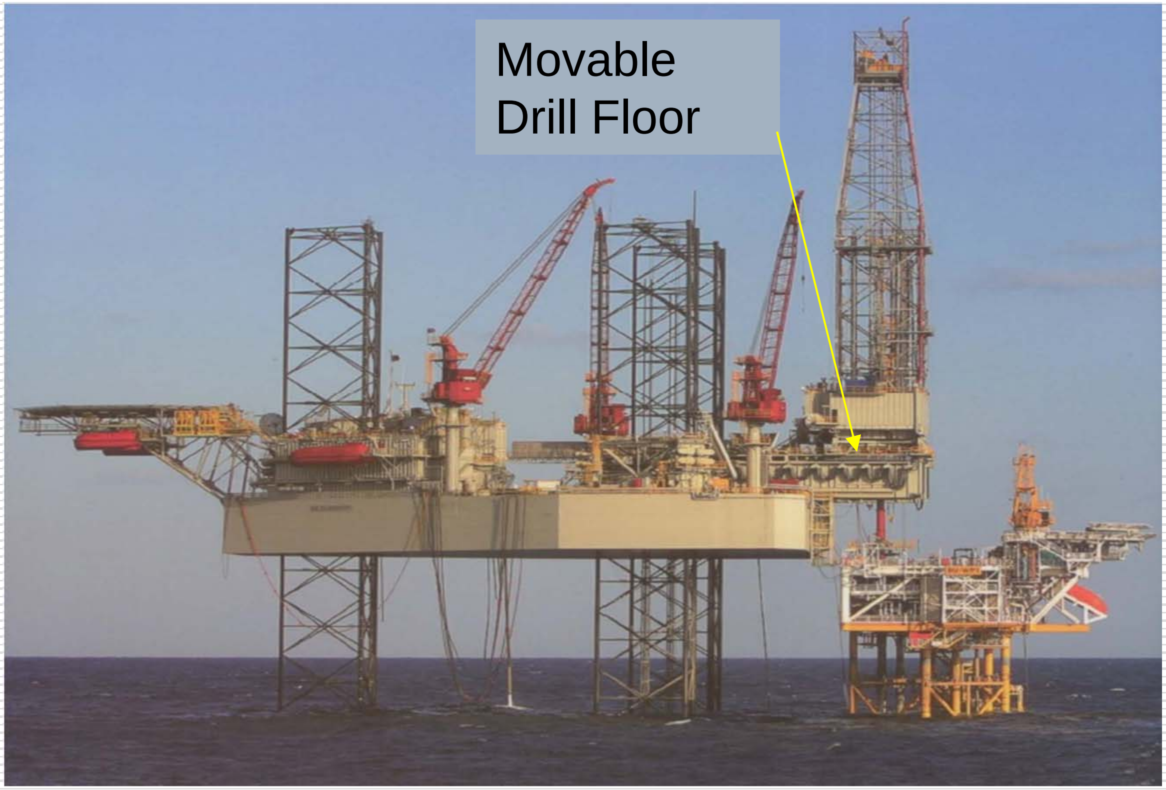
Jackup Rigs



Jackup *is a semi-fixed structure with floating hull.*

Jackups are predominantly used for drilling though in some cases, it is also used for production in marginal field

Jackups are supported on legs conventionally lattice frames or tubular construction.

A jackup rig drilling a well through an existing wellhead platform using a cantilever rig floor. The jackup rig is supported on to seabed through legs fitted with large mat foundation called Spudcan.

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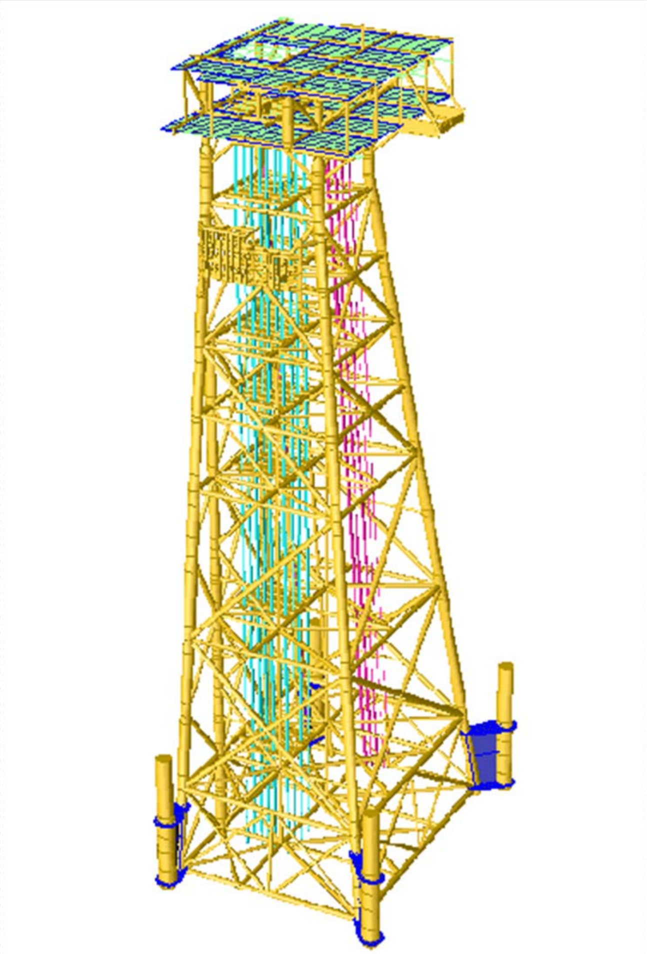
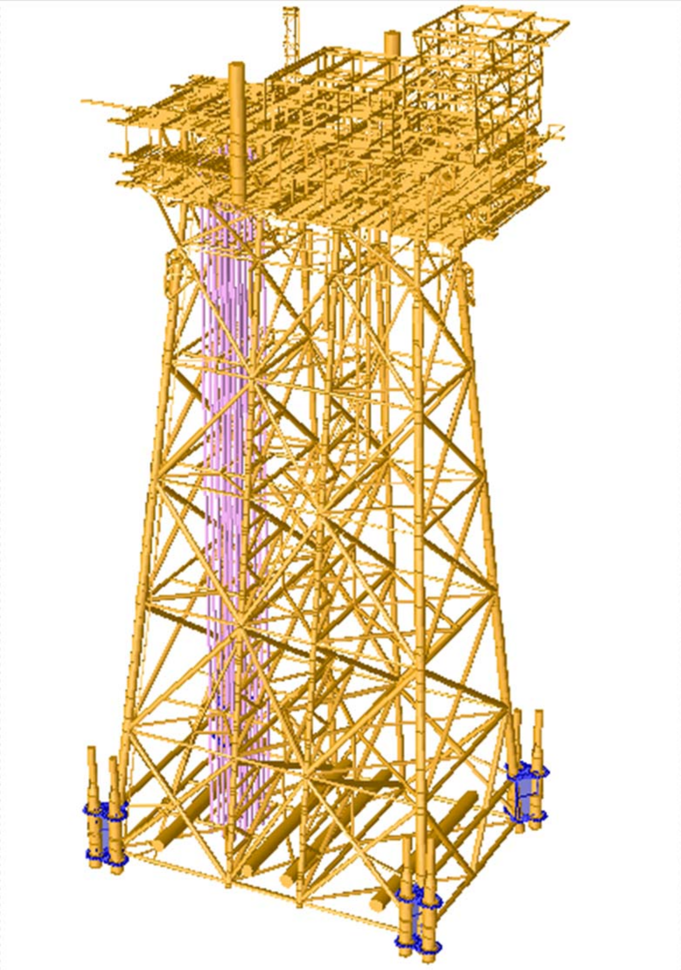
Wellhead platforms





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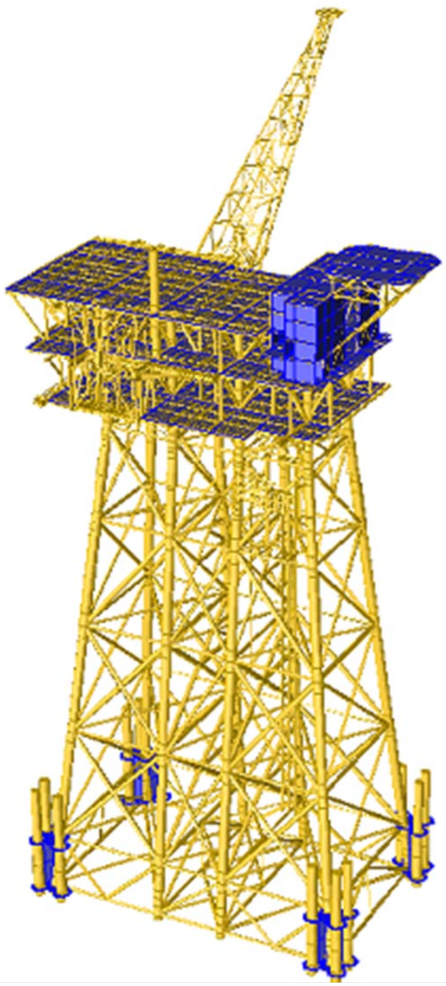
Process platforms



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As we move away from shallow water depth, the safety in design revolves around economy and new technology

Wellhead and Process, Living platforms separated by a distance

Wellhead, Process, Living facilities in a single platforms

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Fixed Offshore Structures

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What it means…

Offshore Structures subjected to most onerous and severe loading conditions….

- Storm Wind, Waves and Currents
- Water Depths in excess of 600m for fixed structures
- Water Depths in excess of 3000m for floating structures
- Operating in Temperature far below normal temperature
- Special Materials required resist corrosive environment
- Loads are cyclic and fatigue loading will be important

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YOU WILL BE DESIGNING STRUCTURES TO SERVE IN MOST HOSTILE ENVIRONMENT

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AS HIGH AS SKY SCRAPERS

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FLOATING STRUCTURES

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When do we opt for floating structures ?

- Water Depth exceeding 500m
  - Design and installation of fixed structures becomes uneconomical and practically impossible !
- Hostile Environmental conditions
  - Possible to relocate to safe areas in case of extreme environmental conditions if operations permit.
- Large Topside Loads (both weight and size)
  - Often limited by pile foundation capacity and footprint size of superstructure

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What can they designed for ?

- Drilling
  - Structures suitable even in shallow water due to their mobility – Drill ships and semi's used for drilling
- Production
  - Can support large size topsides – often a problem in fixed structures
- Storage
  - Not possible in fixed structures and is a useful method for marginal fields where offloading is not continuous

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FLOATING STRUCTURES

- **Tension Leg Platform (TLP)**
- **Spar Platform (Classic or Truss)**
- **Articulated Tower**
- **Floating Production System (FPS)**
- **Floating Production, Storage and Offloading System (FPSO)**

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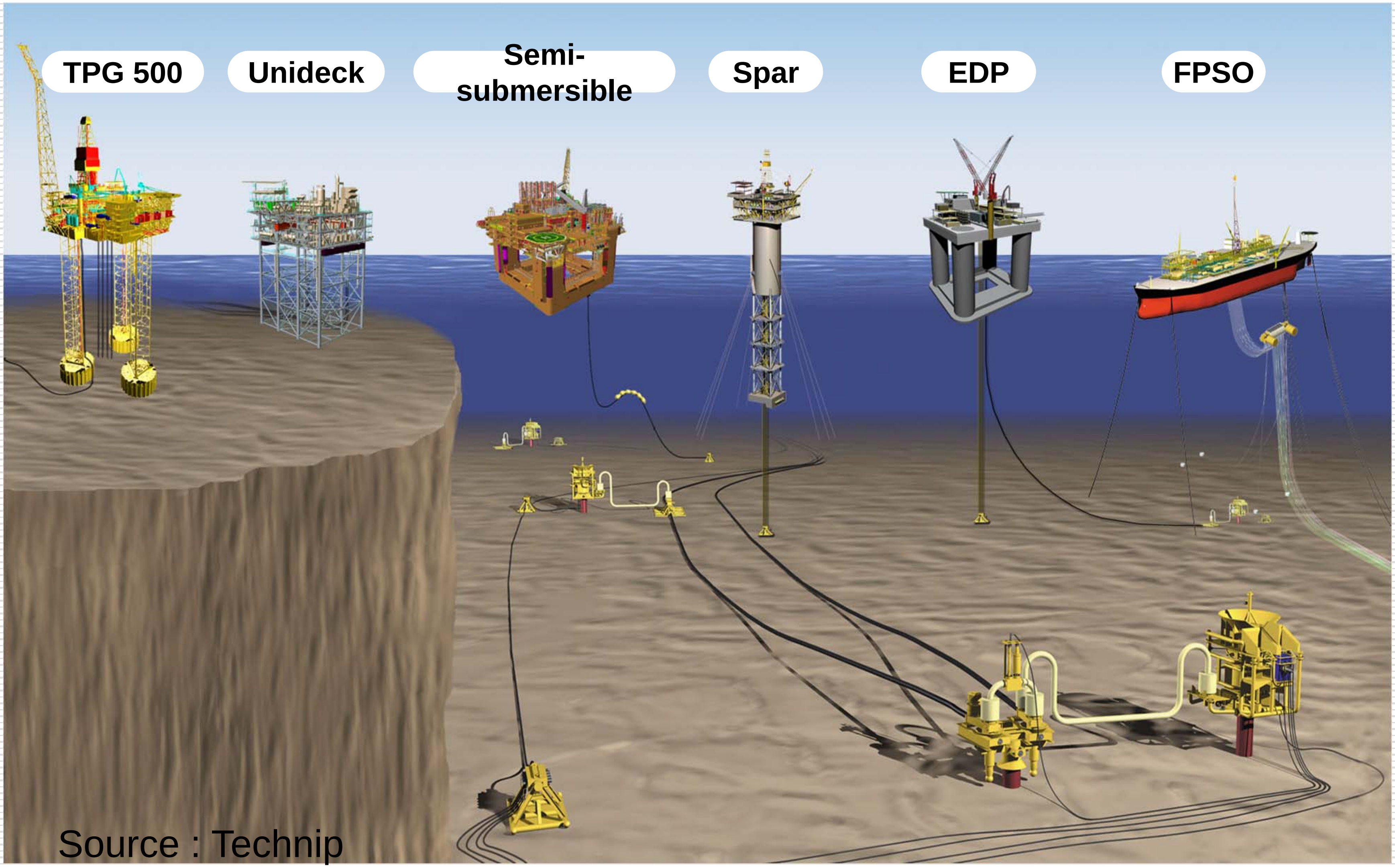
Engineering for Oil and Gas Exploration



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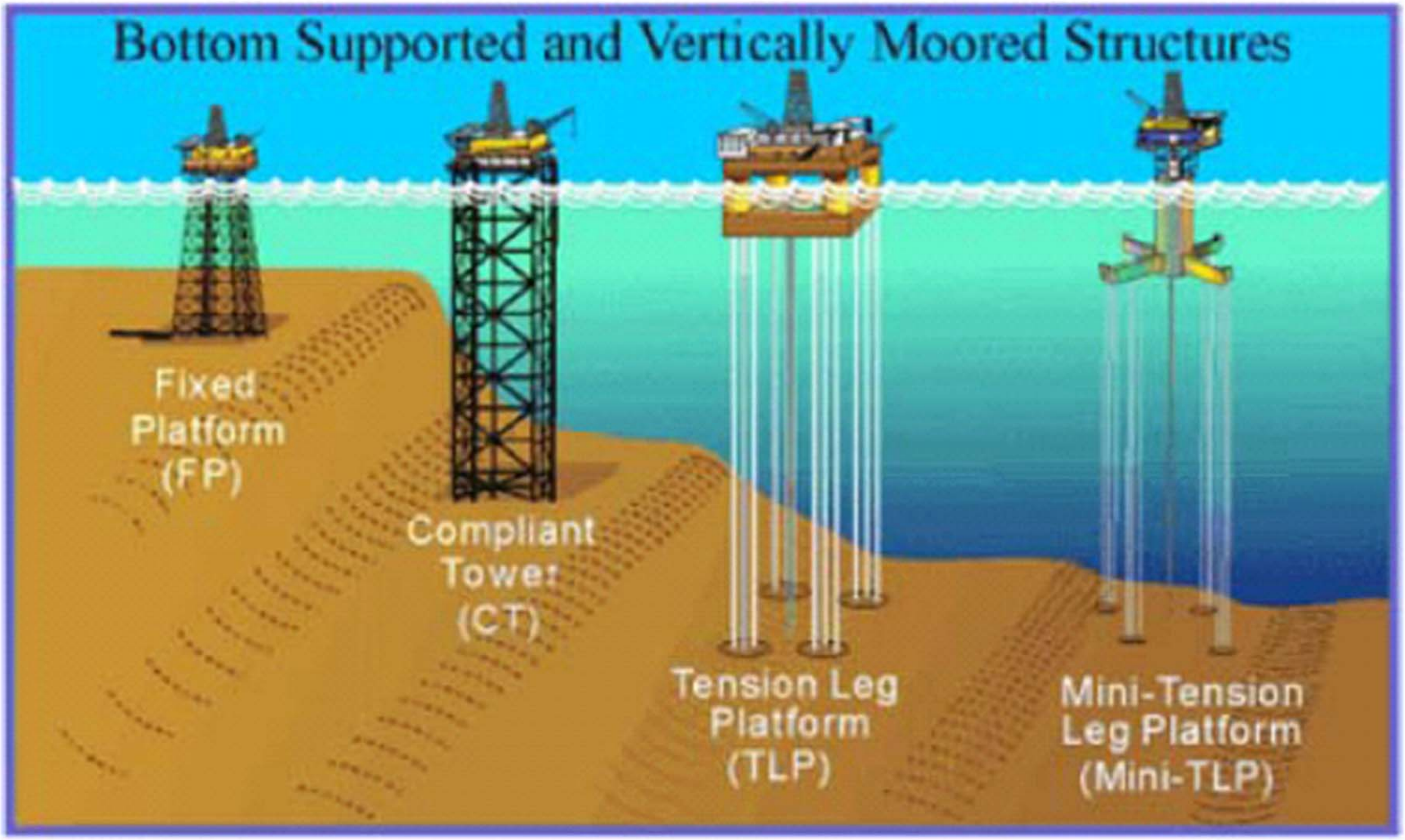

Source : MMS, USA

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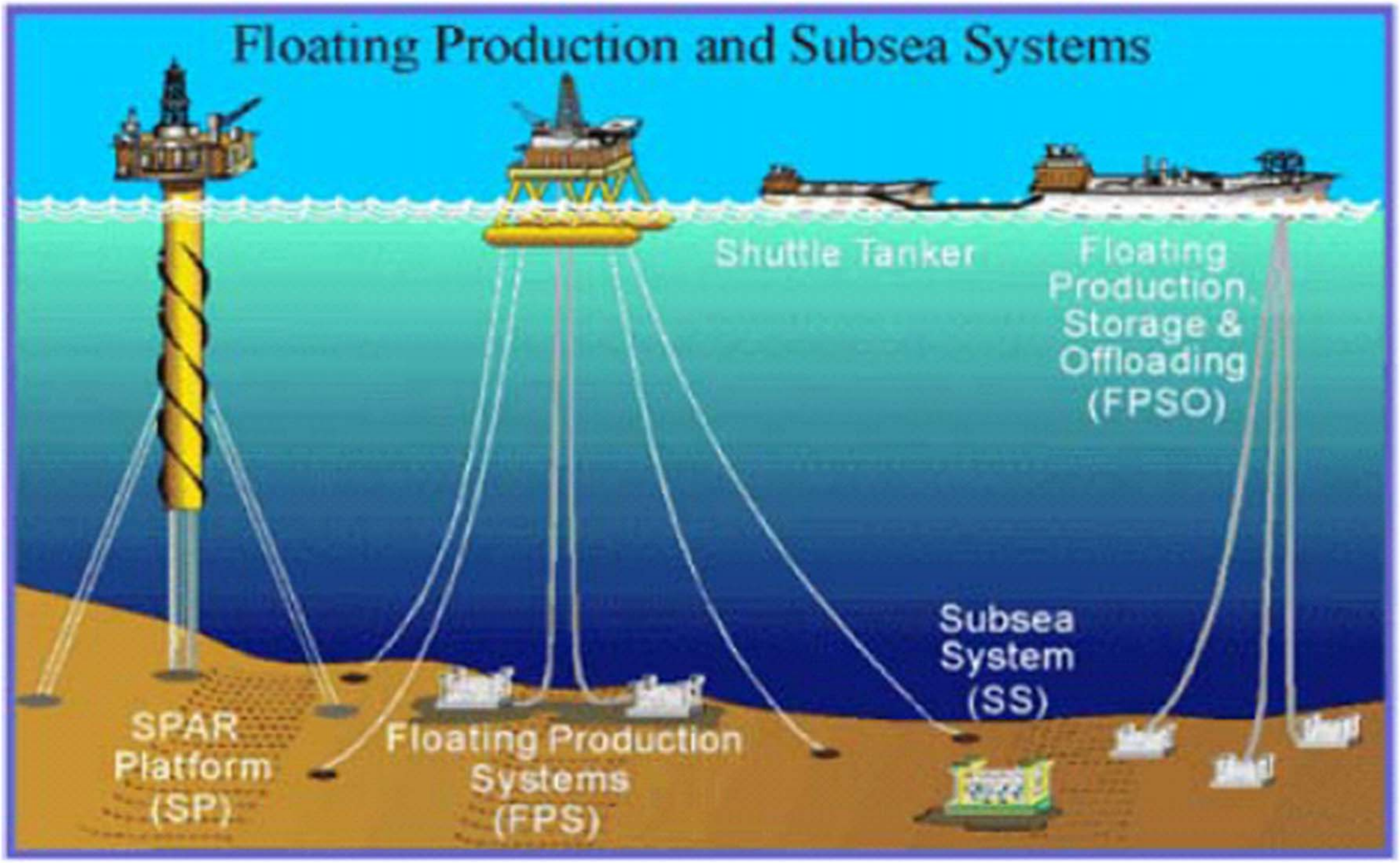

Source : MMS, USA

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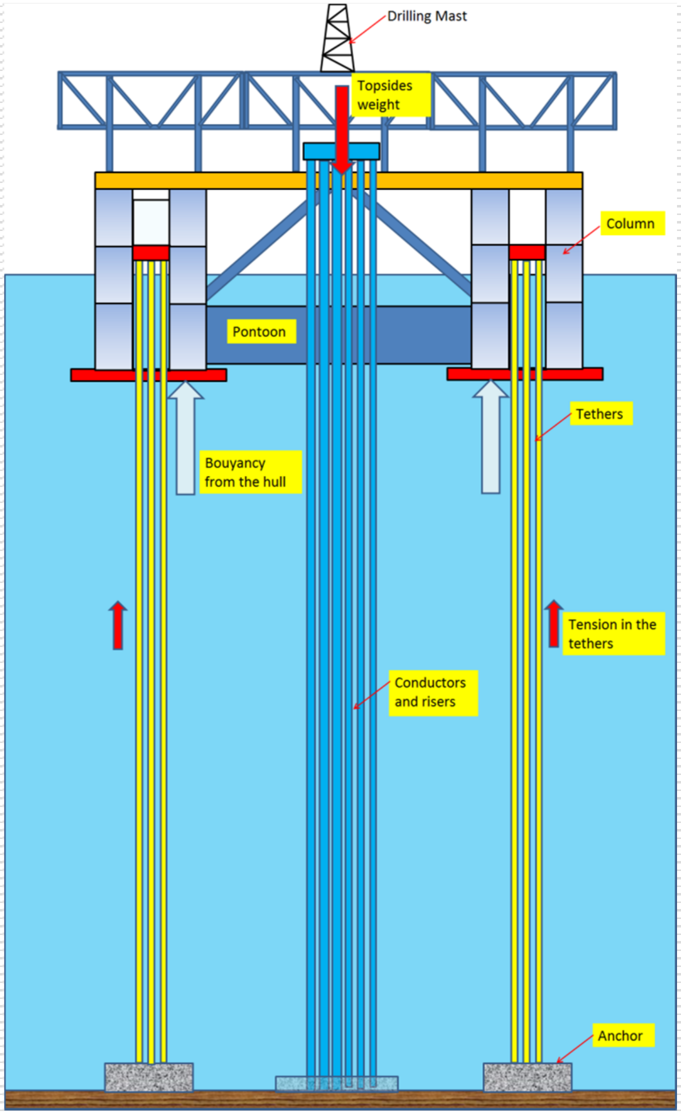
Tension leg platform

- Tension Leg Platform concept is arising from a set of buoyant columns held on to the sea bed by means of cables, thus producing effective tension in the cables.
- The TLP uses tubular members as tension supports between the pontoon and the seabed and thus the effective tension avoid the buckling of the tubes under any compression loading during movement of the floater downwards.
- The floater supports the topside payload by means of sufficient buoyancy from the hull.
- This reduces the vertical motion considerably.



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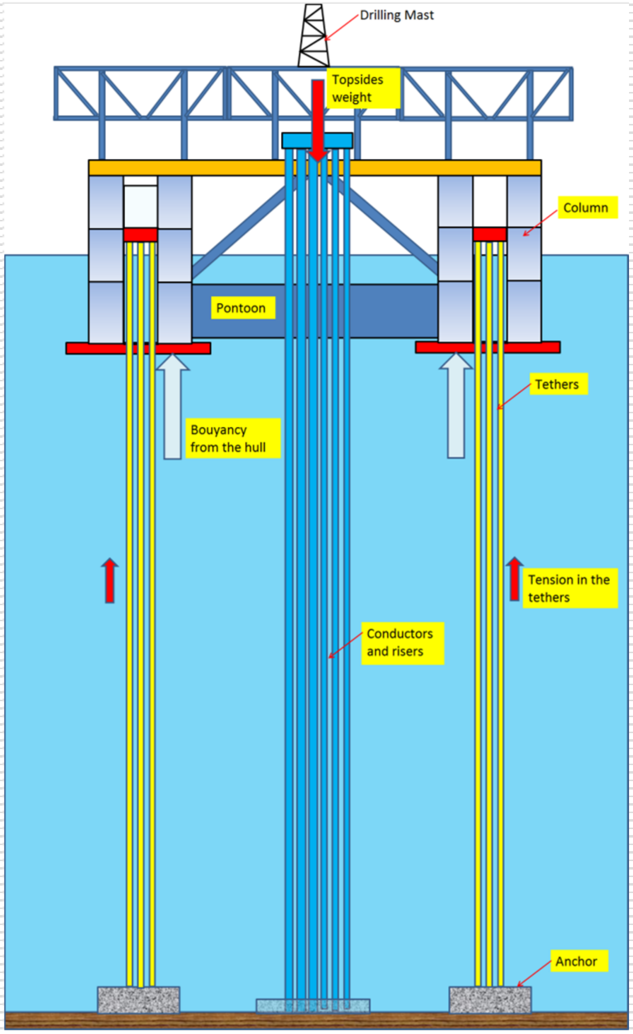
Tension leg platform



Tension Leg Platform (TLP) *is a floating hull, usually supported on four columns and pontoons.*

The columns are connected to hull through vertical tethers and anchored to seabed with a pretension. The pretension is achieved from the excess buoyancy.

The gravity loads from the hull and the topsides are supported by buoyancy from the hull similar to the ships.

TLPs are very common for deep water applications for drilling and production in excess of 1000m water depth.

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TENSION LEG PLATFORMS



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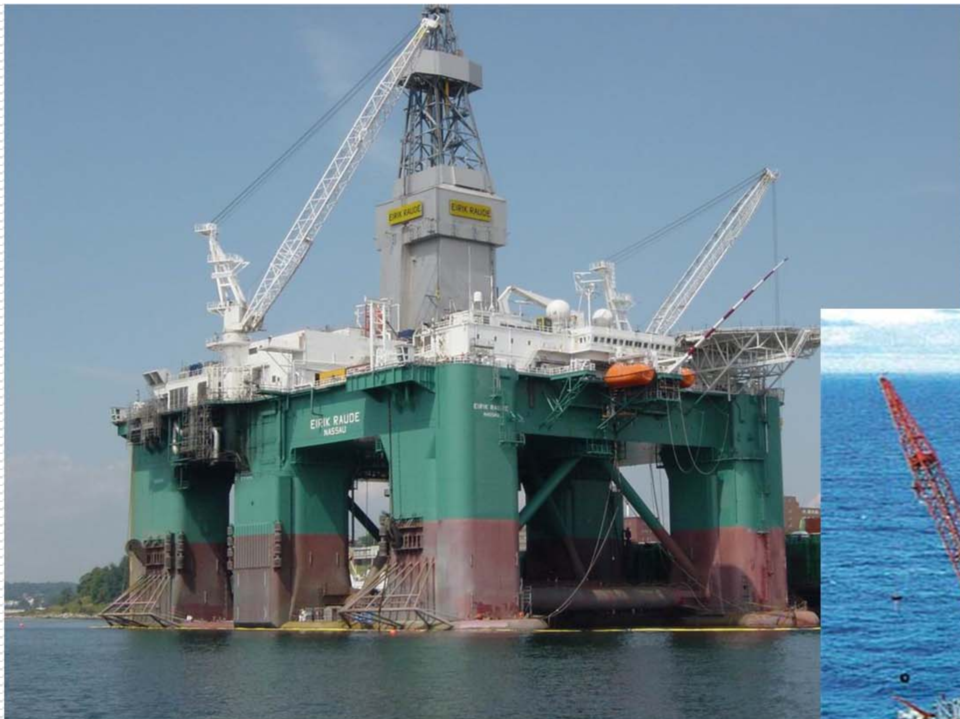
Semi-submersibles



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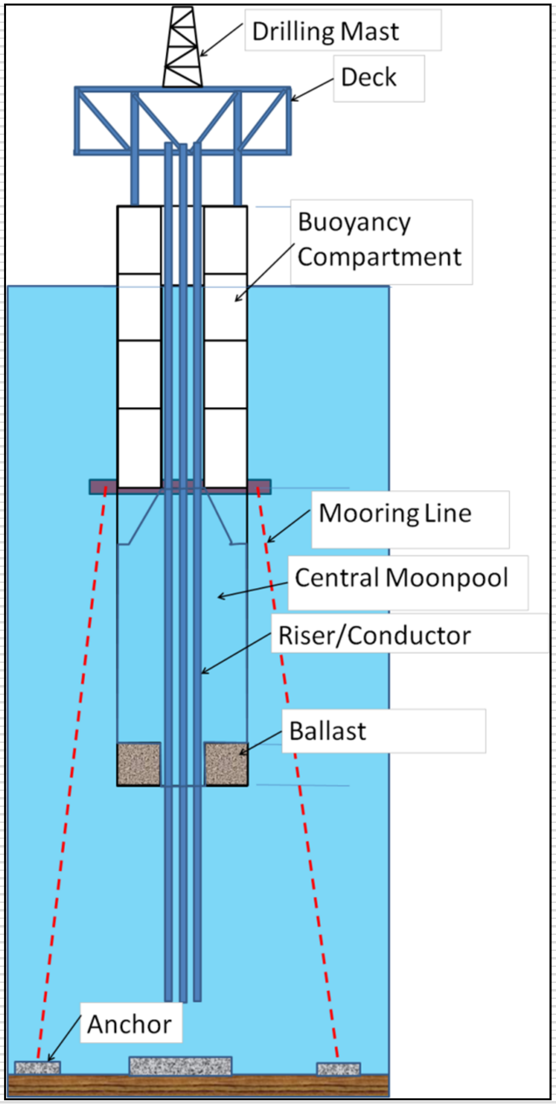
Spar

SPAR – Single Point mooring And Reservoir

- **Spar is a deep draft cylindrical hull floating upright**
- **Payload supported by buoyancy**
- **Moored to seabed by Taut or Catenary mooring lines**
- **Combined Centre of Gravity of Payload, Spar and Ballast kept below the Centre of Buoyancy**
- **Has large volume for storage (Reservoir)**



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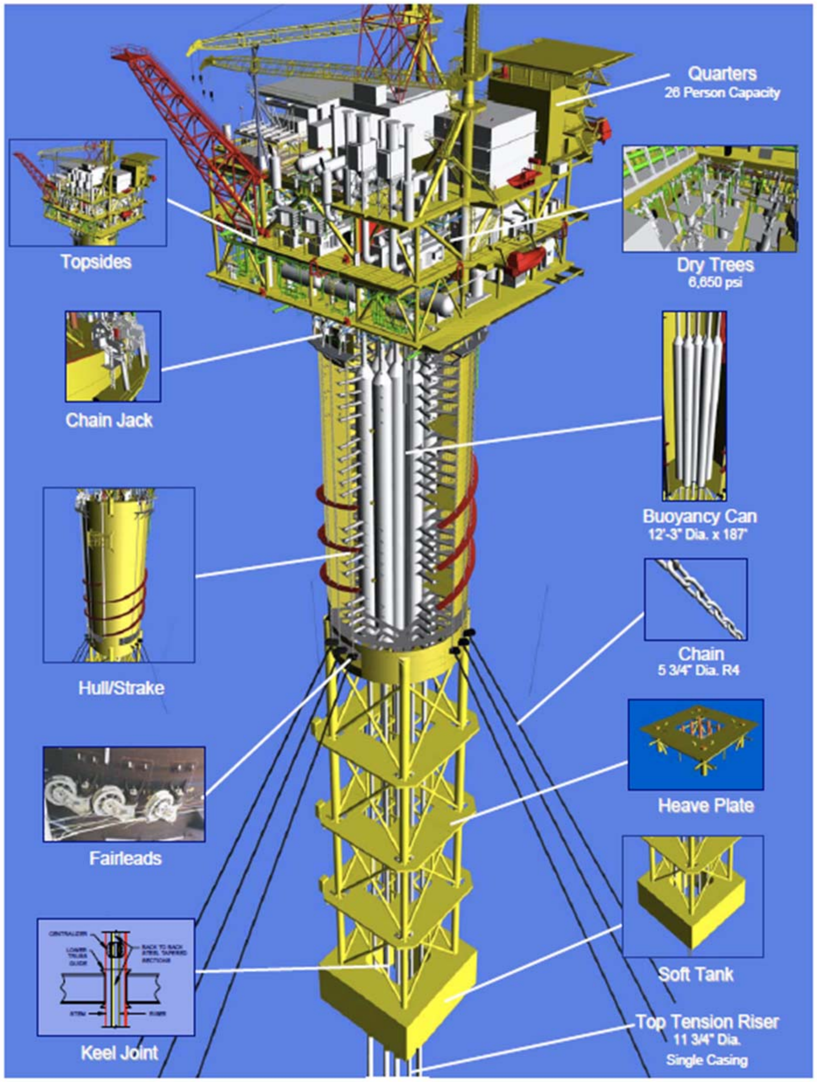
Truss Spar

- Truss Spar is a variation of the floating cylinder with additional extension using open truss at the bottom.
- This provides additional supports below the hull to the risers.
- Further, the ballast tank is located at the bottom of the truss to increase the stability by shifting the COG downwards.
- This is the most commonly used Spar hulls in the industry



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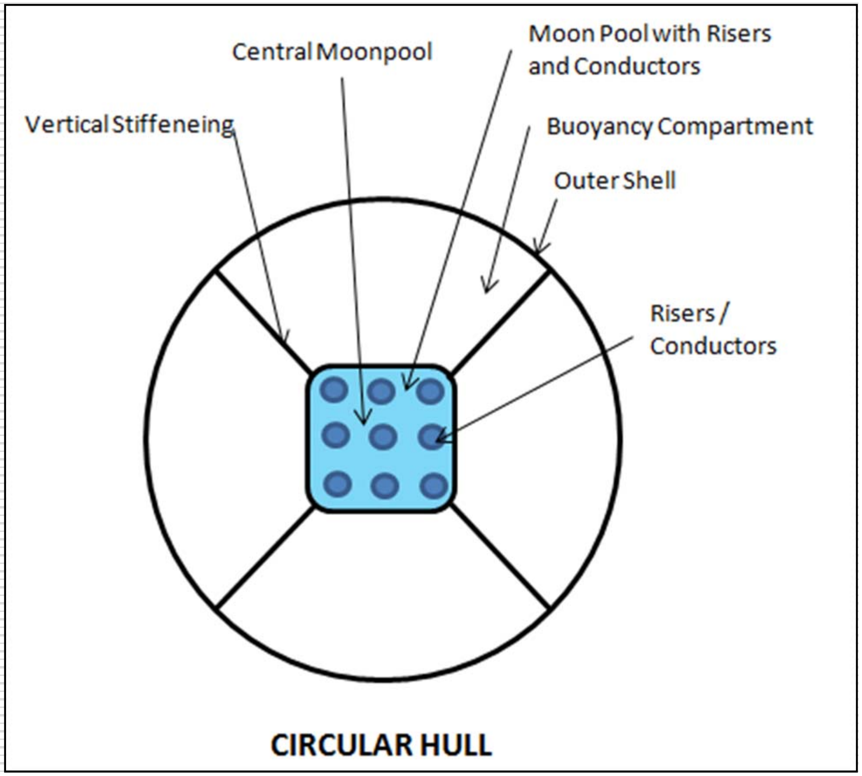
Typical Section of Spar

Similar to any floating hulls such as the ships, the Spar hull is divided in to compartments both in vertical and horizontal direction.

The central area is open to the sea called "Moon pool" allows the drilling and production risers from seabed to the topsides.

Compartments are as 4 or 6 or 8 in plan and number of compartments in vertical direction is made depending on the storage and buoyancy requirements.



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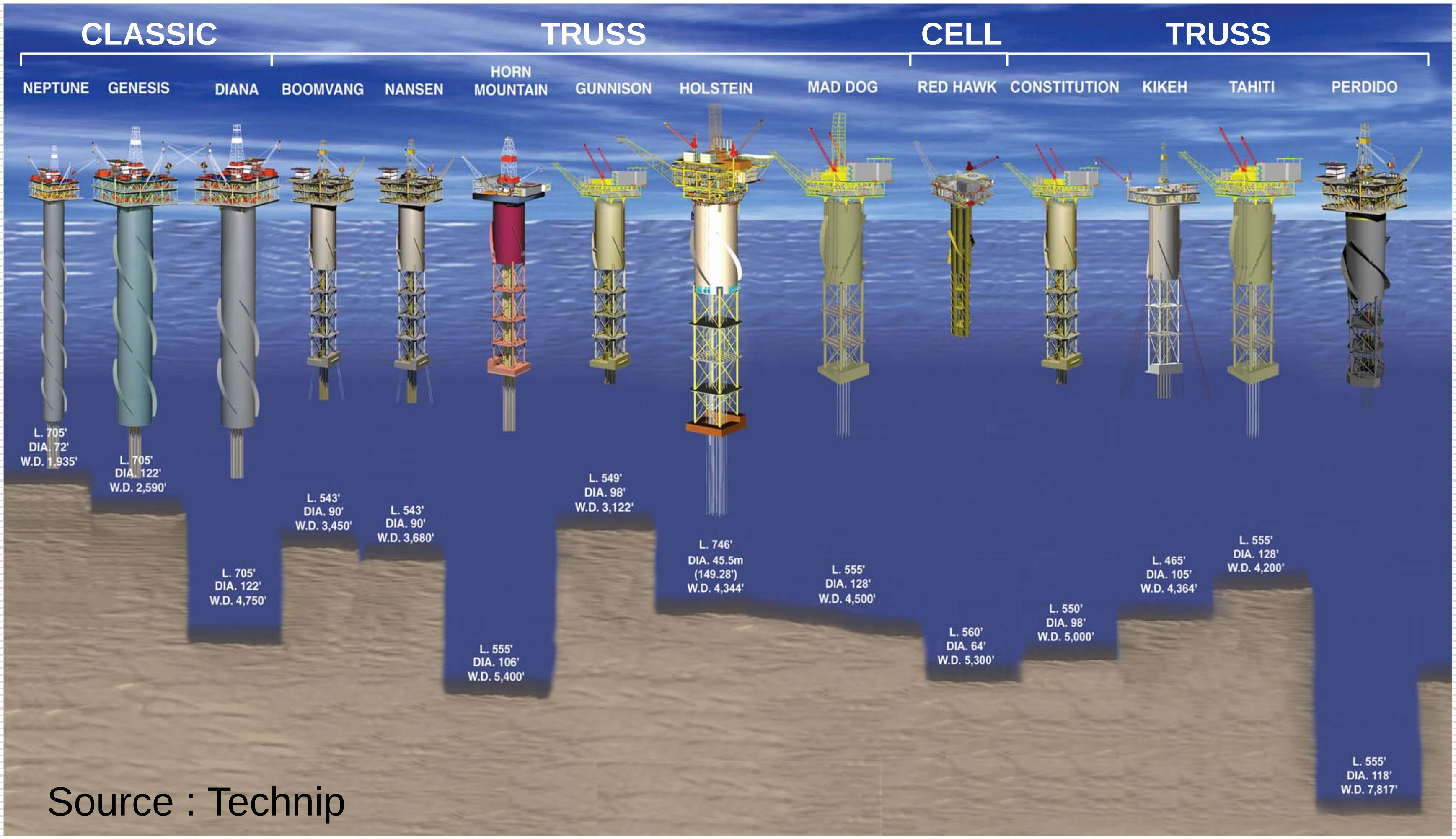
Spar Hull types



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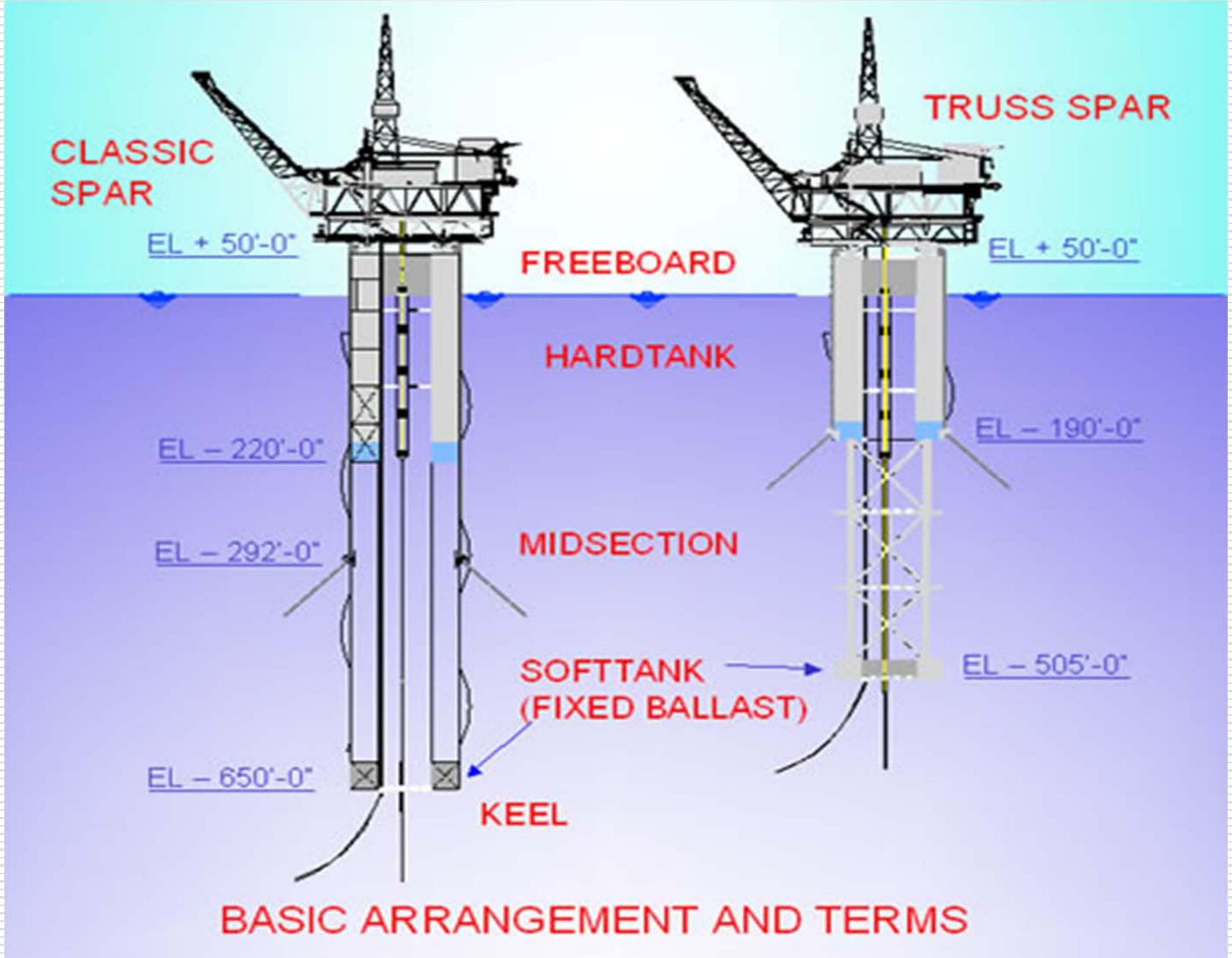
SPAR Hull Section



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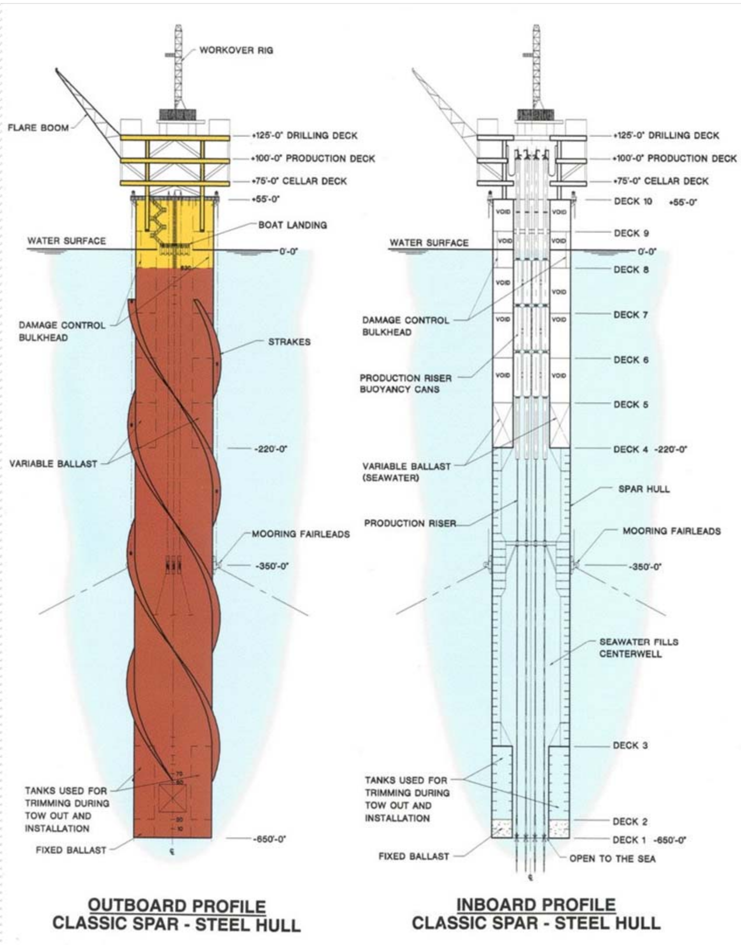
SPAR PLATFORM



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Floating Production, Storage and Offloading (FPSO)

Floating Production, Storage & Offloading System (FPSO) consists of a large tanker type vessel moored to the seafloor.

An FPSO is designed to process and store production from nearby subsea wells and to periodically offload the stored oil to a smaller shuttle tanker.

The shuttle tanker then transports the oil to an onshore facility for further processing.

An FPSO may be suited for marginally economic fields located in remote deep water areas where a pipeline infrastructure does not exist.

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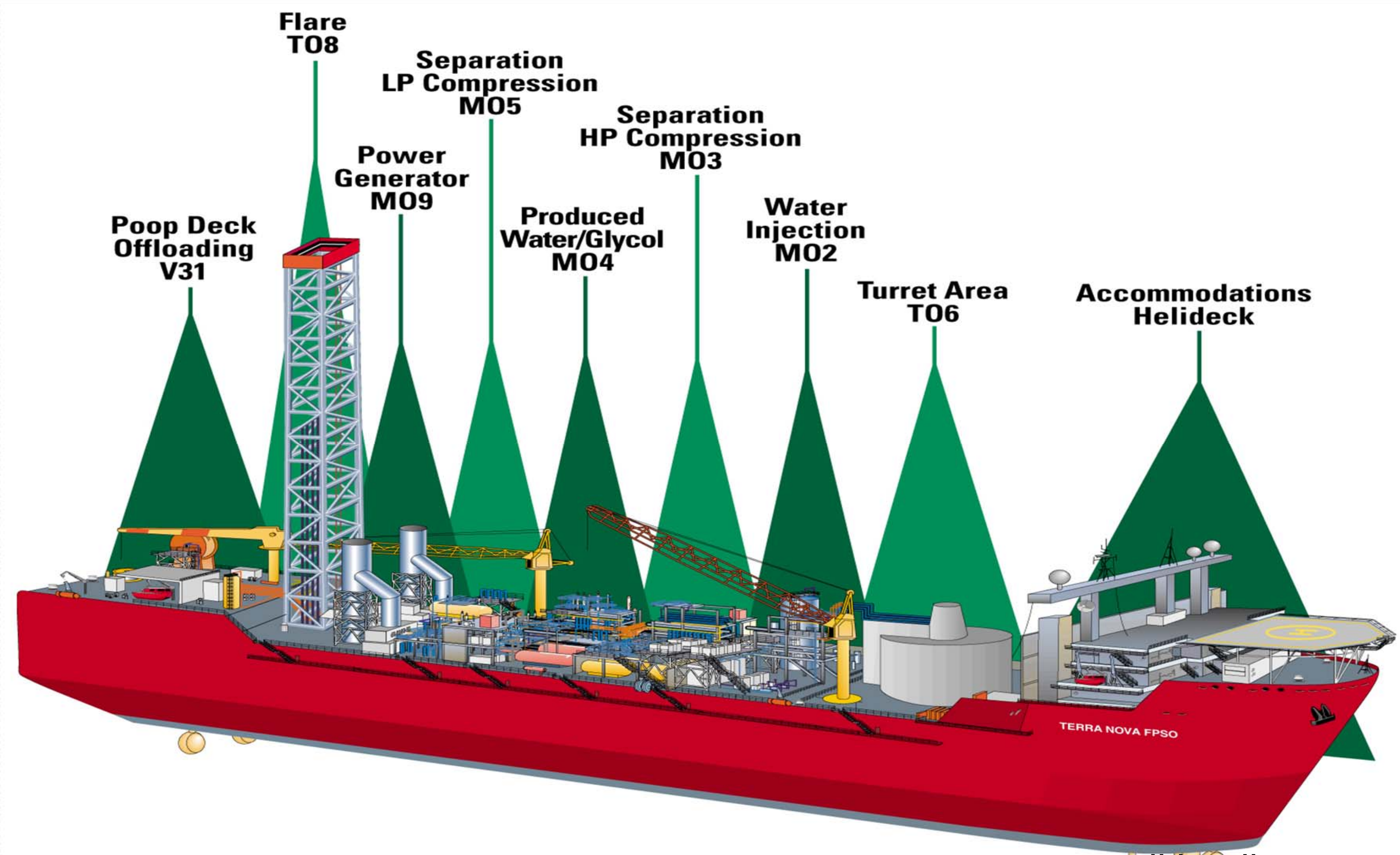
TYPICAL FPSO MODULAR ARRANGMENT



Courtesy : Wikipedia

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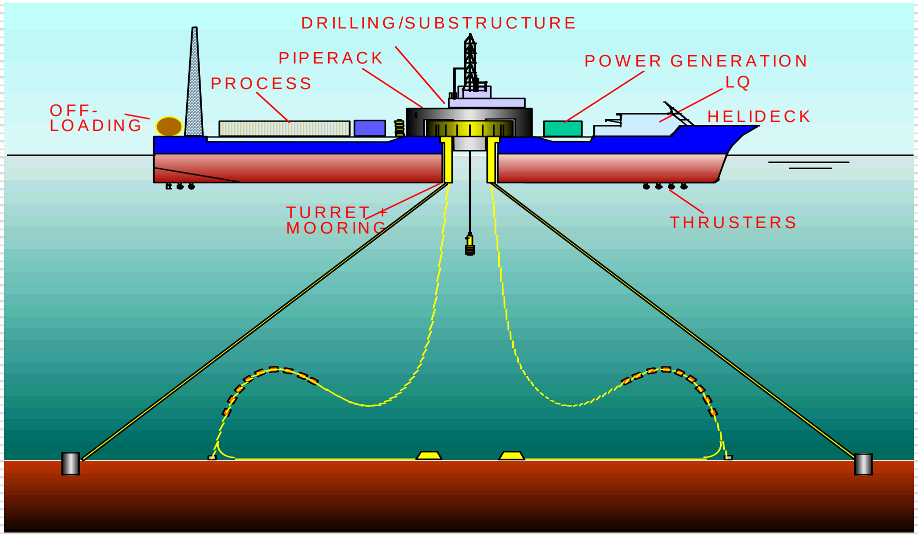
TURRET MOORED FPSO's

External Turret Moored FPSO



Internal Turret Moored FPSO

Turret mooring is a device attached to the FPSO so that the mooring lines are attached to the seabed and the device allows the FPSO to revolve around. The is termed as weather waning and thus reduces the motion response of the ship considerably. This also permits the flow of fluid through a swival at the top without damaging the fluid pipe.

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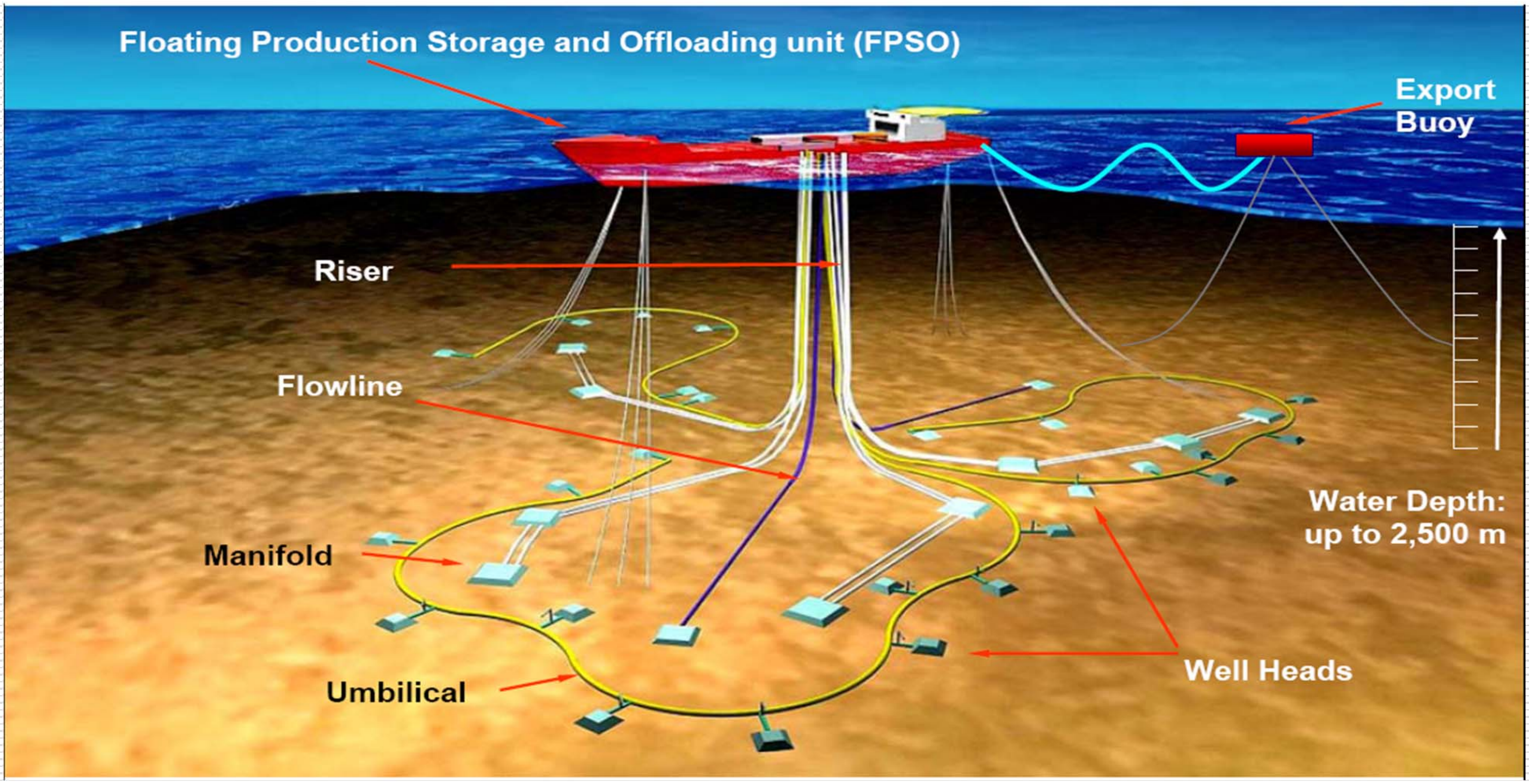
SPREAD MOORED FPSO



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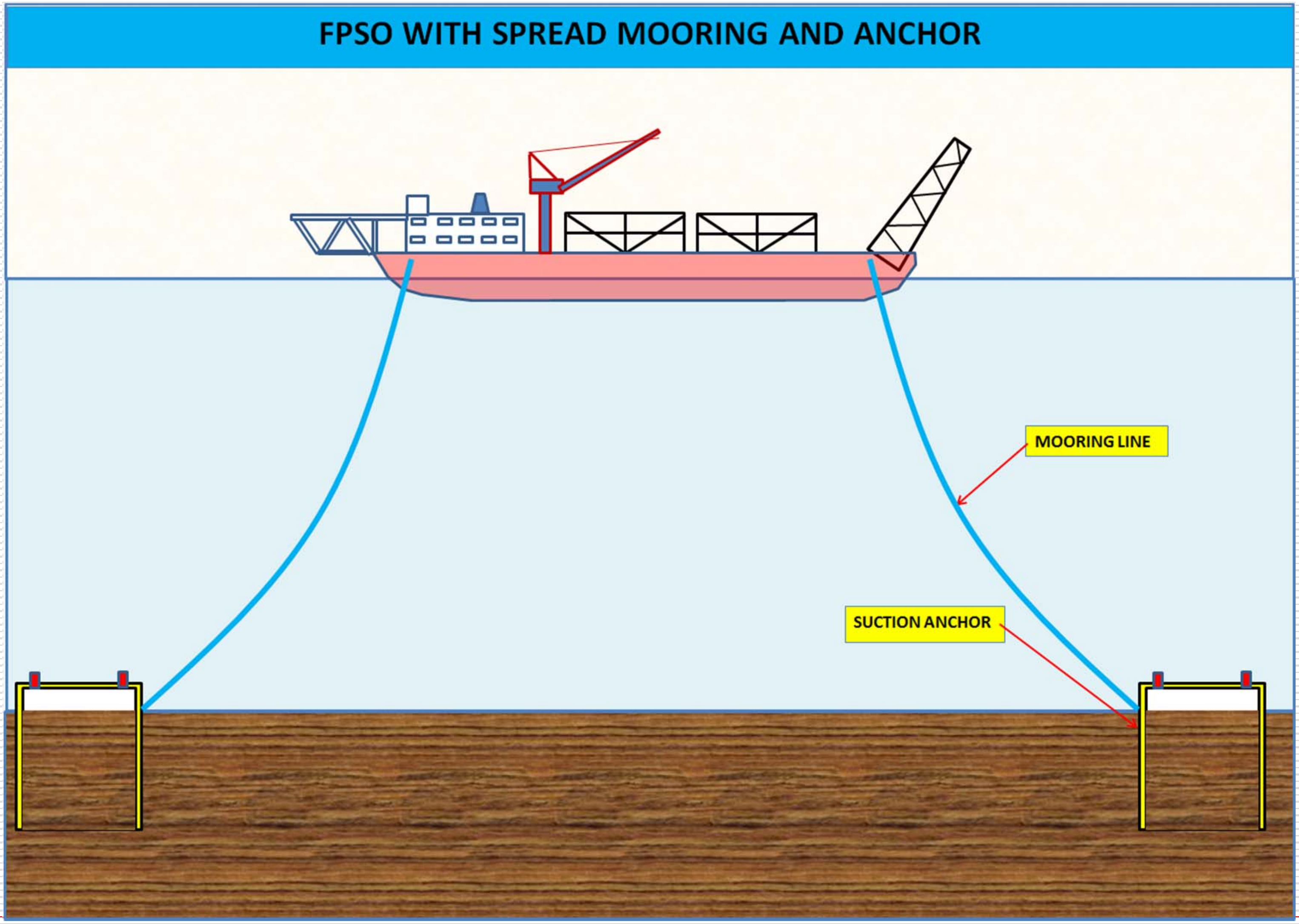

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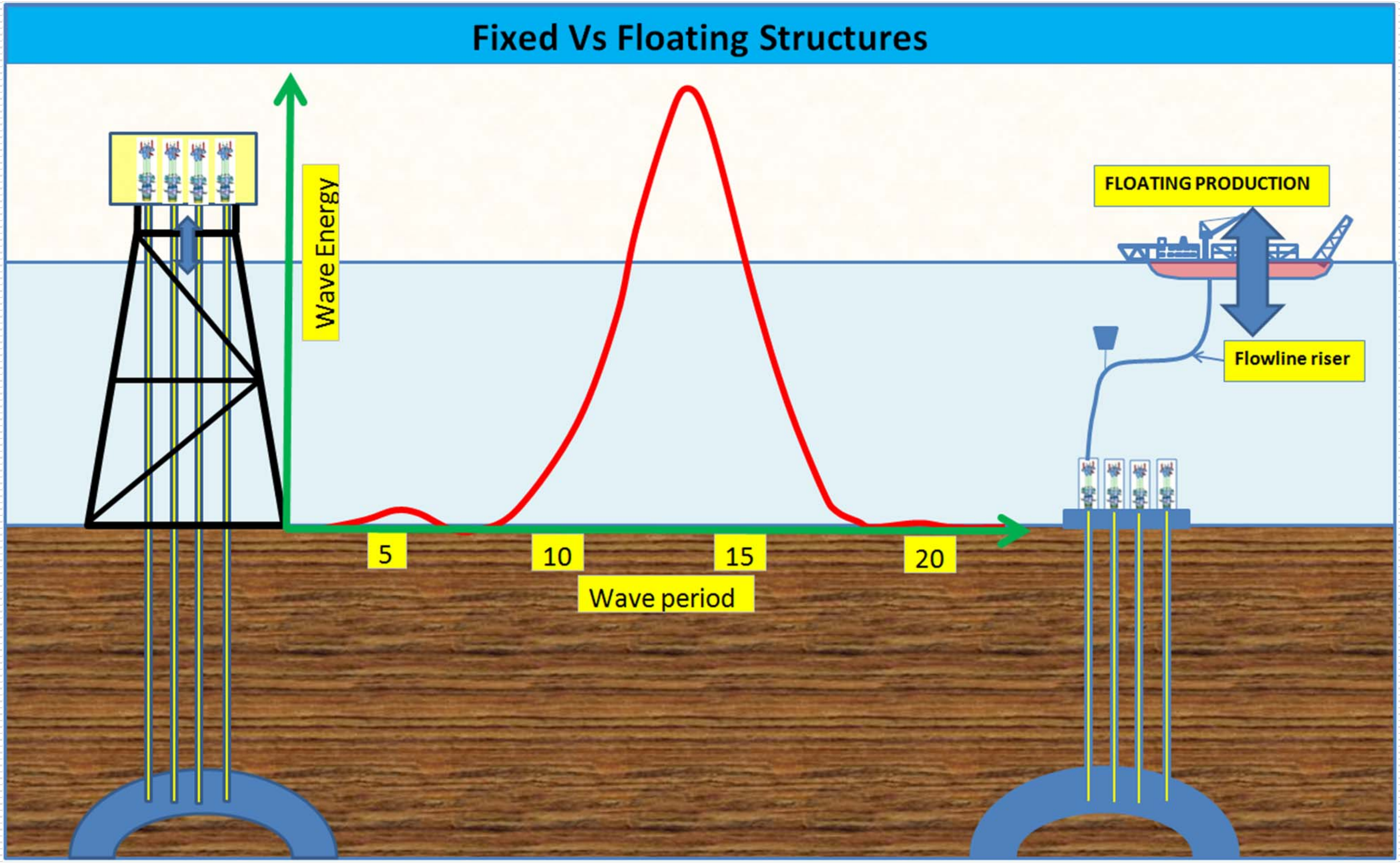

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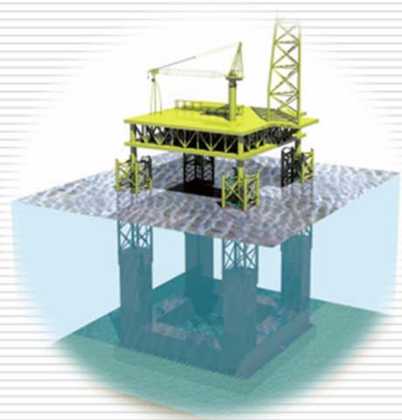
GRAVITY STRUCTURES



Gravity Base Structures - Development

The early development of gravity platforms in the 1970s was driven by the generic requirement to store large volumes of oil and support a heavy topsides in deep water. A large number of platforms were constructed of this type, characterized by the Olav Olsen's "**Condeep**" concept.

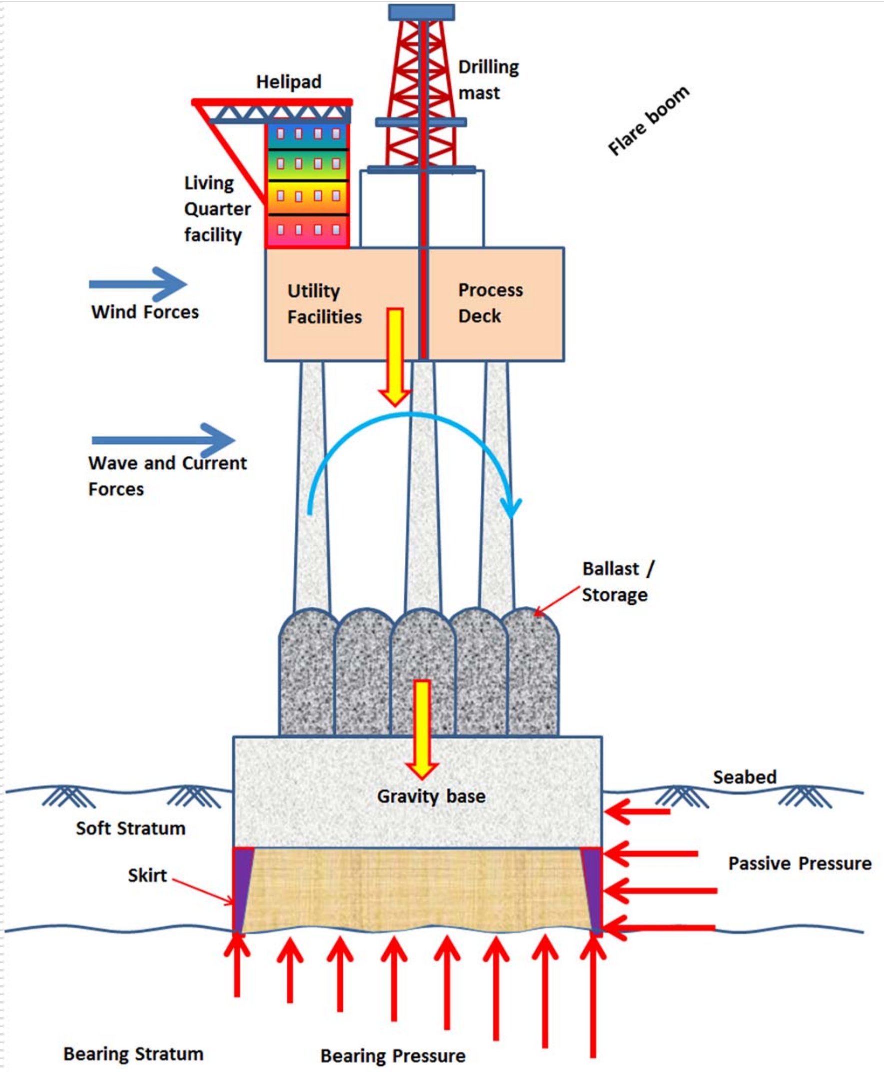
All of these structures were partially built in a dry dock and then completed afloat in sheltered waters. At that time, there was no pipeline infrastructure, and the capacity of heavy lift vessels was only a few thousand tons. It was determined that the oil storage requirement could be used to design a structure with sufficient buoyancy and stability to transport a heavy topsides from an inshore location to site.

Therefore, topsides could be assembled inshore, mated with the substructure at a sheltered deep water location and extensively hooked up inshore, before the whole facility was transported to the field and installed.

Engineering for Oil and Gas Exploration

The key characteristics singly, or in combination, that make CGBS units the preferred solution are:

- Requirement for oil or condensate storage
- Heavy topsides
- Soil conditions that make piled substructures unattractive, such as on Australia's North-West Shelf
- Remote hub applications at the edge of the continental shelf where shallow water processing can be provided for deep water subsea wells
- Desire to have a higher local content than has been achieved on previous field developments.



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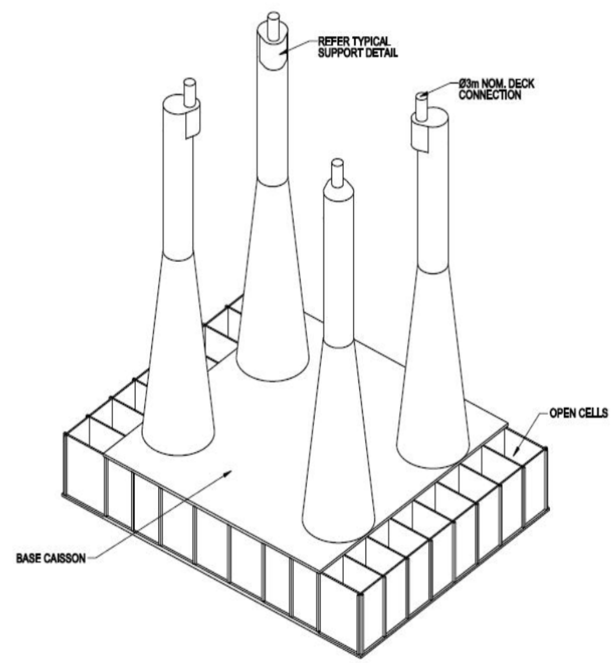
Concrete Gravity Base Structures - Elements

- **Base Caisson**: Used to provide buoyancy during wet tow of the CGBS from the casting basin to the installation site
- **Open Cells**: The open cells provide additional buoyancy for float-out from the casting basin. Once the CGS reaches sufficiently deep water the open cells are flooded to prevent uncontrolled filling by green water during wet tow. After installation of the CGS crushed rock ballast is placed in the open cells to provide additional on-bottom weight for global stability during extreme environmental conditions.
- **Shafts**: The four full height shafts are used to support the topsides. The risers and appurtenances may be installed on the inside or outside of the shafts. The shafts have conservatively been designed for the wave loading attracted by externally mounted appurtenances, although there is sufficient internal shaft space to locate most appurtenances internally. The final location of the appurtenances will be determined in subsequent phases of design.



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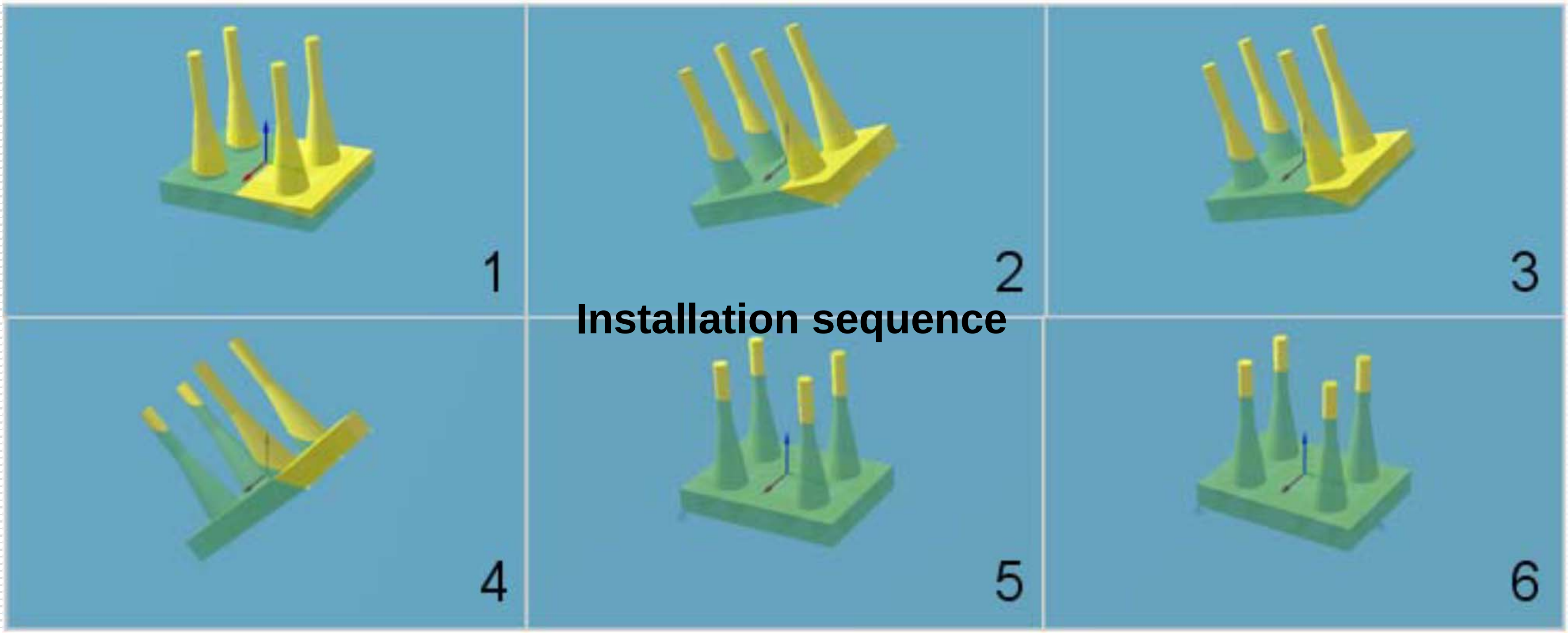
Installation

- The CGBS shall be installed using the inclined installation method.
- The stability during each stage of the installation shall be checked to ensure a sufficient margin of positive stability.



Installation sequence

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Ballasting Compartments

- The ballasting compartments within the base shall be formed from interconnected structural cells.
- Individual cells shall be interconnected both at a high and low level by penetrations through the intermediate walls to permit flow of water and to vent air from the cells.
- The compartments shall be designed to be watertight when subjected to design hydrostatic pressures.
- All of the compartments within the caisson base shall have to be required for installation.
- The shafts continue below the caisson roof and will not be flooded until after installation.

Sea Water Inlets

- A minimum of two sea water inlets should be provided to ensure that installation may continue with one inlet blocked. This may be due to a valve that cannot be opened or detritus blocking the inlet.
- The inlets should not be located close together so as to reduce the risk of common mode blockage.

Construction

Construction of Base Slab

Construction of Base Caisson Walls

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Concrete Gravity Base Structures – Construction

Construction of Roof Slab

Construction of Shafts

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Concrete Gravity Base Structures – Float-out / Towing

Float-out from casting basin

Wet Towing to installtion site

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Concrete Gravity Base Structures – Installation

CGBS Installation

Topsides Float-over

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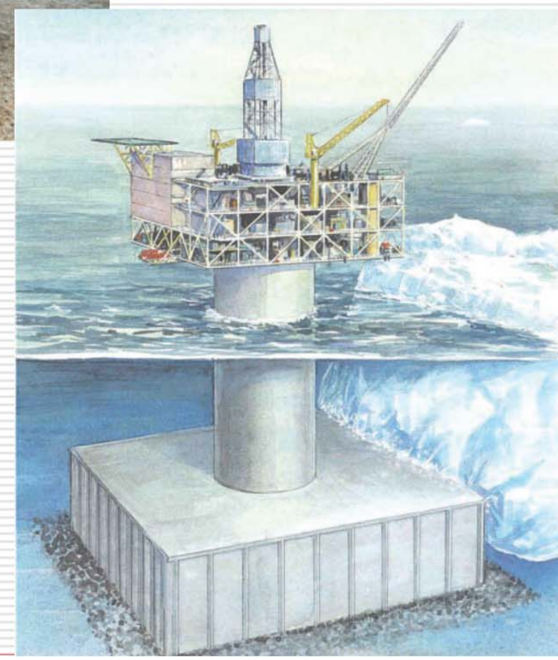
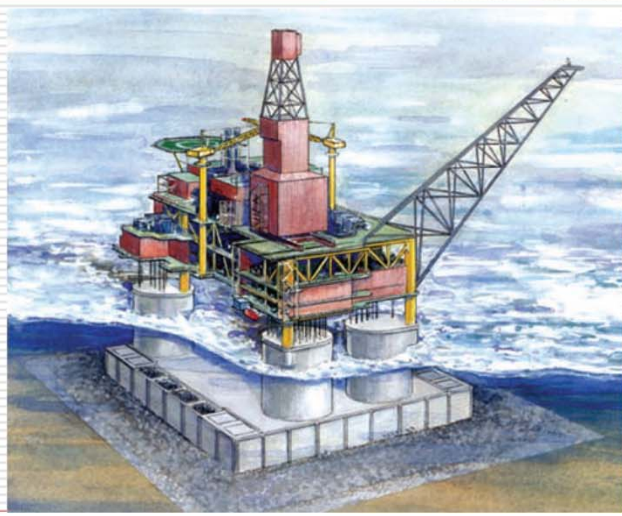
Gravity Base Structures – Future Concepts





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Fabrication

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Yard Facilities

- Quay Side (water front)
- Large Space (with sufficient ground bearing capacity)
- Welding shops
- Welding and Inspection equipment
- Painting Shop
- Yard cranes
- Jacks and winches

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TYPICAL FABRICATION YARD

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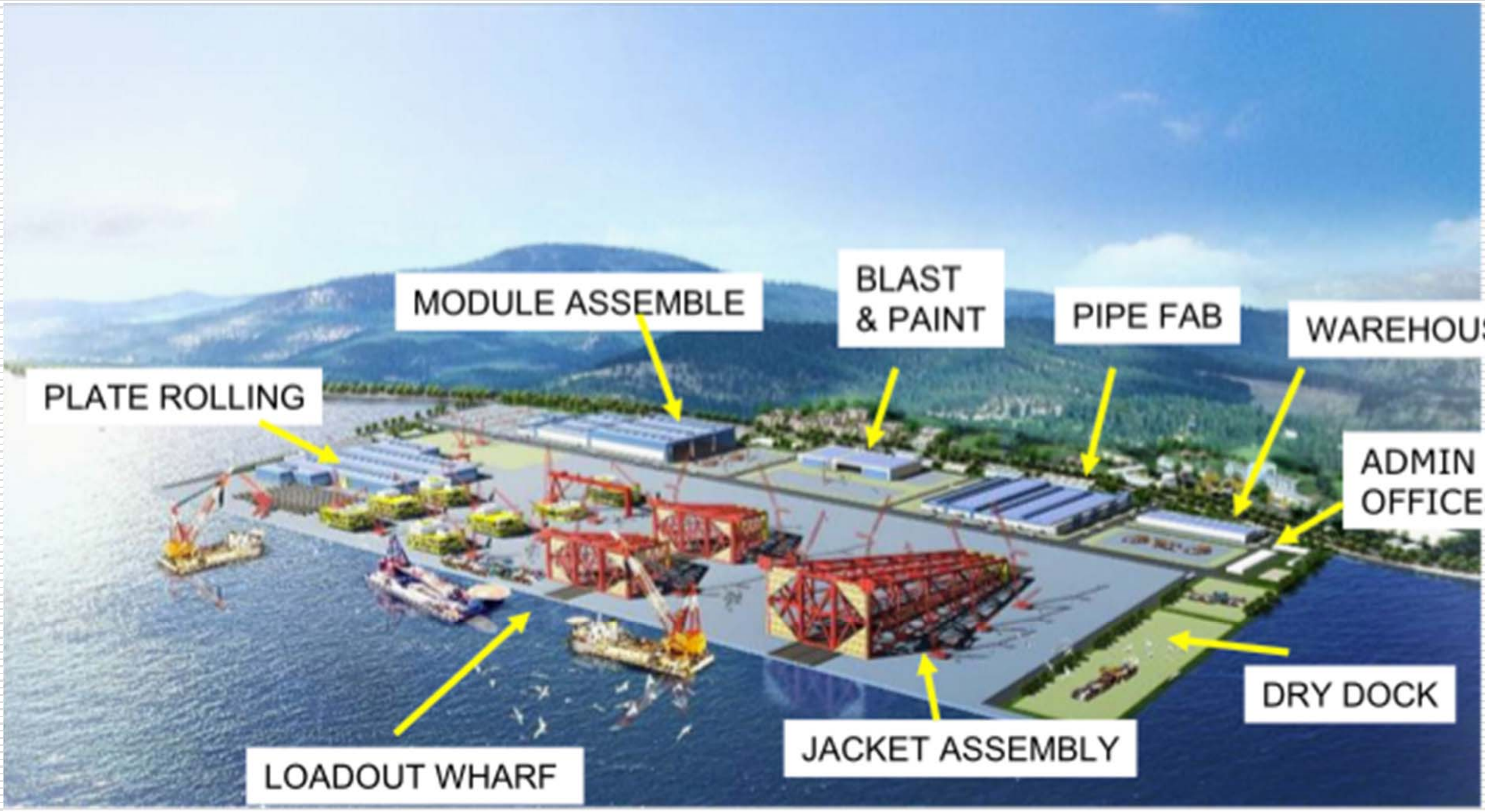
TYPICAL FABRICATION YARD



900,000 SQM FACILITY – 200,000 T/ YEAR CAPACITY

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ANODES BOUYANCY TANKS.

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INSTALLATION

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Forces Induced on Structures

- **Pre-service Stage** – During the fabrication and Installation, the structures are subjected to forces due to the method of installation. Hence an understanding of the method of installation is required. Following sub segments of installation is discussed.
  - Loadout
  - Lifting
  - Transportation
  - Launch
  - Upending

- **Operational Stage** – The loads arising from its functional requirements. This includes its service loads and associated environmental loads from wave, current and wind.

- **Survival Stage** – Loads arising from extreme storm condition. This includes platform weight and extreme storm wave, current and wind loads

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LOADOUT

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LOADOUT METHODS

- **LIFTED LOADOUT** – For small jacket and decks, where crane either land based or floating is available with adequate capacity, loadout can be done by lifting and placing it on the cargo barge.
- **SKIDDED LOADOUT** – For larger jackets and decks, of several thousand tonnes weight, usually skidded loadout is employed to avoid large capacity cranes. The jacket or deck will be mounted on a temporary skid support either continuous or discrete and will be pulled on to the barge using winches.
- **TRAILER LOADOUT** – Recent times, the trailer loadout is getting more popular due to its robustness and quick preparatory time. Trailers are multi-axle load balancing wheels with appropriate spreader girders on top. The jacket or deck will be moved from quayside on to the barge using these trailers and they will be removed.

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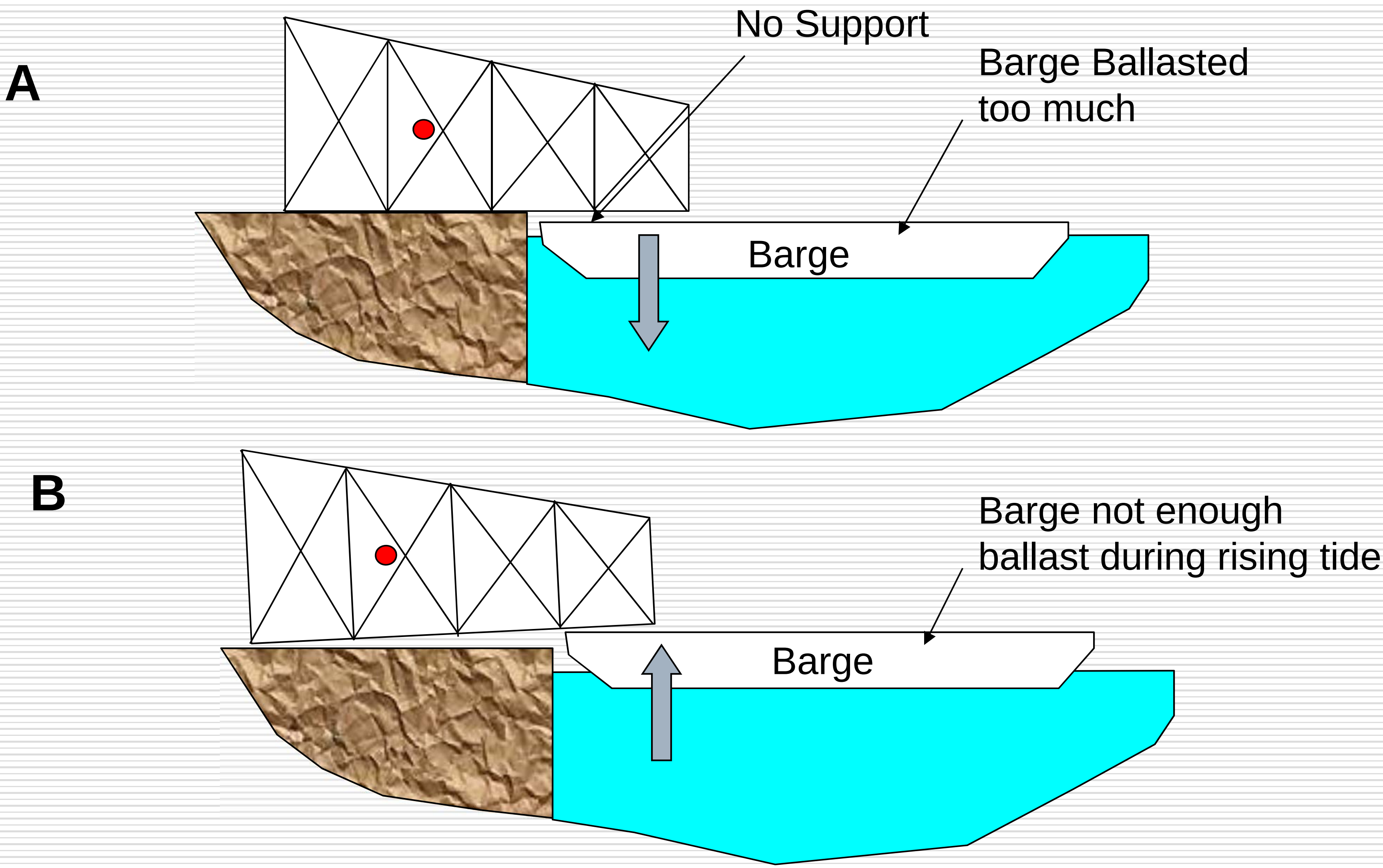

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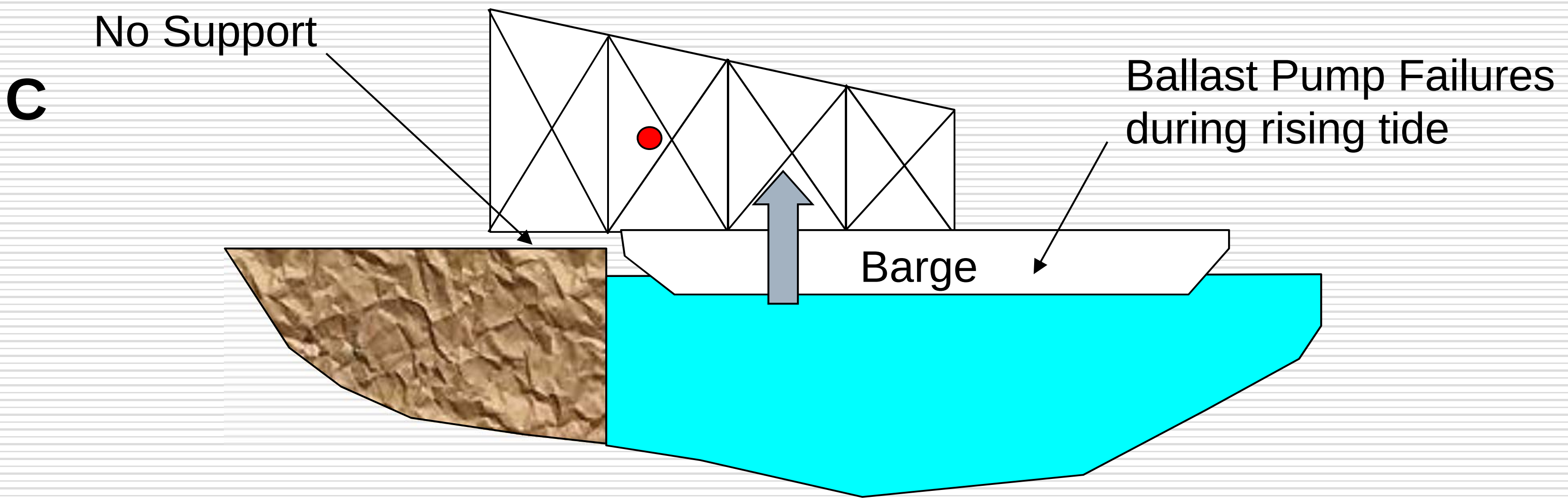

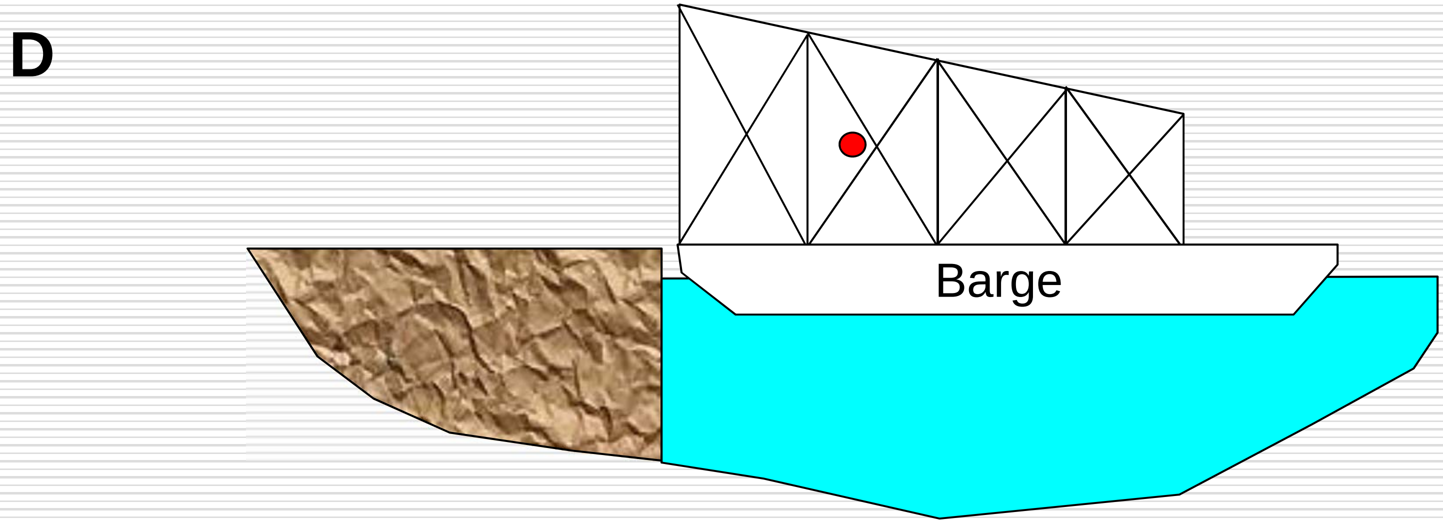

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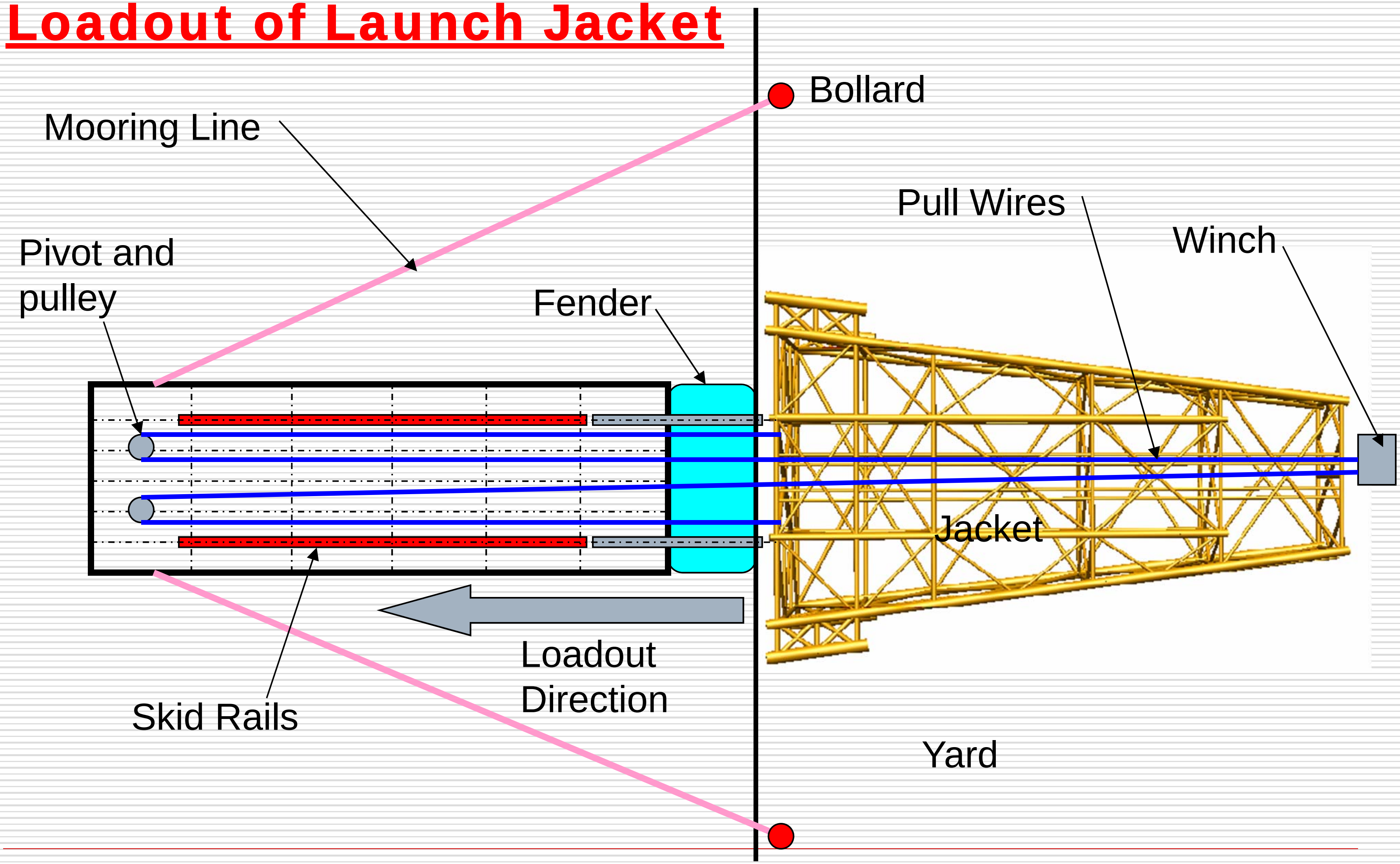
Loadout of Launch Jacket



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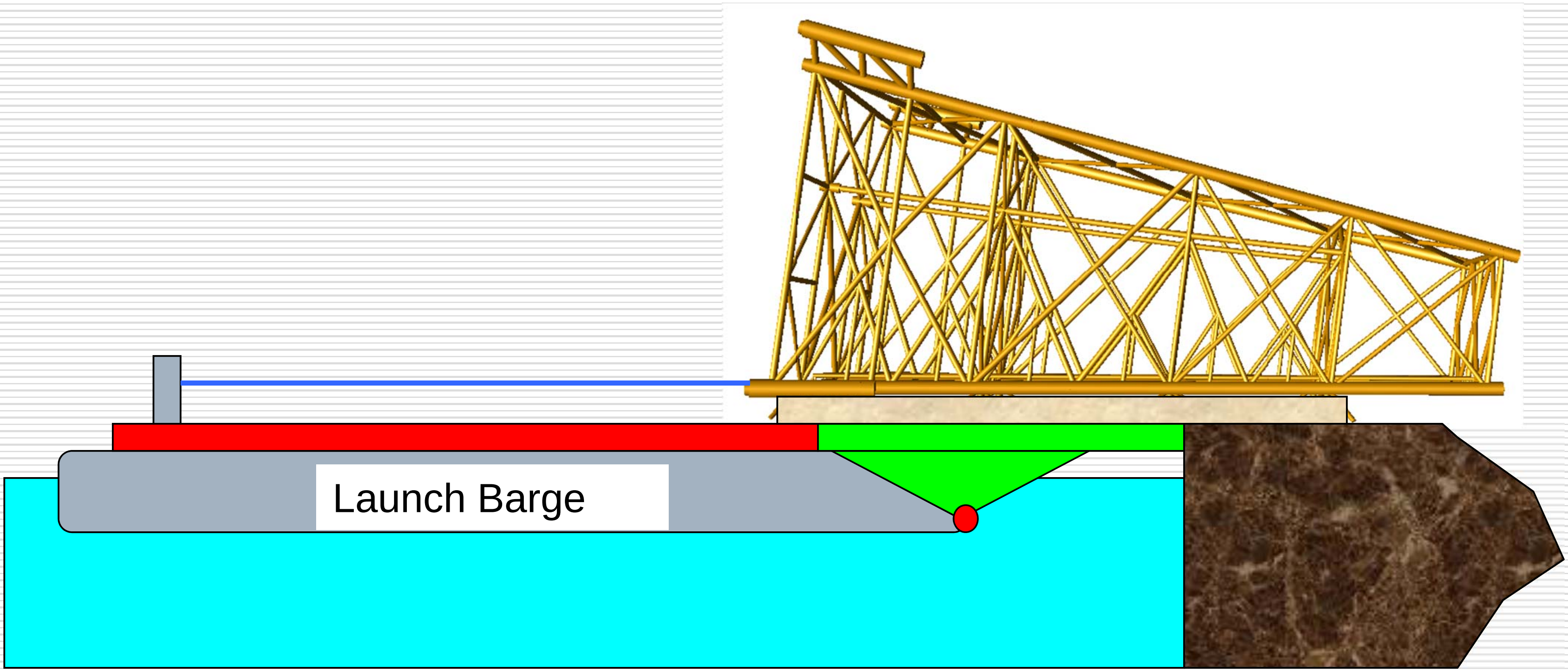
LOADOUT OF LAUNCH JACKET



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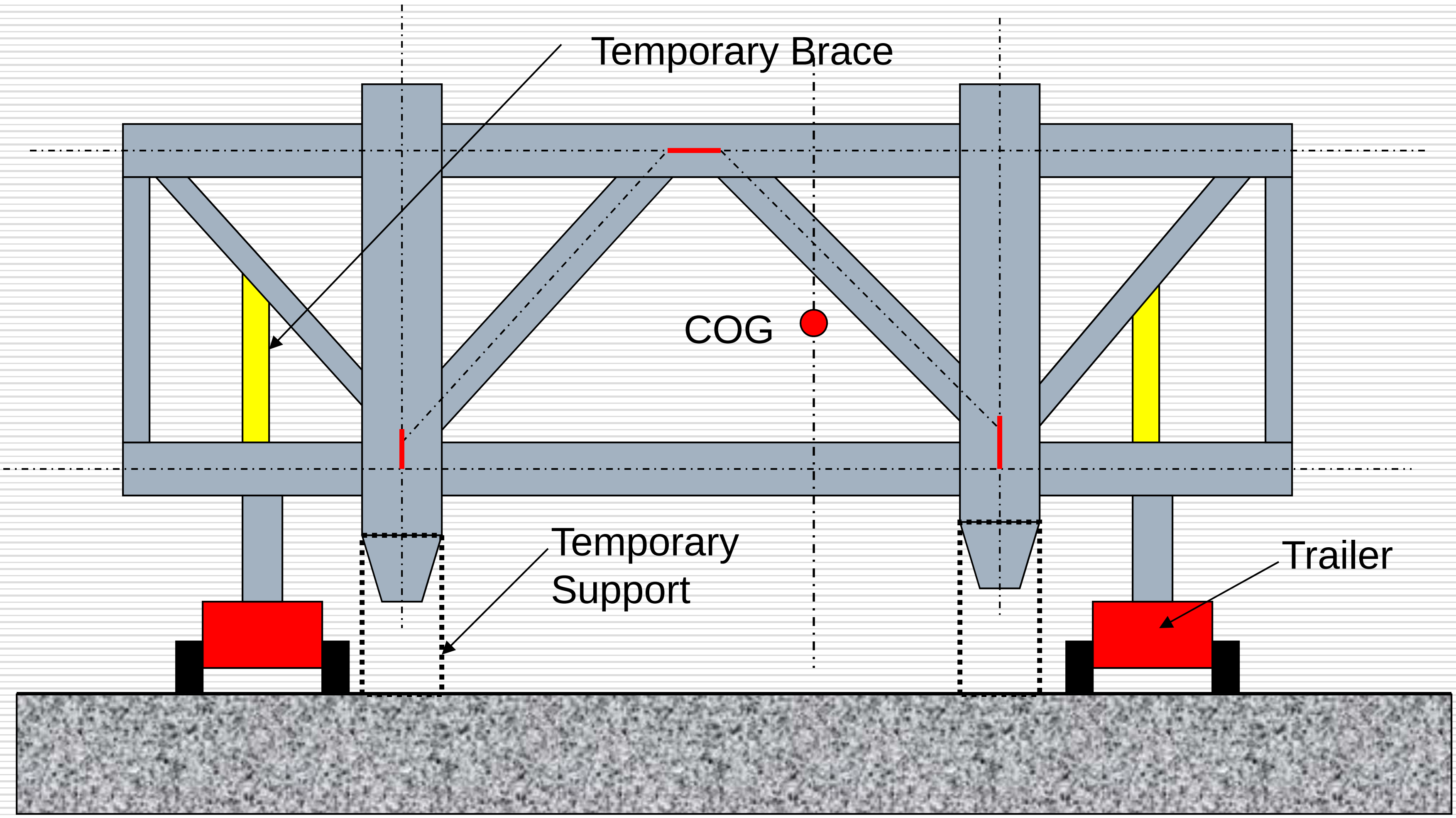
DECK TRAILER LOADOUT



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TRAILER CARRYING A DECK MODULE

Trailer

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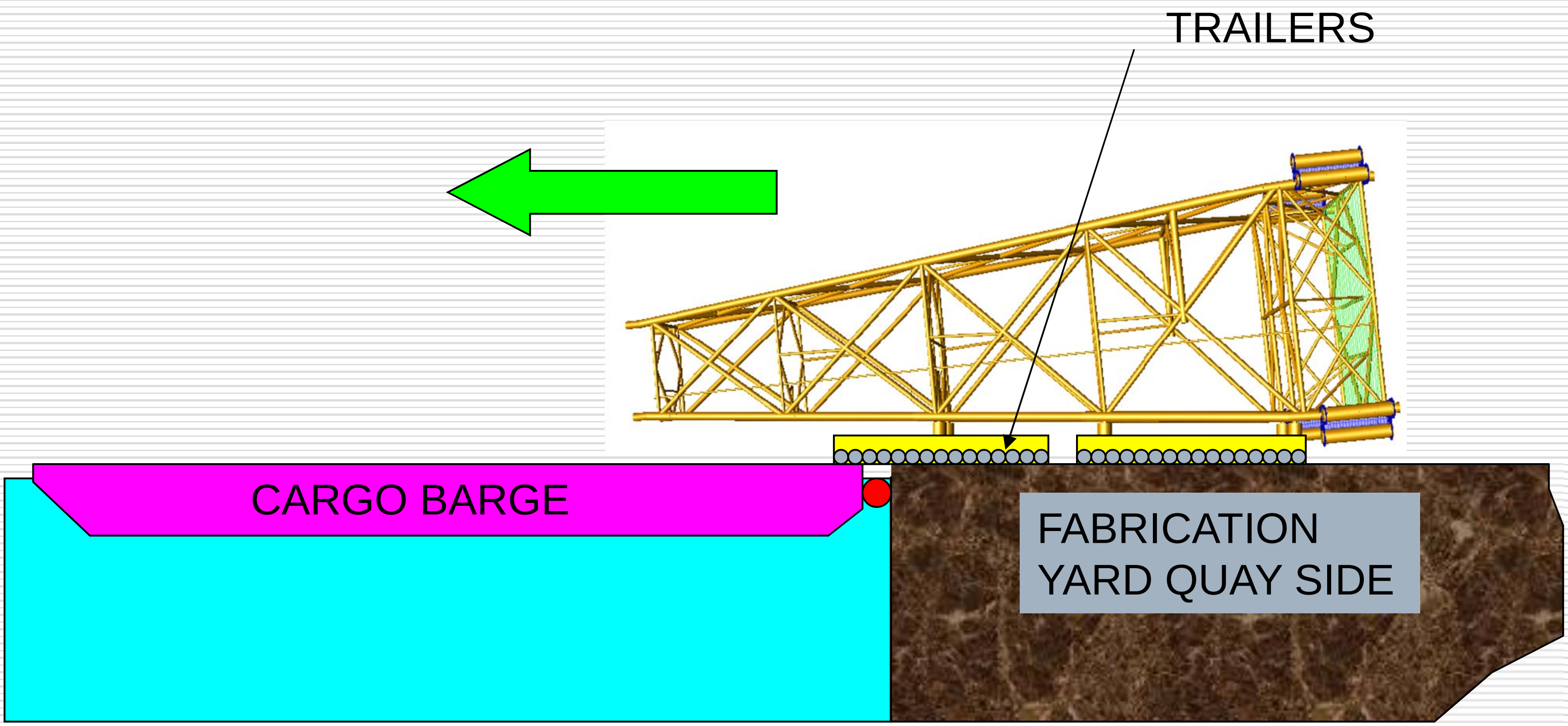
JACKET TRAILER LOADOUT



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TRANSPORTATION

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TRANSPORTATION METHODS

- **DRY TOW** – The transportation method adopted for most offshore structures are using dump barges and tugs are normally used for towing. Usually tugs will move at a speed of around 6 knots (Approx 3 m/sec).

- **WET TOW** – For faster transportation, self propelled vessels can be used such as conventional ship shape vessels and semi-submersible type carriers. Usually used for trans-continental tow. The speeds can reach as much as 10 to 12 knots. Reduce transportation time by half thus reducing the risk along the route.

- **SELF TOW** – Large jackets, gravity platform structures, spare type structures some times self towed to the site using tugs. Special care needs to taken for such transportation arrangements.

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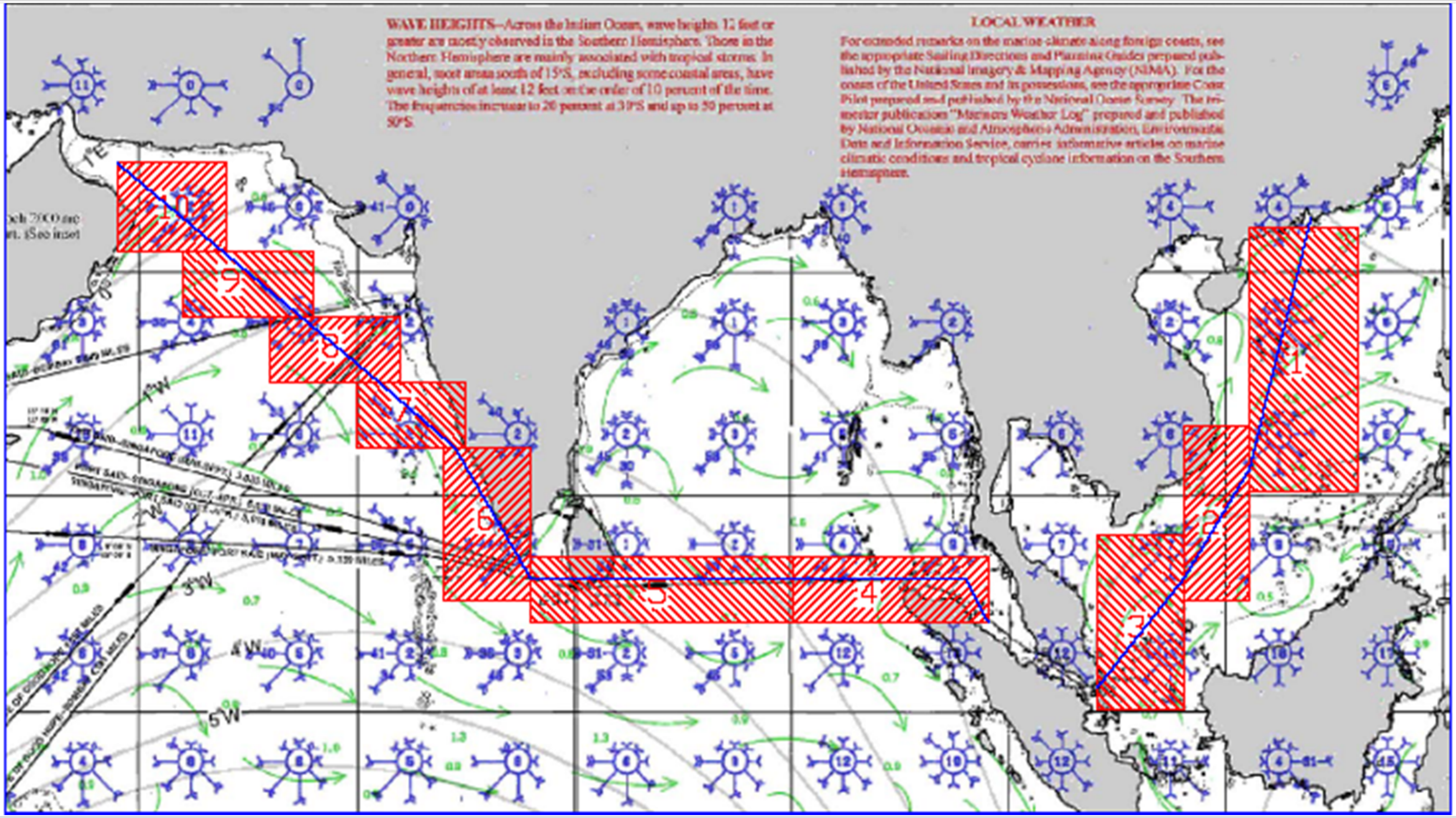
TYPICAL TRANSPORTATION ROUTE



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JACKET READY FOR TOW

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DECKS BEING TOWED

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LIFTING

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LIFT METHODS

- **SINGLE CRANE** – Generally single crane lift is adopted for all cases depending on the capacity. Examples of this type of lift is jacket or deck lift in offshore. Most of the vessels in asian region fitted with cranes in the range of 1000 Tonnes to 3500 Tonnes.
- **DUAL CRANE** – For larger jackets, some times dual crane lift is used. Typically Heerama vessel is fitted with dual cranes and can be used for lifts as much as 16,000 Tonnes.
- **MULTIPLE CRANES** – Multiple crane lifts are notmally not used in offshore operation due to problem associated with control and is used in jacket upending in the yard. Some time also used for upending jacket panels and lifting deck panels.

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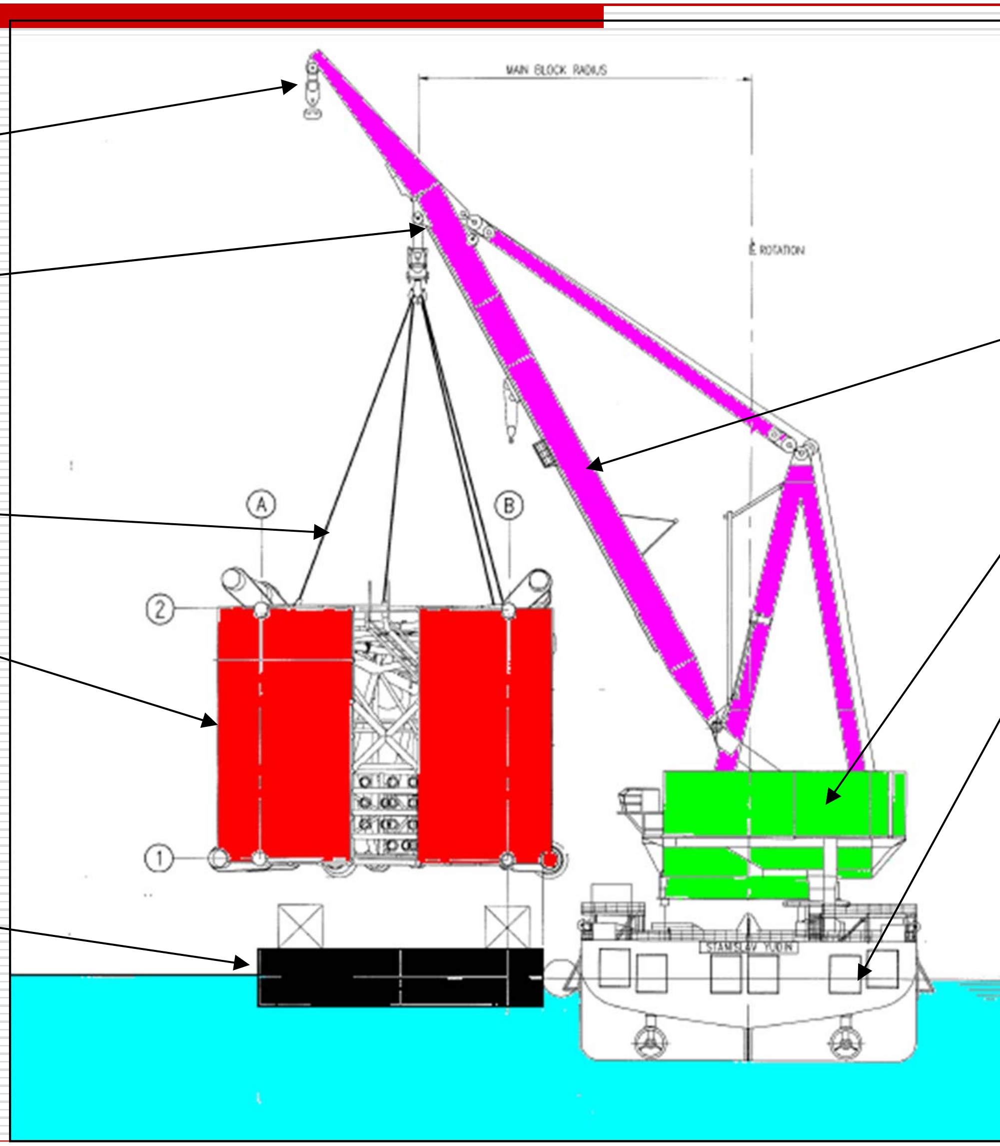

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JACKET LIFTED OFF THE BARGE

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DECK LIFTED OFF THE BARGE

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Engineering for Oil and Gas Exploration

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Engineering for Oil and Gas Exploration

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LAUNCHING

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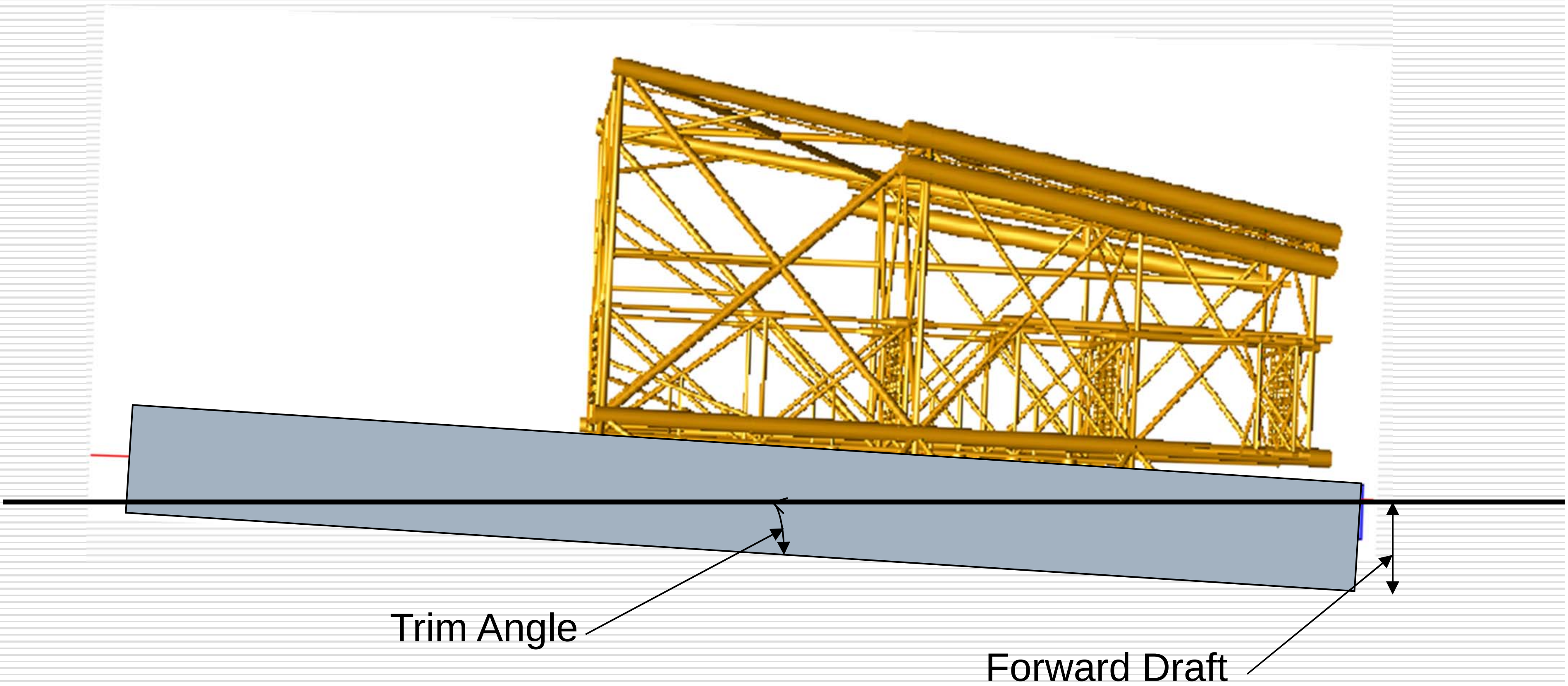
BARGE TRIM



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LAUNCH DURATION

- After cutting the sea-fastening, jacket will move forward towards the rocker arm.
- If the jacket does not move, artificial push using strand jack or winch shall be applied to overcome the initial static friction.
- Once the jacket starts to move, generally the launch duration shall not take more than 2 to 3 minutes

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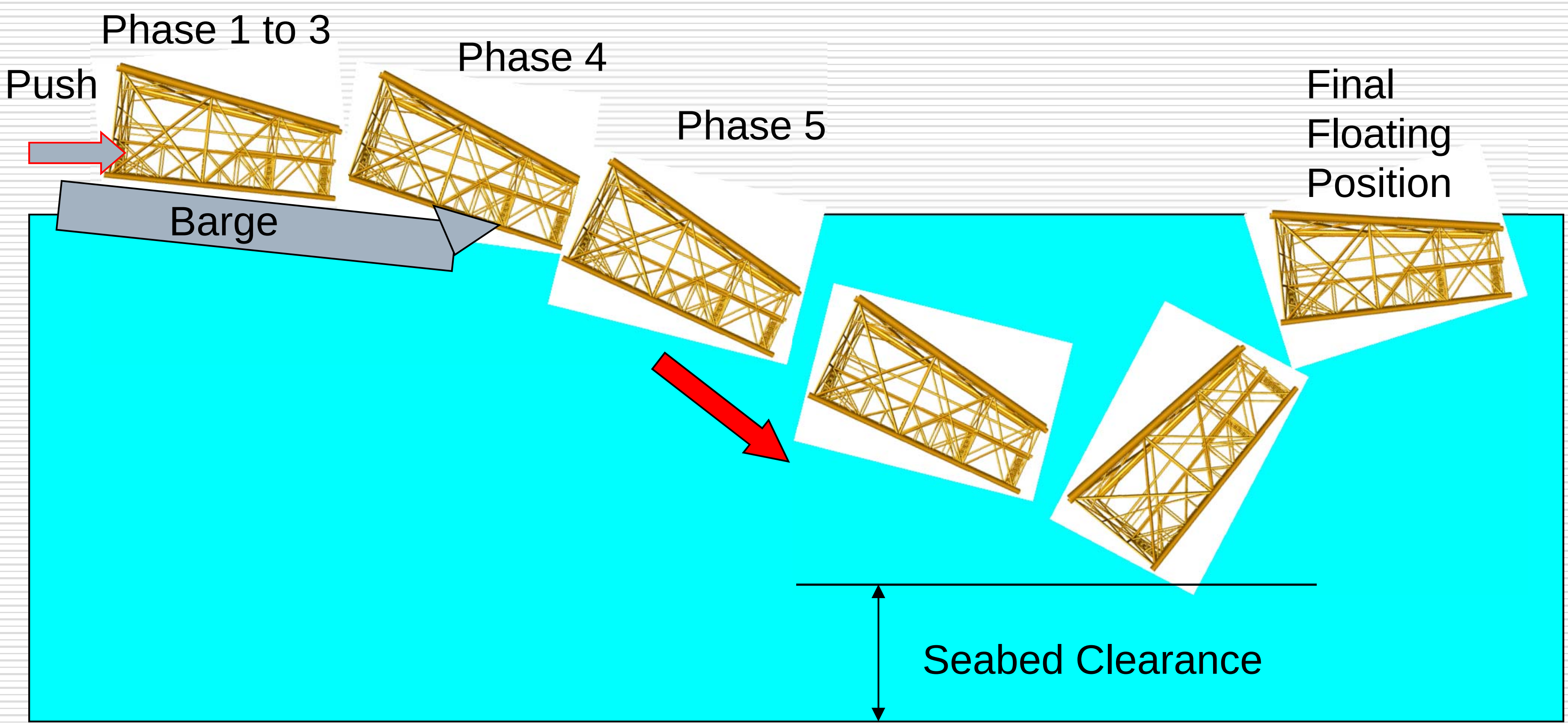
JACKET LAUNCH TRAJECTORY



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Design for Pre-Service Loads (A jacket After Launch)

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