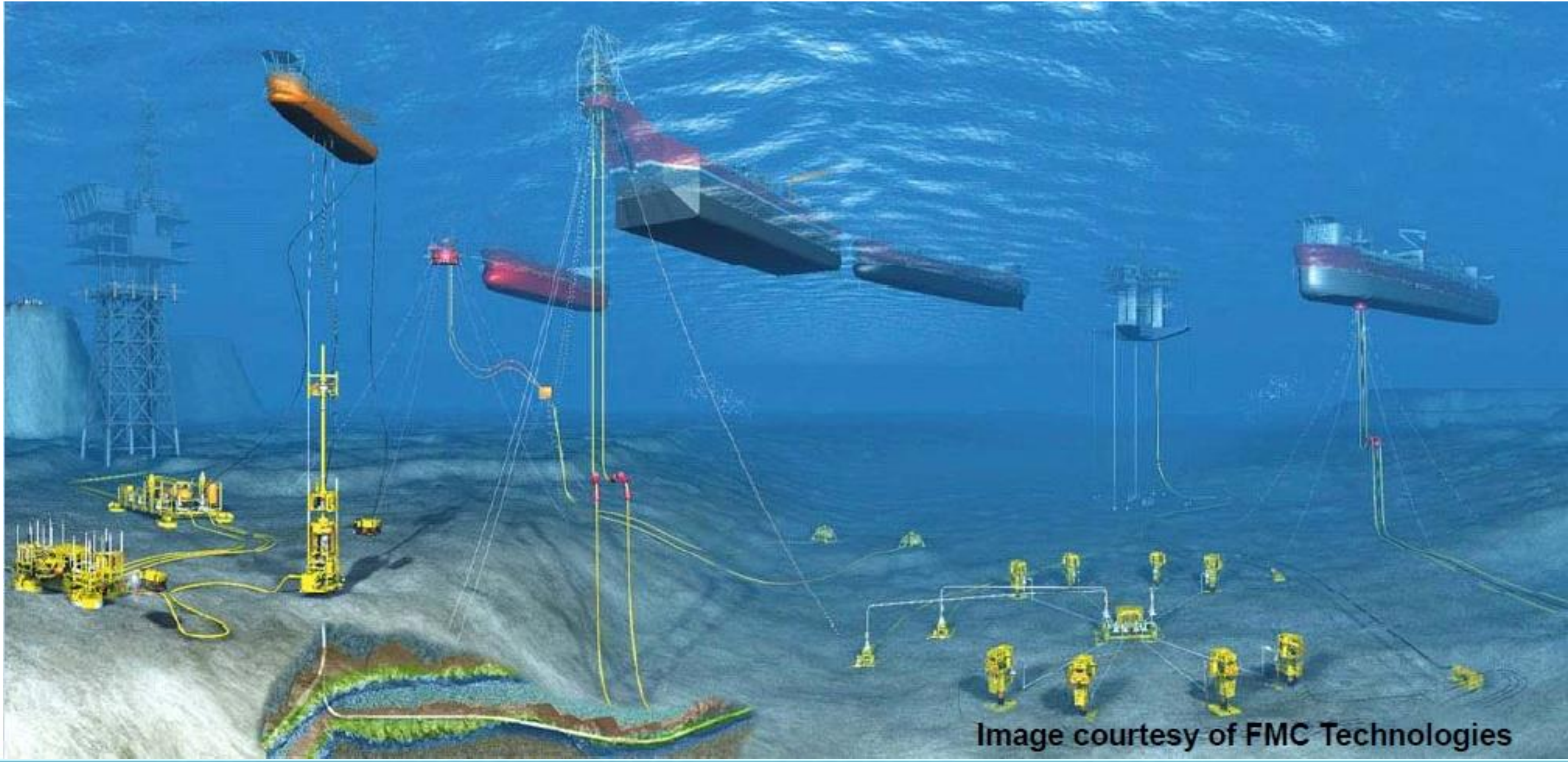



# Introduction to Offshore Platform Engineering

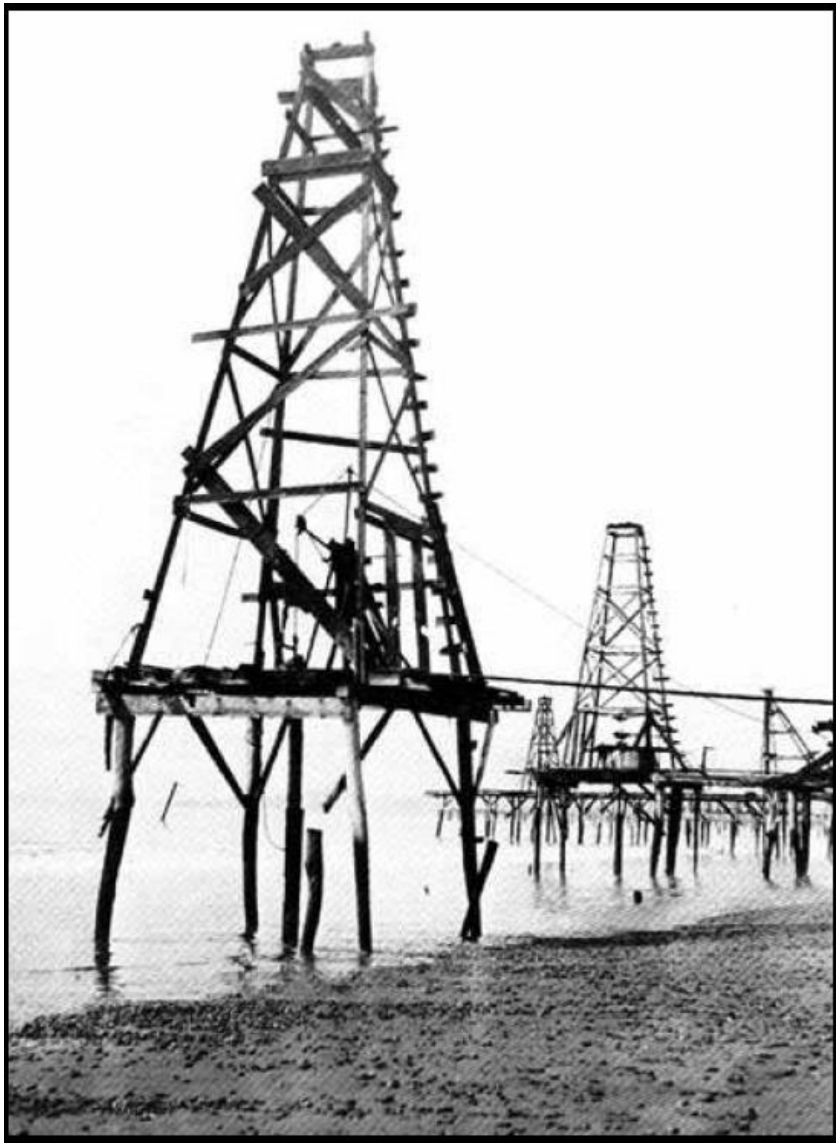
Yutaek Seo

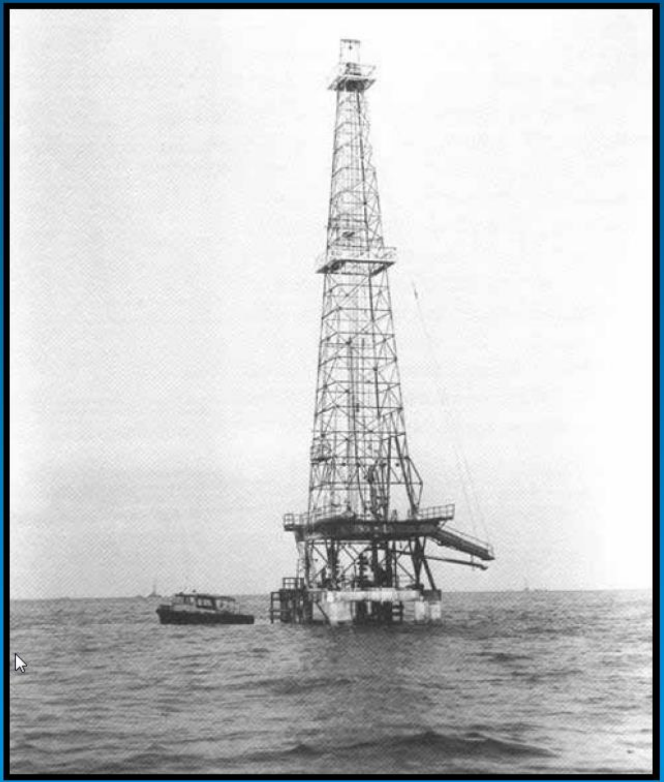
# Early Days of Offshore Engineering

Huntington Beach, California

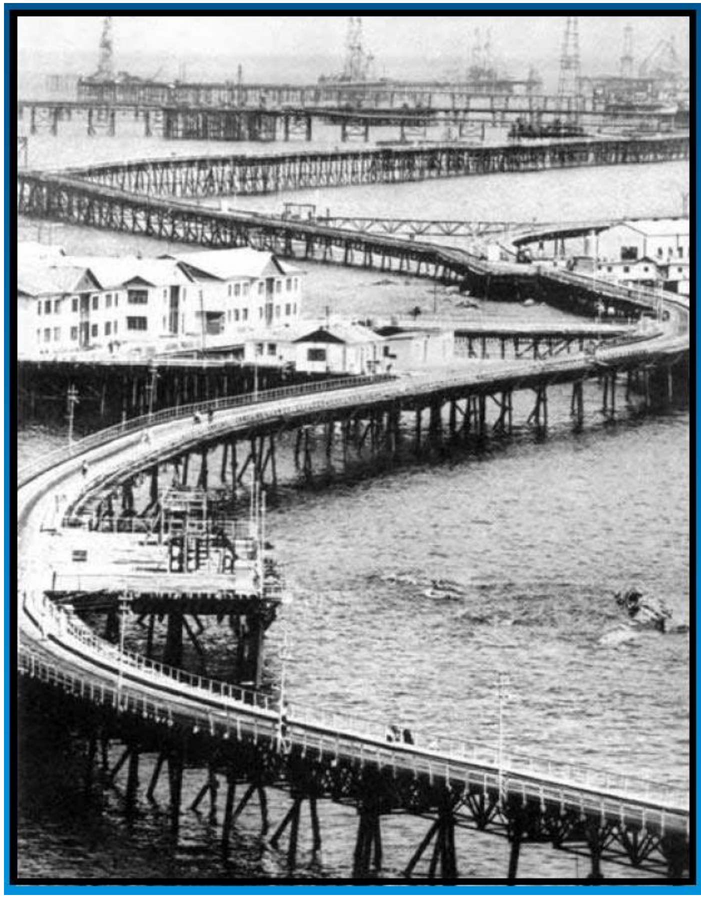
Summerland, California

# Production Platform in Summerland



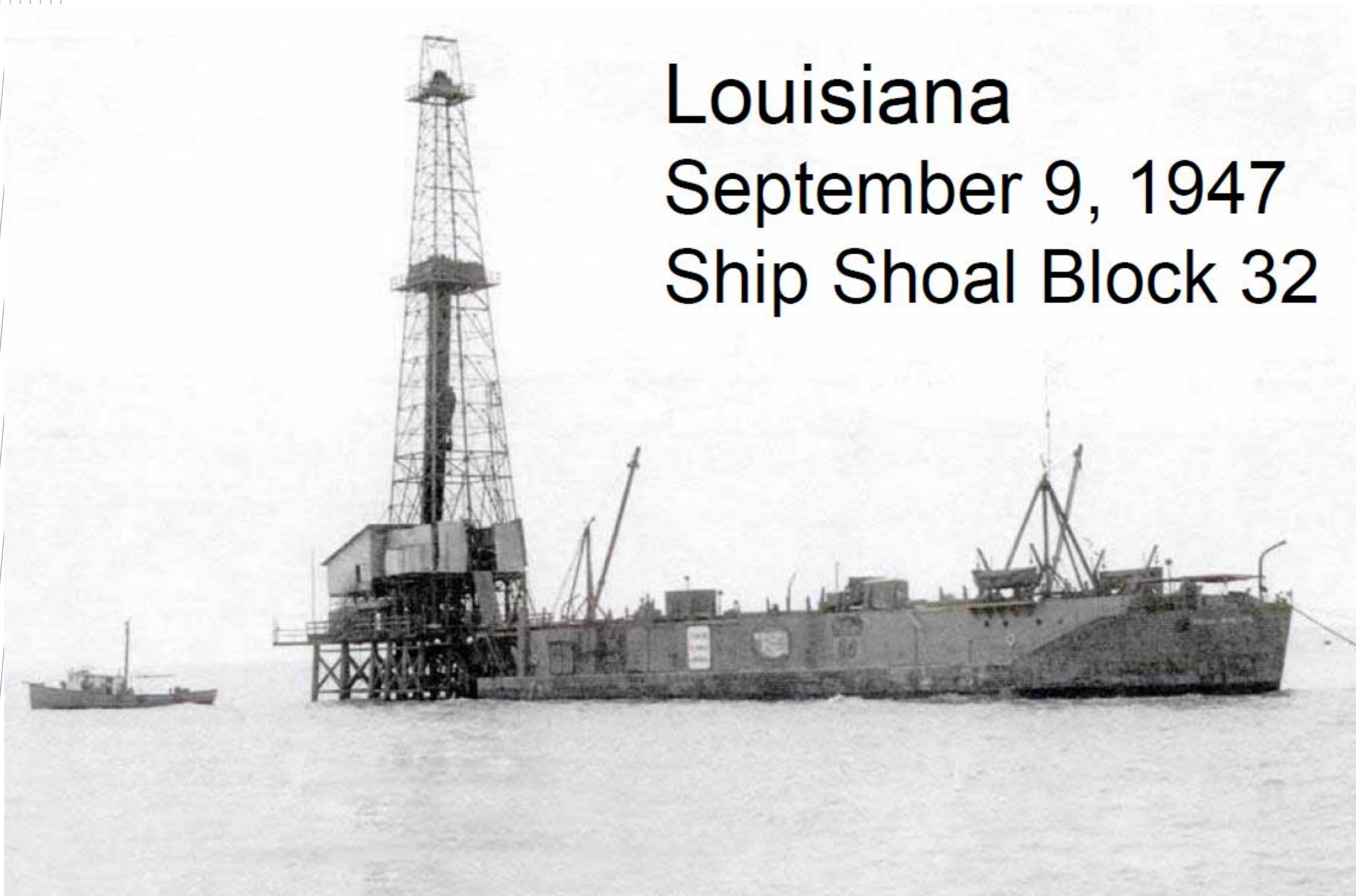


Lake Maracaibo, Venezuela



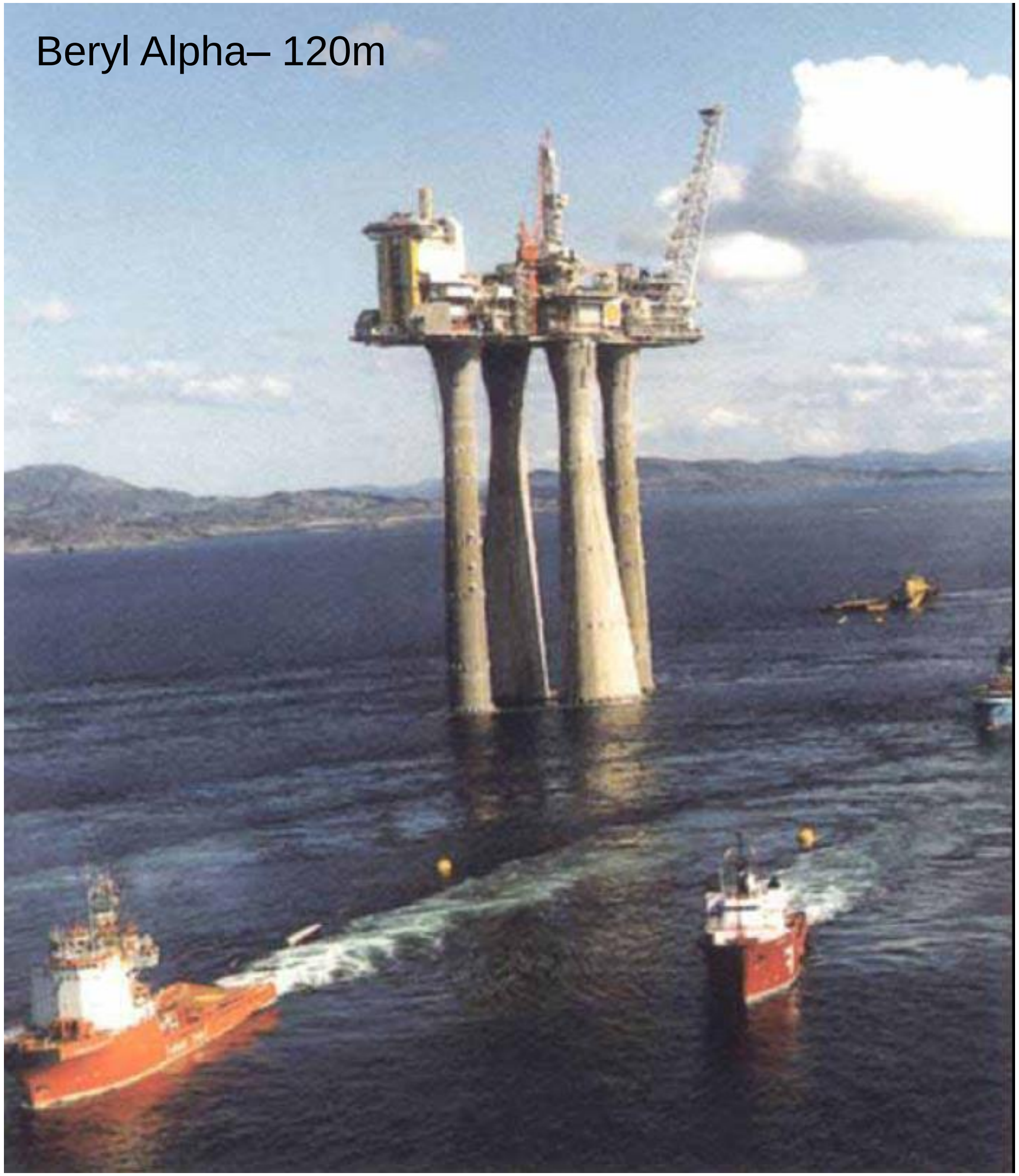
Caspian Sea
Soviet Era
Up To 100 KM Offshore

# When did the Offshore Industry begin ?



# Fixed Platform – using pile foundation

# GBS – Concrete base



# Fixed Platform for Deepwater

# Safety and Environment

## Piper Alpha

- On 06 July 1988, work began on one of two condensate-injection pumps, designated A and B, which were used to compress gas on the platform prior to transport of the gas to Flotta.  A pressure safety valve was removed from compressor A for recalibration and re-certification and two blind flanges were fitted onto the open pipe work. The dayshift crew then finished for the day.

- During the evening of 06 July, pump B tripped and the nightshift crew decided that pump A should be brought back into service. When the pump was operational, gas condensate leaked from the two blind flanges and, at around 2200 hours, the gas ignited and exploded, causing fires and damage to other areas with the further release of gas and oil. Some twenty minutes later, the Tartan gas riser failed and a second major explosion occurred followed by widespread fire. Fifty minutes later, at around 2250 hours, the MCP-01 gas riser failed resulting in a third major explosion. Further explosions then ensued, followed by the eventual structural collapse of a significant proportion of the installation.
- **167 men died on the platform.  59 men survived – most of them badly burned.**

## Thunder hose

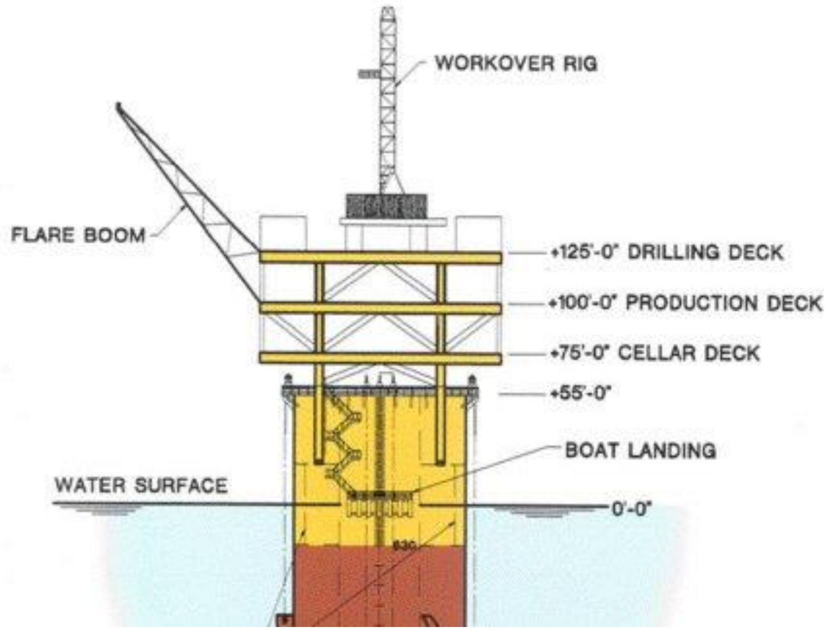
- *Thunder Horse* was evacuated with the approach of Hurricane Dennis in July 2005. After the hurricane passed, the platform fell into a 20 degree list and was in danger of foundering.

BP Thunder Horse Platform

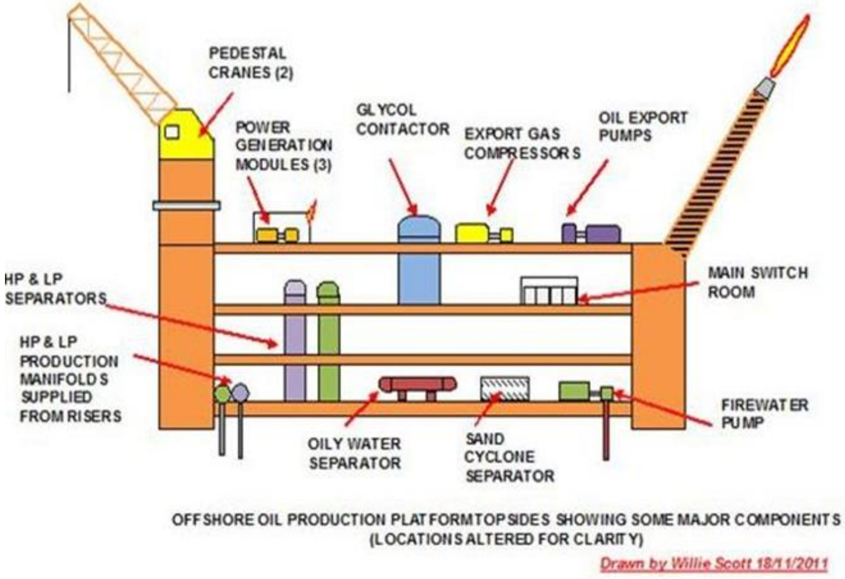
- The platform was designed for a 100-year event, and inspection teams found no hull damage and no leaks through its hull. Rather, an incorrectly plumbed 6-inch length of pipe allowed water to flow freely among several ballast tanks that set forth a chain of events causing the platform to tip into the water.
- The platform was fully righted about a week after *Dennis*, delaying commercial production initially scheduled for late 2005. During repairs, it was discovered that the underwater manifold was severely cracked due to poorly welded pipes. An engineering consultant said that the cracked manifold could have caused a catastrophic oil spill.
- The platform took a nearly-direct hit six weeks later from Hurricane Katrina, but was undamaged.

# Topside deck: SPAR, Semi-Submergible

- Drilling deck on top of the SPAR, where drilling facilities, living quarter, and chemicals storage exist.
- Production deck below the drilling deck, where oil and gas processing facilities, power generation, and utilities exist.
- Cellar deck accommodates cooling water system, piping, and manifolds.




http://www.globalsecurity.org/military/systems/ship/images/spars-image2.jpg



# 해양플랫폼의 분류

- Fixed

  : Supporting structures made of concrete or carbon steel are fixed on the seabed and supported the weight of the deck and other facilities.

  - Jacket Platform
  - GBS(Gravity-based Structure)
  - Jack-up rig/barge

- Compliant

  : Carbon steel structure is fixed on the seabed, however the platform is affected by the wave and current. Floating structures are fixed on the seabed using steel wires.

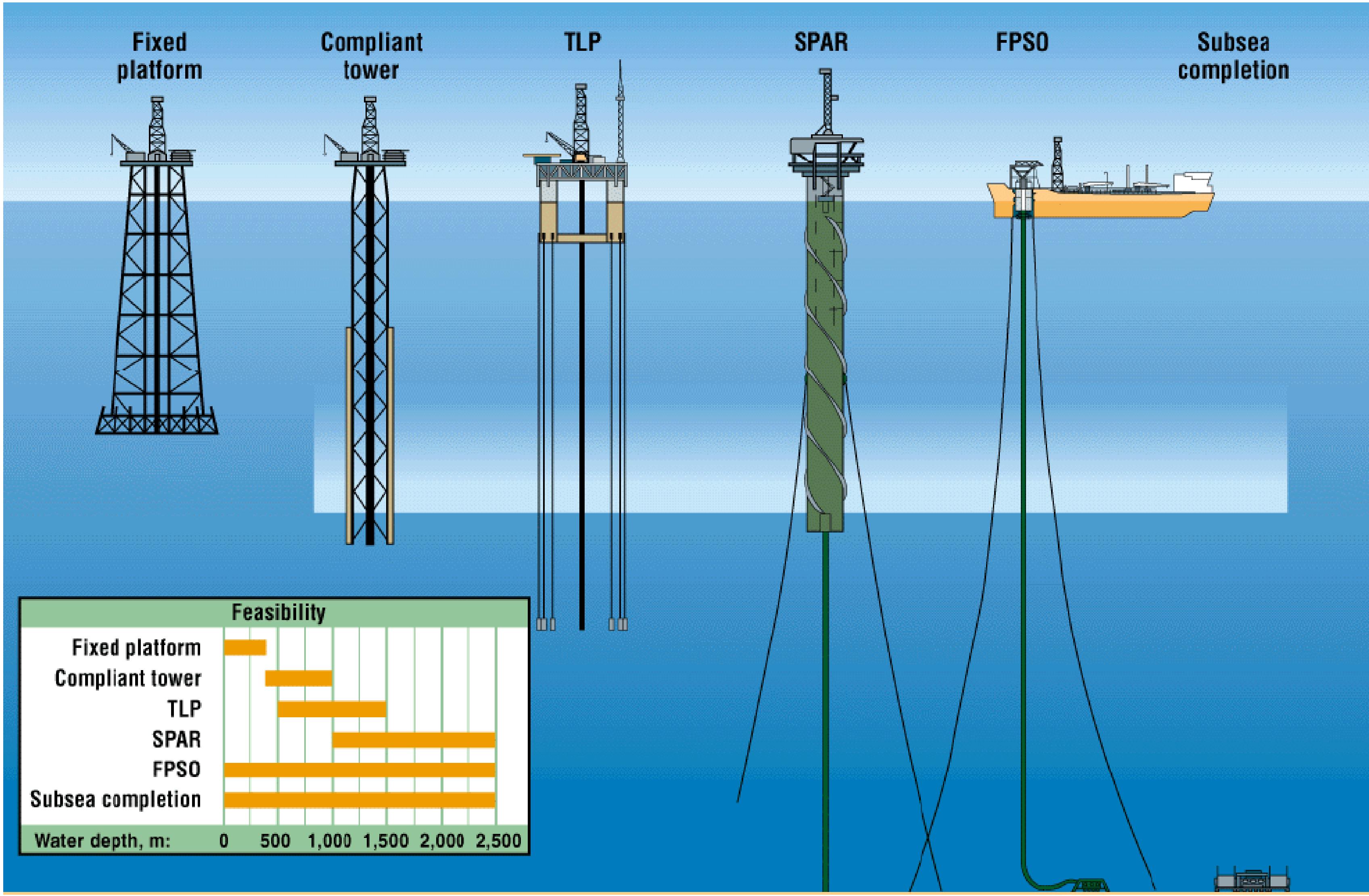
  - Compliant Tower
  - TLP (Tension Leg Platform)
  - SPAR

- Floating

  : Floating structures having production facilities on tops of it.

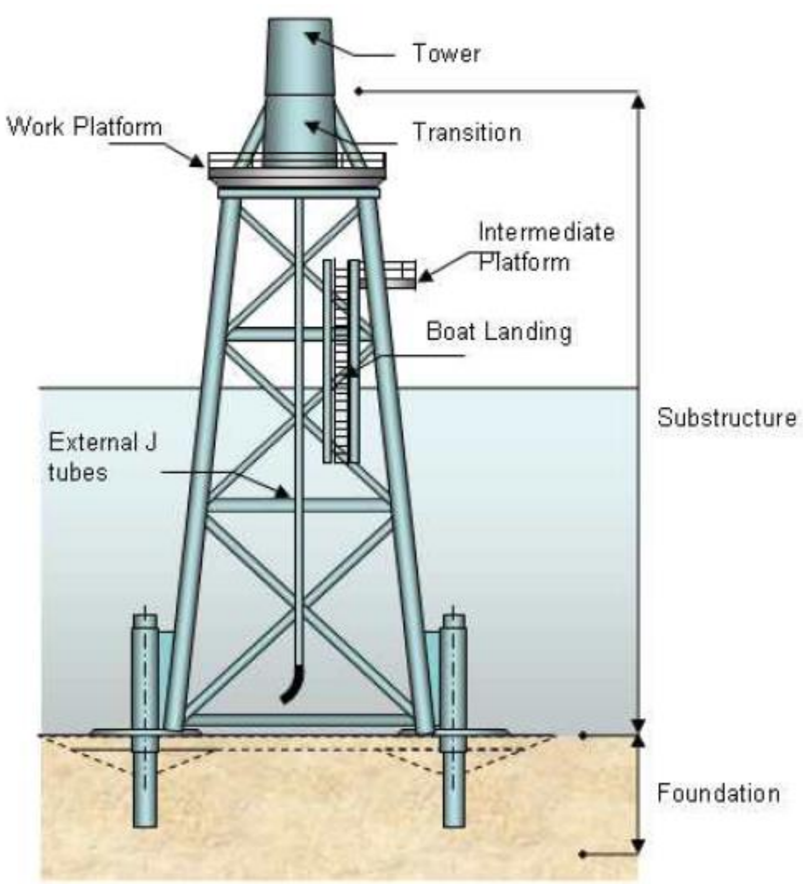
  - Semi-submersible structure
  - Ship-shaped

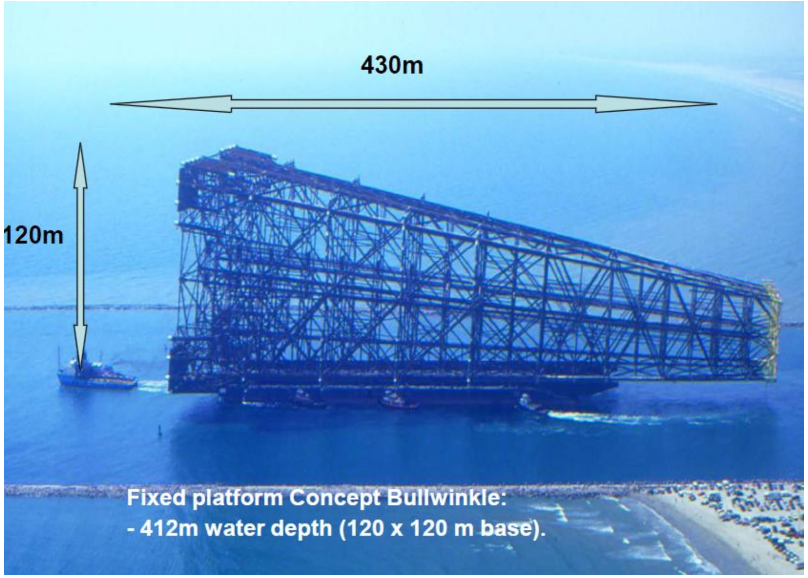
    FPSO (Floating Production Storage & Offloading)
    FSO(floating storage and offloading)
    FSRU (Floating Storage Regasification Unit)
    RV(Regasification vessel)


Fixed platform
Compliant tower
TLP
SPAR
FPSO
Subsea completion
Feasibility
Fixed platform
Compliant tower
TLP
SPAR
FPSO
Subsea completion
Water depth, m: 0 500 1,000 1,500 2,000 2,500

# Classification of host system : Fixed type

- Fixed jacket structure
  : water depth up to 520m

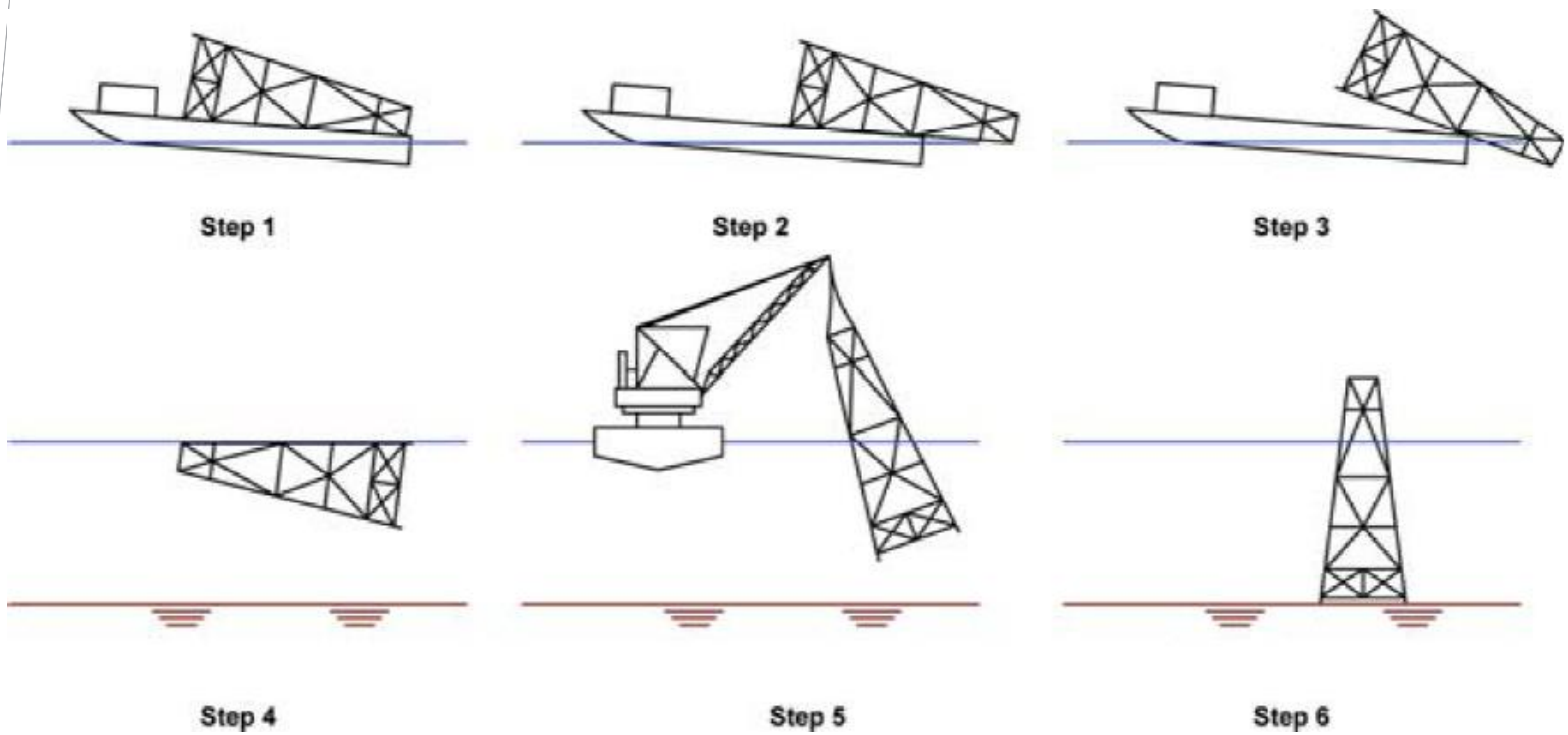



# Transportation

- Mostly constructed on shore, then moved to the installation point using barges.
- Big jackets used its cylindrical pipes as buoyancy tanks until they were towed to the installation point.


# Installation



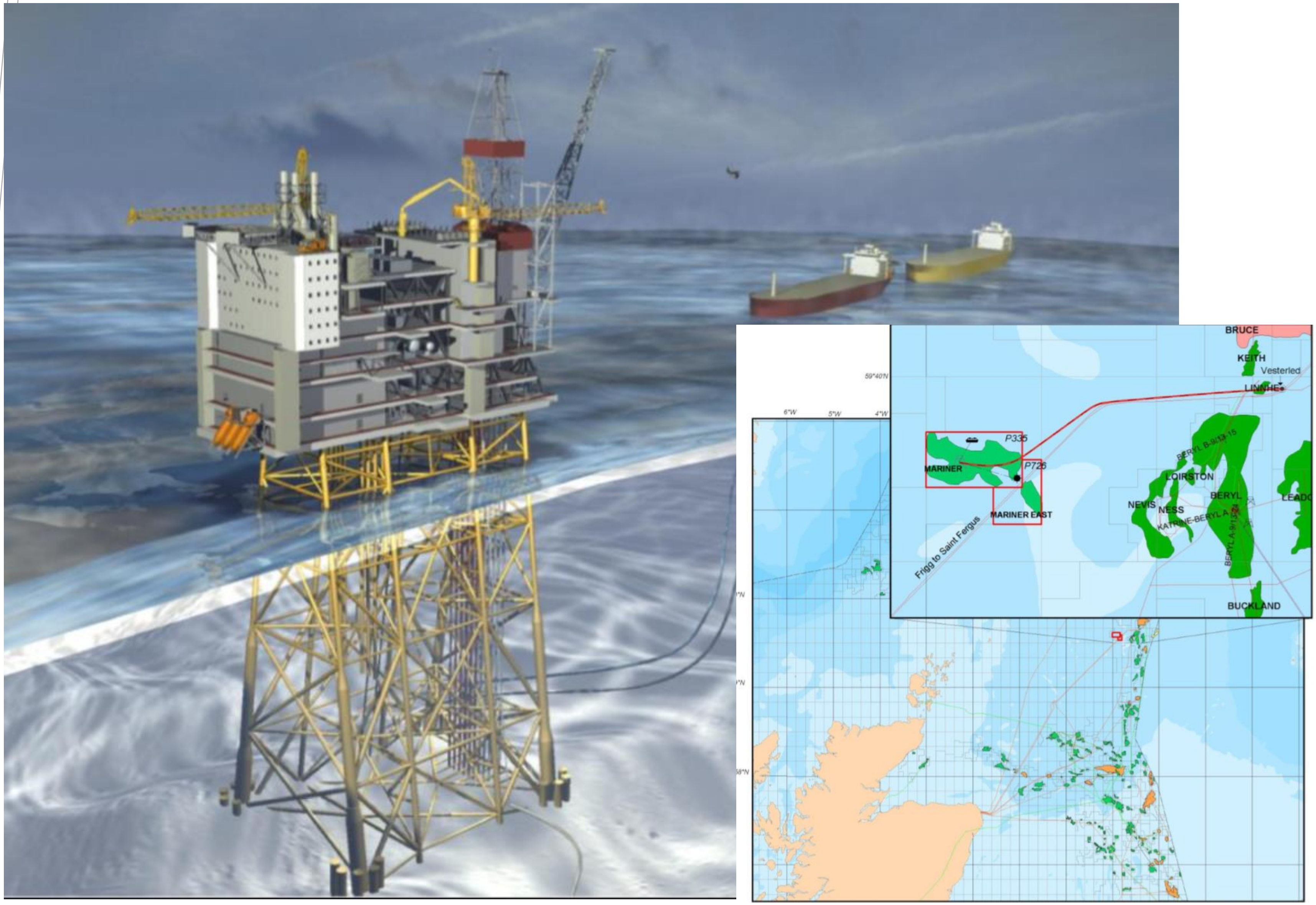
# Deck and production modules

- Topsides are manufactured onshore and transported to the platform using barges, then lifted using the offshore crane and welded.
- Analysis for crane dynamics크레인의 거동을 고려한 해석 필요

  : Numerical analysis for cranes to confirm the weight of all modules must be less than the operation weight of the crane.

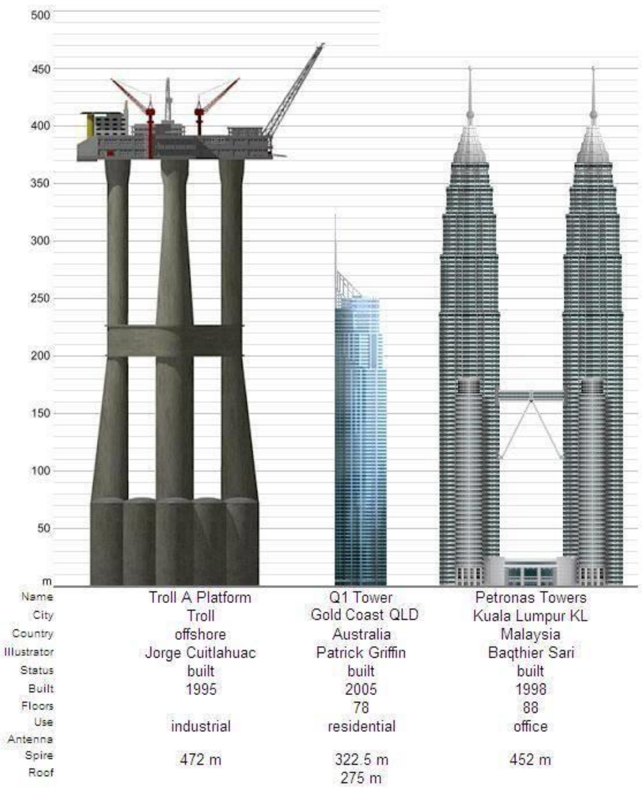
  : No damage to modules during lifting.

# Example: Mariner platform



# GBS (Gravity-based Structure)

- A **gravity-based structure** (GBS) is a support structure held in place by gravity. A common application for a GBS is an offshore oil platform.
- A GBS intended for use as an offshore oil platform is constructed of steel reinforced concrete, often with tanks or cells which can be used to control the buoyancy of the finished GBS.
- When completed, a GBS is towed to its intended location and sunk. Prior to deployment, a study of the seabed have to be done in order to ensure it can withstand the vertical load exerted on it by that structure.




http://www.industrytap.com/see-the-largest-and-tallest-object-ever-moved-its-taller-than-the-empire-state-building/1877

Troll A platform (Troll oil field, 1955): Water depth 300m (Total length 470m)

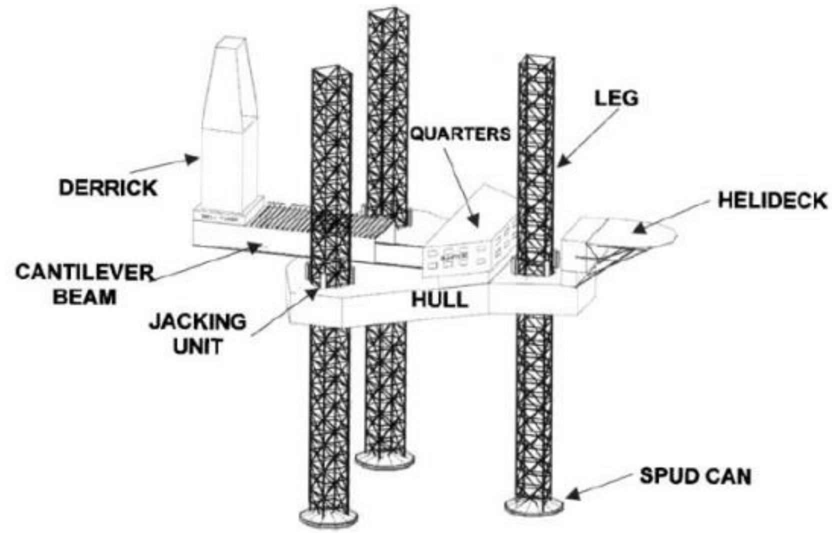
- Concrete gravity platform


# Split concept (Bridge connected platform)

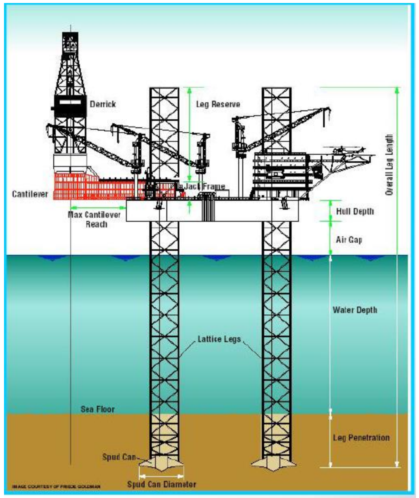
- Gravity base platform with production and small jacket platform

# 잭업 (Jack-up rig/barge)

- A **jackup rig** or a self-elevating unit is a type of mobile platform that consists of a buoyant hull fitted with a number of movable legs, capable of raising its hull over the surface of the sea.
- The buoyant hull enables transportation of the unit and all attached machinery to a desired location.
- Once on location the hull is raised to the required elevation above the sea surface supported by the sea bed. The legs of such units may be designed to penetrate the sea bed, may be fitted with enlarged sections or footings, or may be attached to a bottom mat.
- Generally jackup rigs are not self-propelled and rely on tugs or heavy lift ships for transportation.
- Usually for water depth of 90~120m, max. 150 m

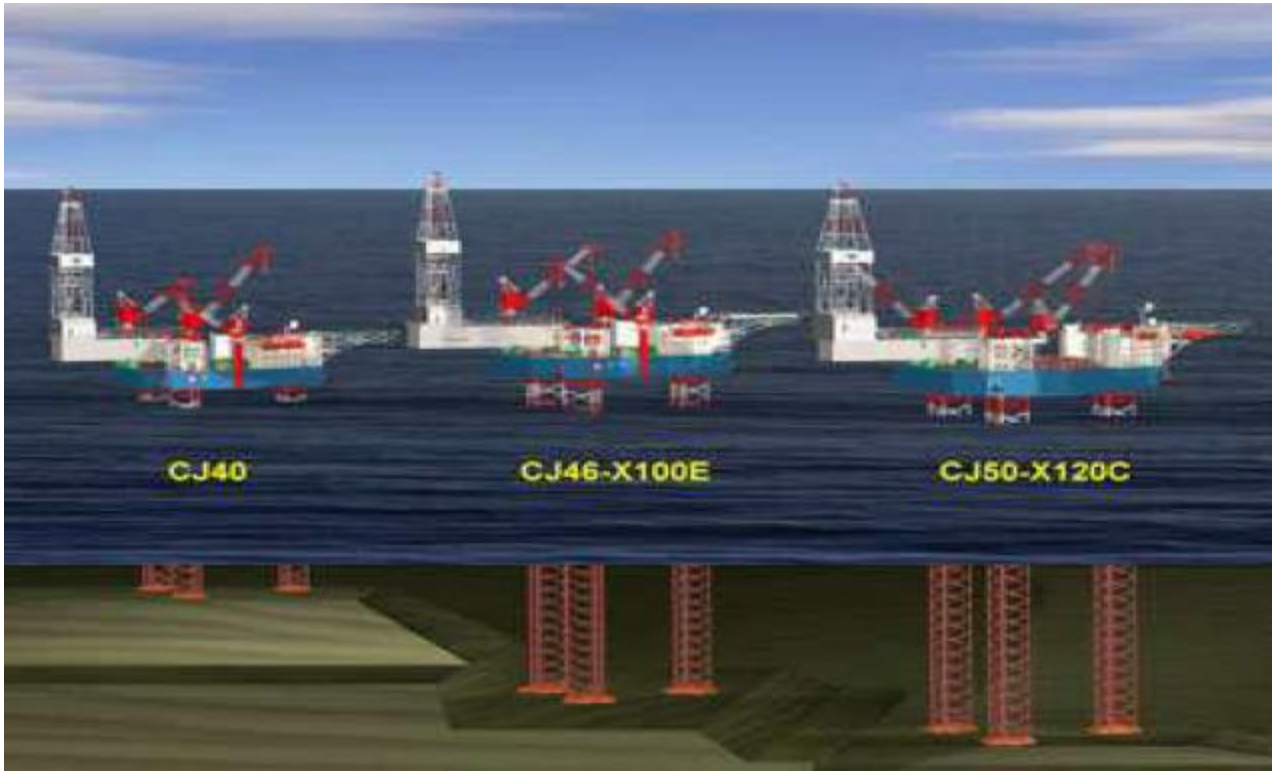


Chakrabarti, Handbook of offshore engineering, 2005



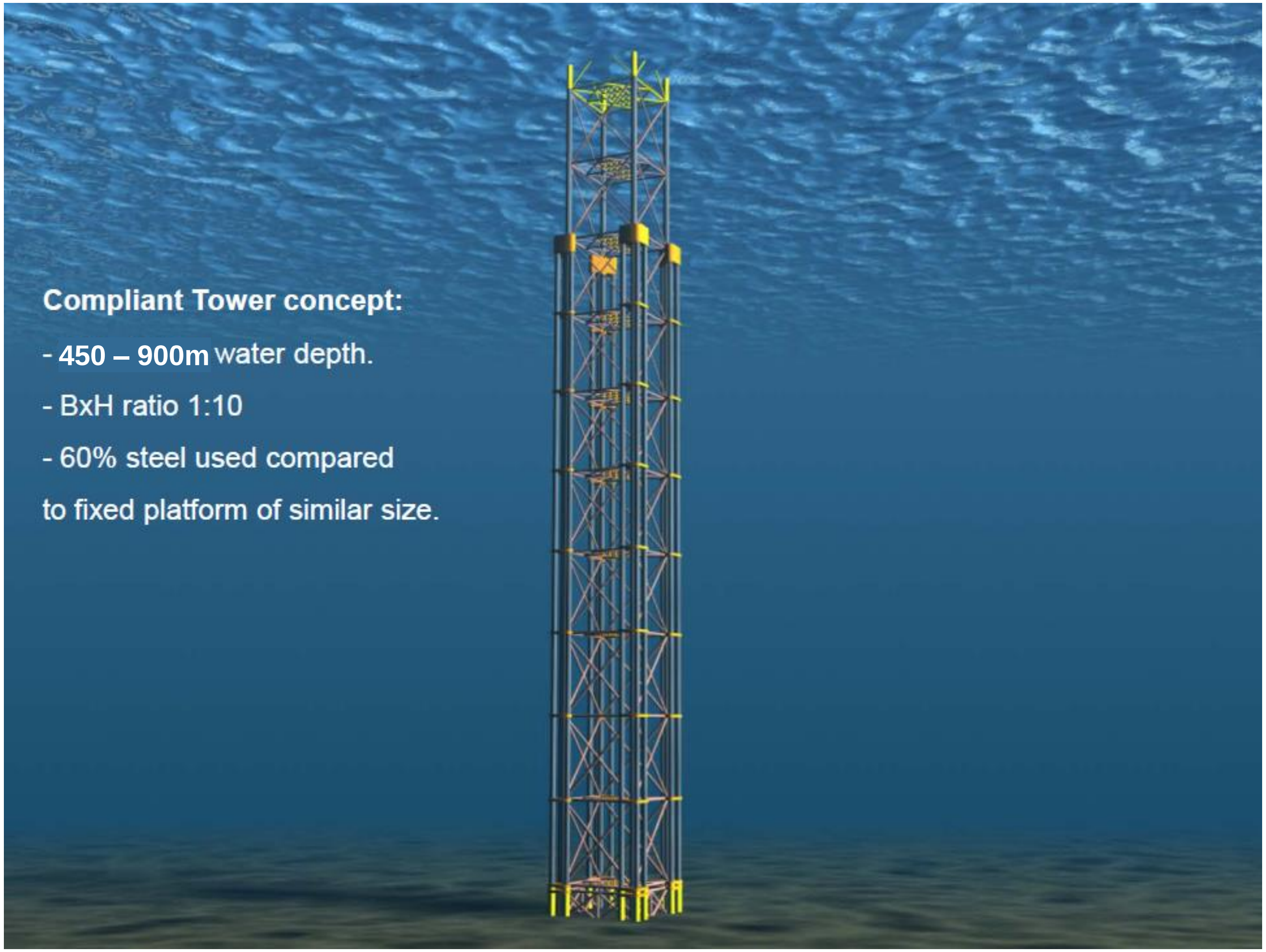
- Jack-up platform

: platforms that can be jacked up above the sea using legs that can be lowered (water depth up to 170m)



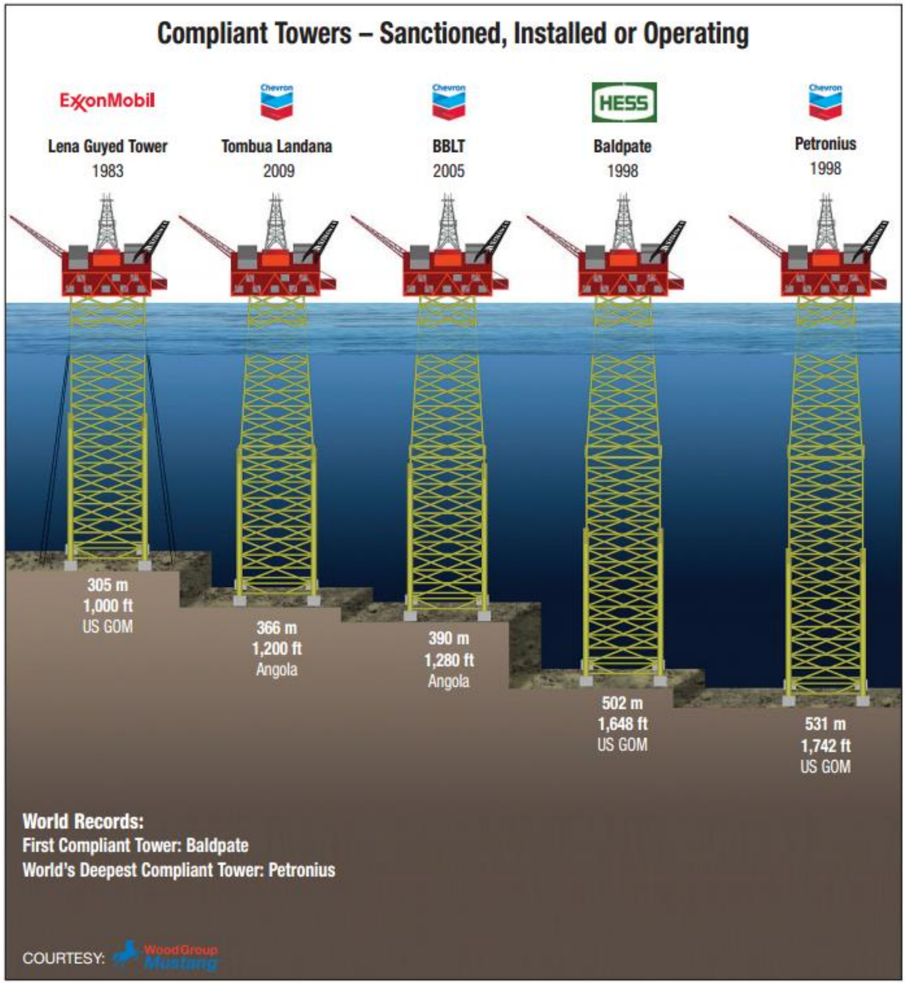
# Classification of host system
# : Compliant type

- Compliant tower



# CT (Compliant Tower: 유연탑)

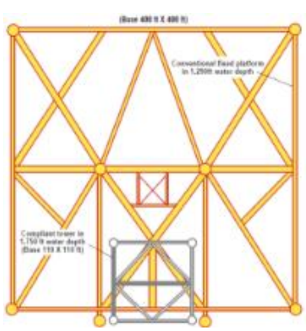
- A **compliant tower** (CT) is a fixed rig structure normally used for the offshore production of oil or gas.
- The rig consists of narrow, flexible (*compliant*) towers and a piled foundation supporting a conventional deck for drilling and production operations.
- Compliant towers are designed to sustain significant lateral deflections and forces, and are typically used in water depths ranging from 1,500 to 3,000 feet (450 to 900 m).
- At present the deepest is the Chevron Petronius tower in waters 623m deep.

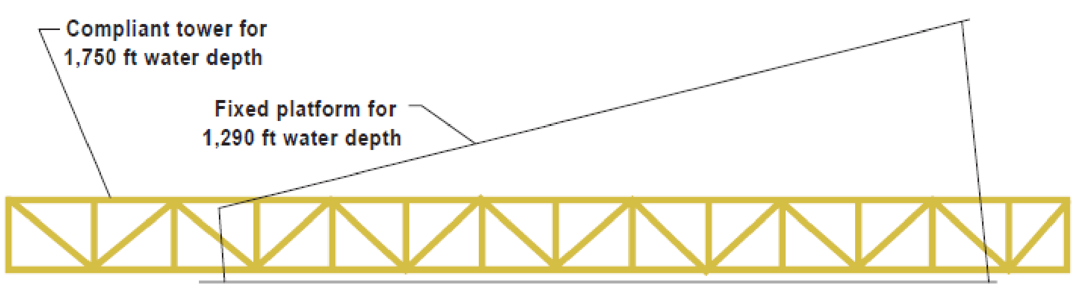



FloaTEC, 2012 Deepwater solutions & records for concept selection, 2012

Petronius platform(GOM): Water depth 535m (total length 610m)

- With the use of flex elements such as flex legs or axial tubes, resonance is reduced and wave forces are de-amplified.
- This type of rig structure can be configured to adapt to existing fabrication and installation equipment. Compared with floating systems, such as TLP and SPARs, the production risers are conventional and are subjected to less structural demands and flexing.
- However, because of cost, it becomes uneconomical to build compliant towers in depths greater than 1,000 meters. In such a case a floating production system is more appropriate, even with the increased cost of risers and mooring.
- Despite its flexibility, the compliant tower system is strong enough to withstand hurricane conditions

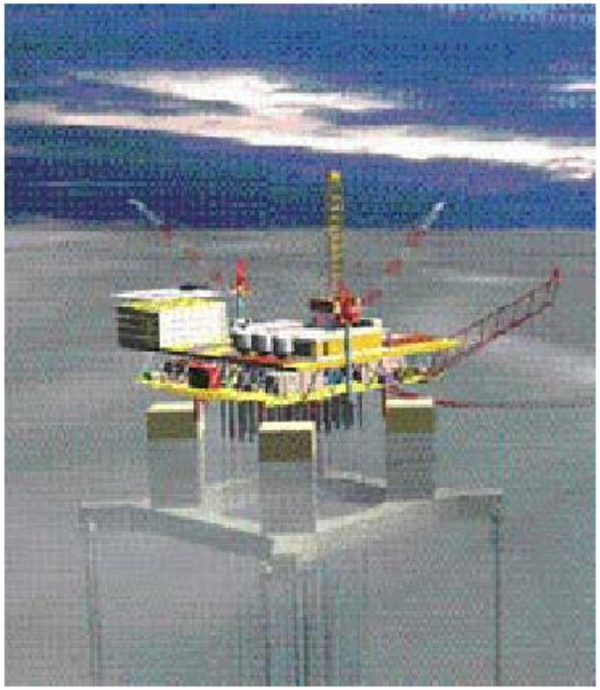




# Classification of host system
# : Compliant type – TLP

- Tension Leg Platform (TLP)
  : water depth up to 2000m

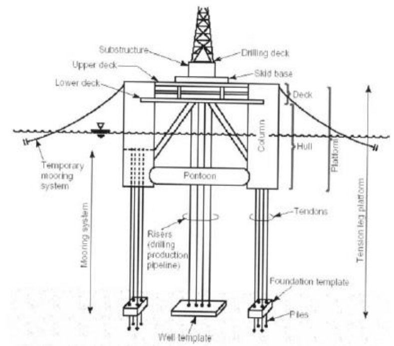

Conventional TLP

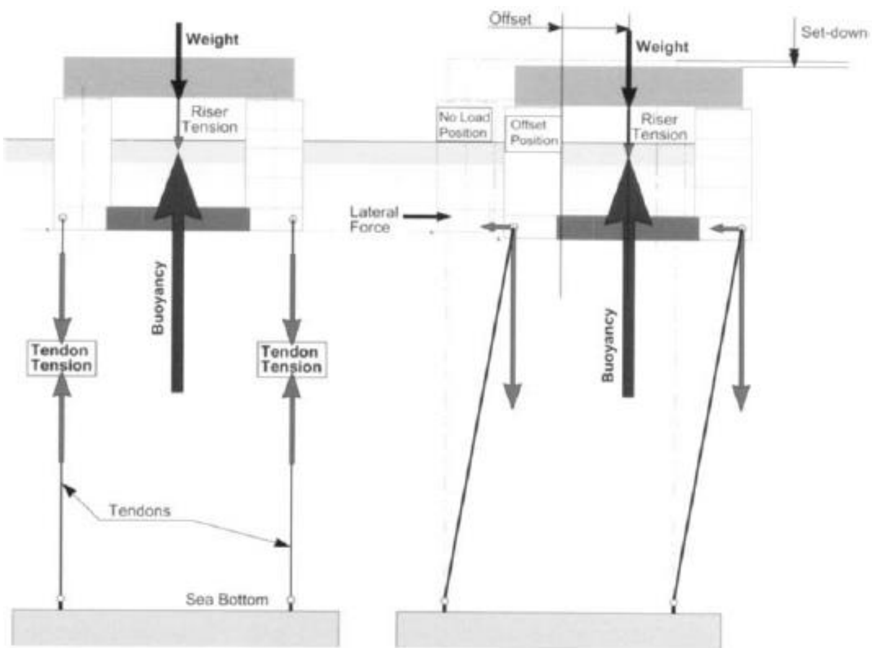

Extended TLP
'Kizomba A & B'


Single Column TLP
'Matterhorn'

# TLP (Tension Leg Platform)

- A TLP or ETLP is a vertically moored floating structure normally used for the offshore production of oil or gas, and is particularly suited for water depths greater than 300 metres (about 1000 ft) and less than 1500 metres (about 4900 ft).
- The platform is permanently moored by means of tethers or tendons grouped at each of the structure's corners.
- A group of tethers is called a tension leg. A feature of the design of the tethers is that they have relatively high axial stiffness (low elasticity), such that virtually all vertical motion of the platform is eliminated.

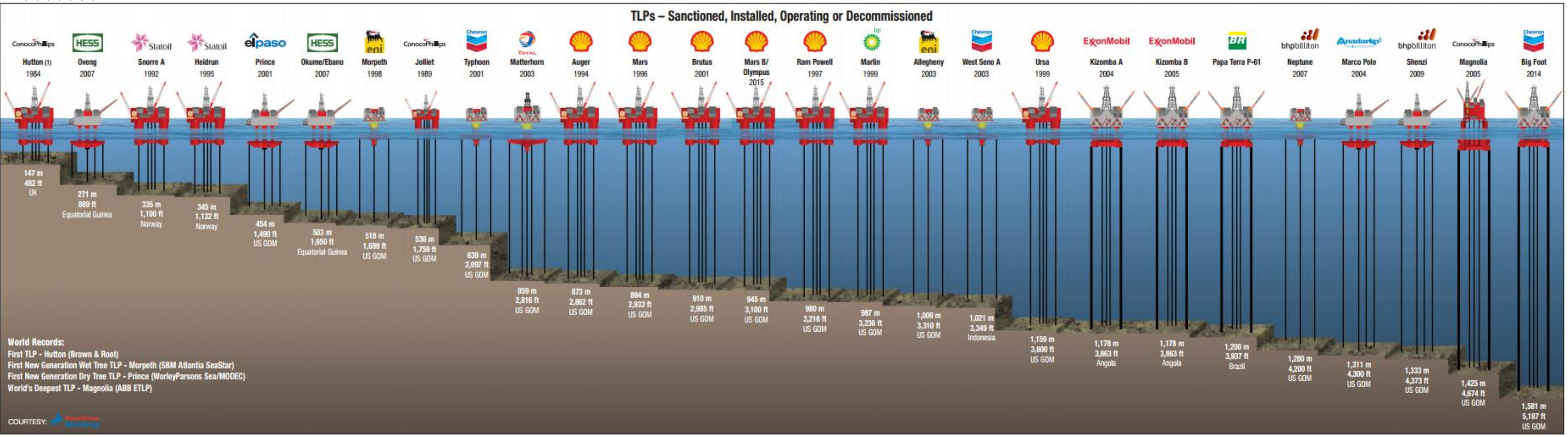



TLP structure and mooring principals (Chakrabarti, Handbook of offshore engineering, 2005)

# World TLP

- This allows the platform to have the production wellheads on deck (connected directly to the subsea wells by rigid risers), instead of on the seafloor.
- This allows a simpler well completion and gives better control over the production from the oil or gas reservoir, and easier access for downhole intervention operations




FloaTEC, 2012 Deepwater solutions & records for concept selection

# Example: Chissonga TLWP Project

# Example: Chissonga Project Schematic

TLWP : Tension Leg Wellhead Platform
FTL : Fluid Transfer Line

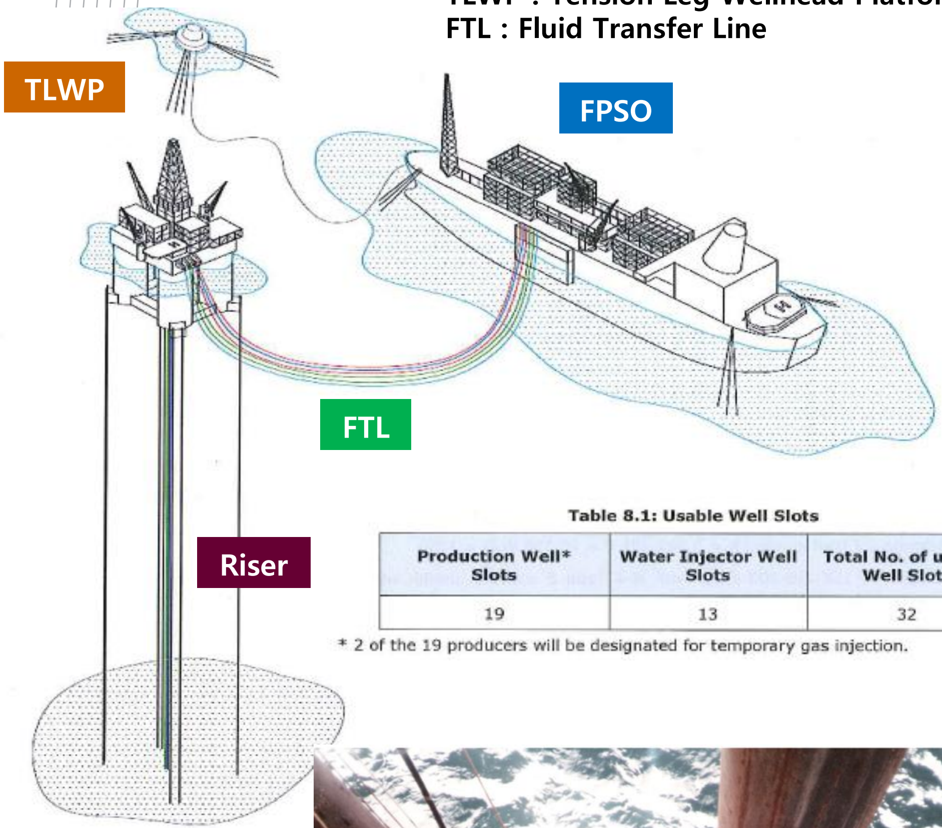
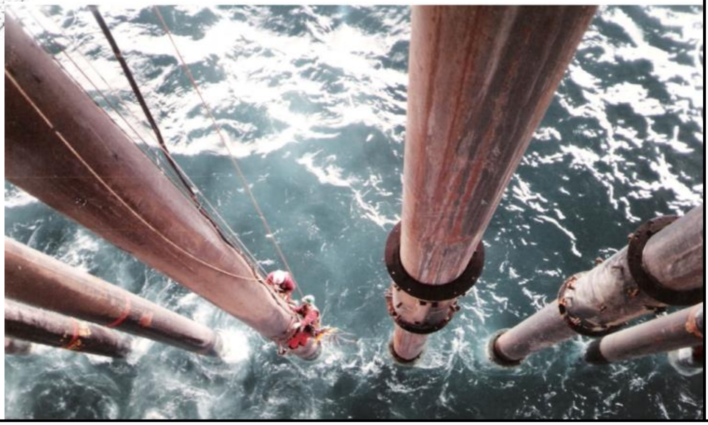
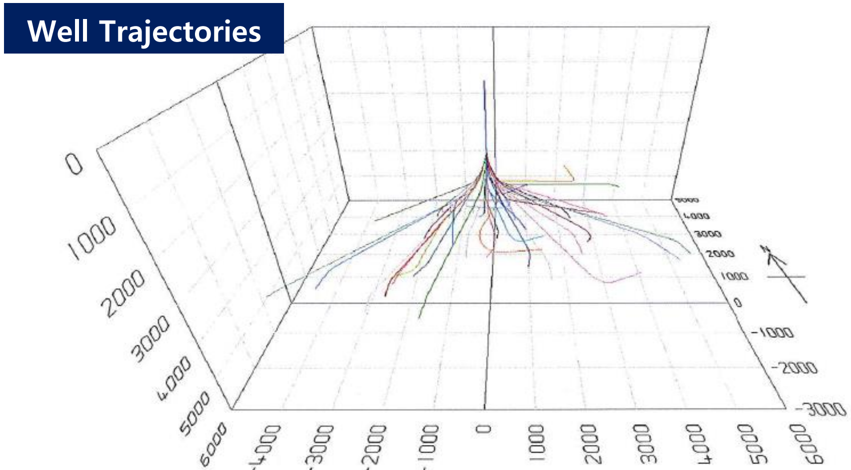


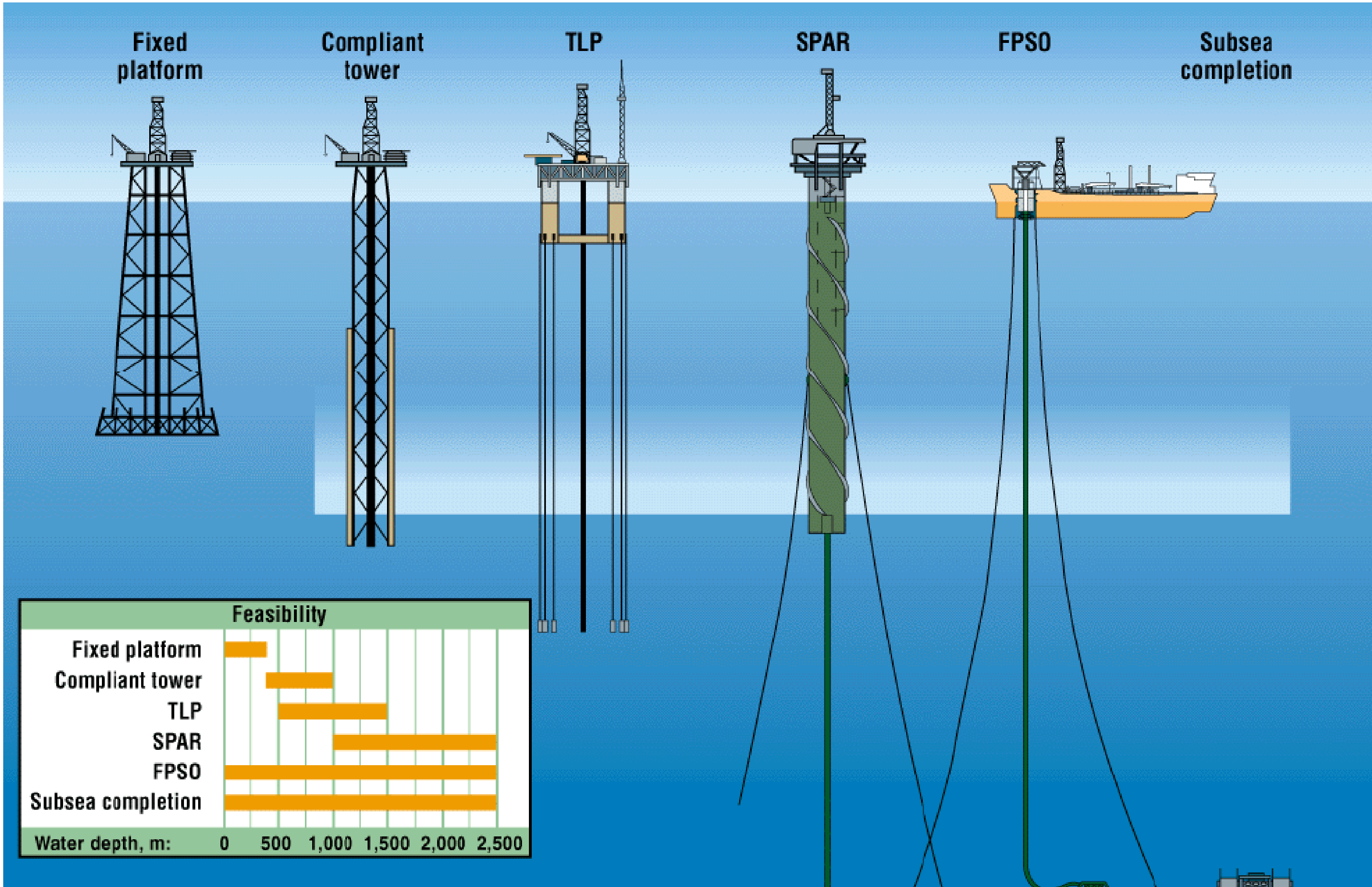

Table 8.1: Usable Well Slots

| Production Well* Slots | Water Injector Well Slots | Total No. of usable Well Slots |
|---|---|---|
| 19 | 13 | 32 |

* 2 of the 19 producers will be designated for temporary gas injection.







Fixed platform
Compliant tower
TLP
SPAR
FPSO
Subsea completion
Feasibility
Fixed platform
Compliant tower
TLP
SPAR
FPSO
Subsea completion
Water depth, m: 0 500 1,000 1,500 2,000 2,500

# Classification of host system
# : Compliant type - SPAR

- Spar

  : max water depth 2500m

Truss Spar

Dry-transport of Spar Hull

Upending of Spar Hull by Heerema HLV (Balder)

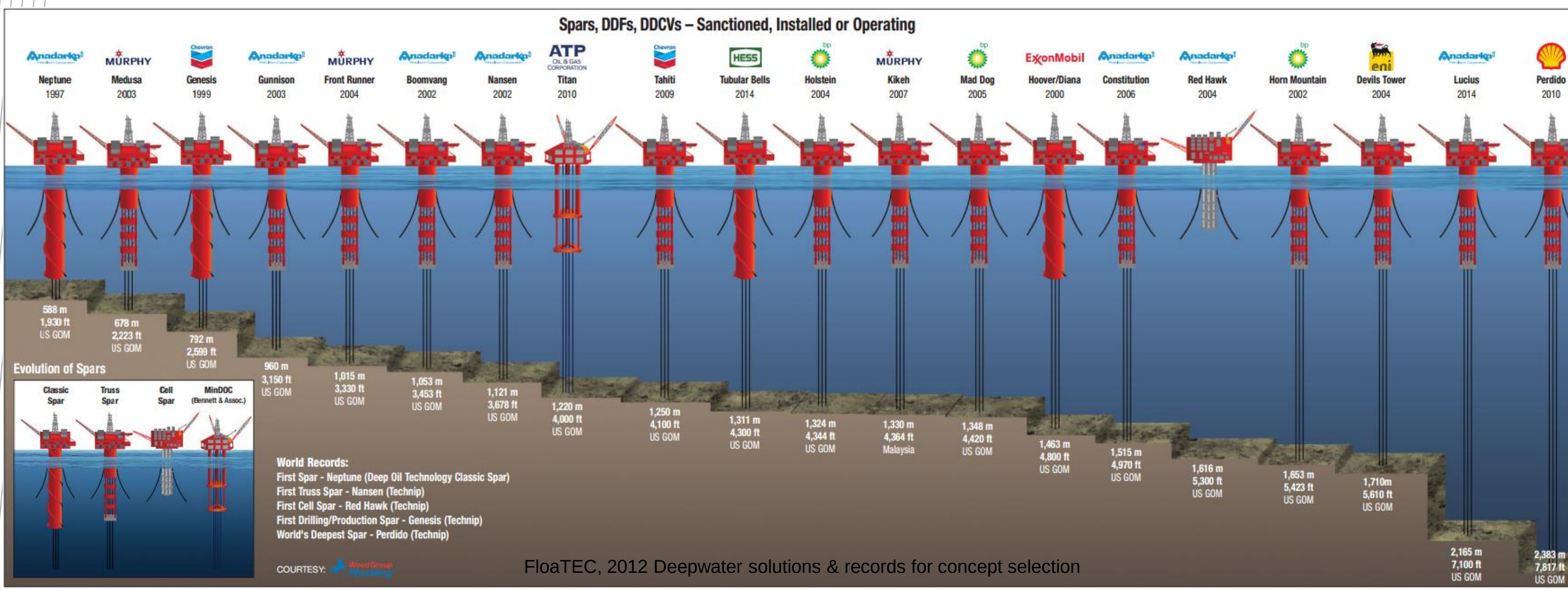
# SPAR

- A **spar** is a type of floating oil platform typically used in very deep waters, and is named for logs used as buoys in shipping that are moored in place vertically.
- Spar production platforms have been developed as an alternative to conventional platforms.
- The deep draft design of spars makes them less affected by wind, wave and currents and allows for both dry tree and subsea production.
- Spars are most prevalent in the US Gulf of Mexico; however, there are also spars located offshore Malaysia and Norway

Mad Dog Spar Platform

# World Spar

- A spar platform consists of a large-diameter, single vertical cylinder supporting a deck. The cylinder is weighted at the bottom by a chamber filled with a material that is denser than water (to lower the center of gravity of the platform and provide stability).
- Additionally, the spar hull is encircled by helical strakes to mitigate the effects of vortex-induced motion. Spars are permanently anchored to the seabed by way of a spread mooring system composed of either a chain-wire-chain or chain-polyester-chain configuration



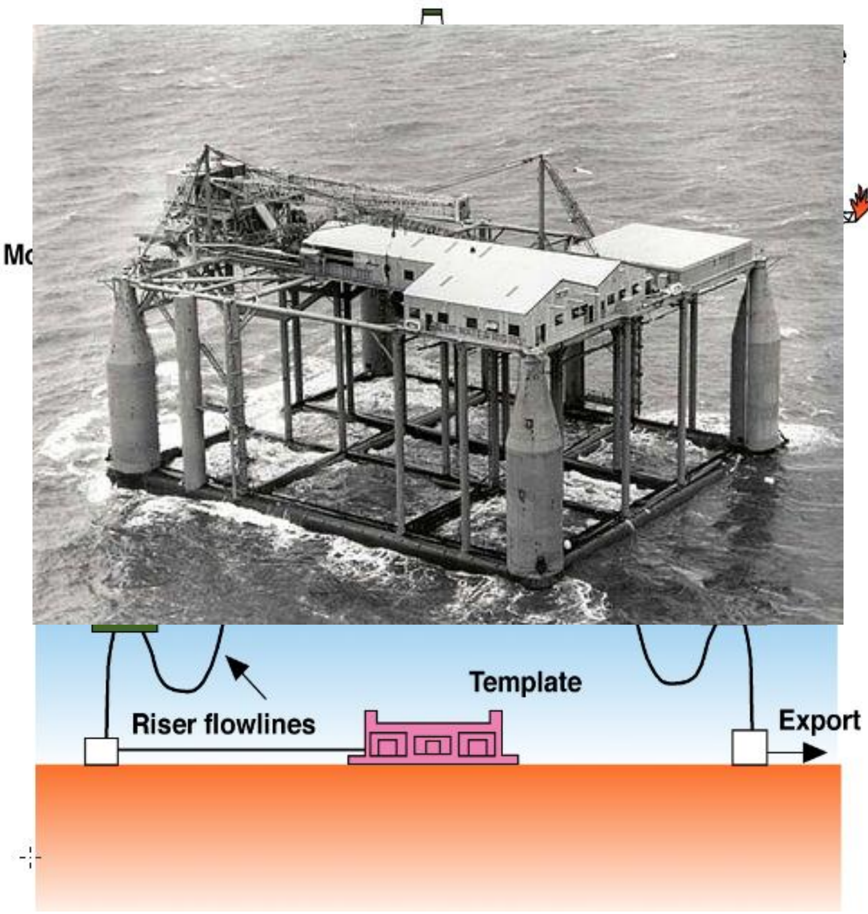

FloaTEC, 2012 Deepwater solutions & records for concept selection

# Classification of host system
# : Floating type

- Semi-submergible

: When oil drilling moved into offshore waters, fixed platform rigs and submersible rigs were built, but were limited to shallow waters. When demands for drilling equipment was needed in water depths greater than 100 feet (30 m) in the Gulf of Mexico, the first jack-up rigs were built.

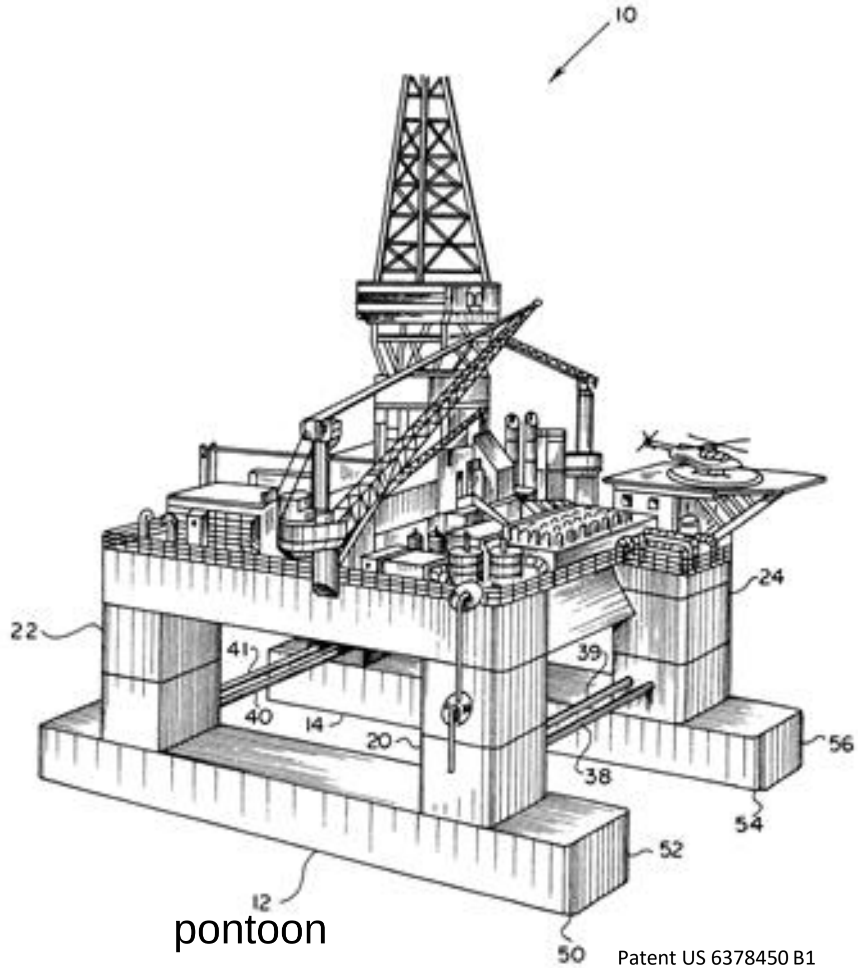
: The first semisubmersible arrived by accident in 1961. Blue Water Drilling Company owned and operated the four column submersible drilling rig *Blue Water Rig No.1* in the Gulf of Mexico for Shell Oil Company. AS the pontoons were not sufficiently buoyant to support the weight of the rig and its consumables, it was towed between locations at a draught midway between the top of the pontoons and the underside of the deck. It was observed that the motions at this draught were very small, and Blue Water Drilling and Shell jointly decided that the rig could be operated in the floating mode




water depths from 60 to 3050 m

# Semi-submersible

- A **semi-submersible platform** is a specialized marine vessel used in a number of specific offshore roles such as offshore drilling rigs, safety vessels, oil production platforms, and heavy lift cranes.
- They are designed with good stability and seakeeping characteristics. Other terms include *semi-sub*, or simply *semi*.
- A semi-submersible obtains most of its buoyancy from ballasted, watertight pontoons located below the ocean surface and wave action.
- Structural columns connect the pontoons and operating deck. The operating deck can be located high above the sea level owing to the good stability of the design, and therefore is kept well away from the waves.



Patent US 6378450 B1

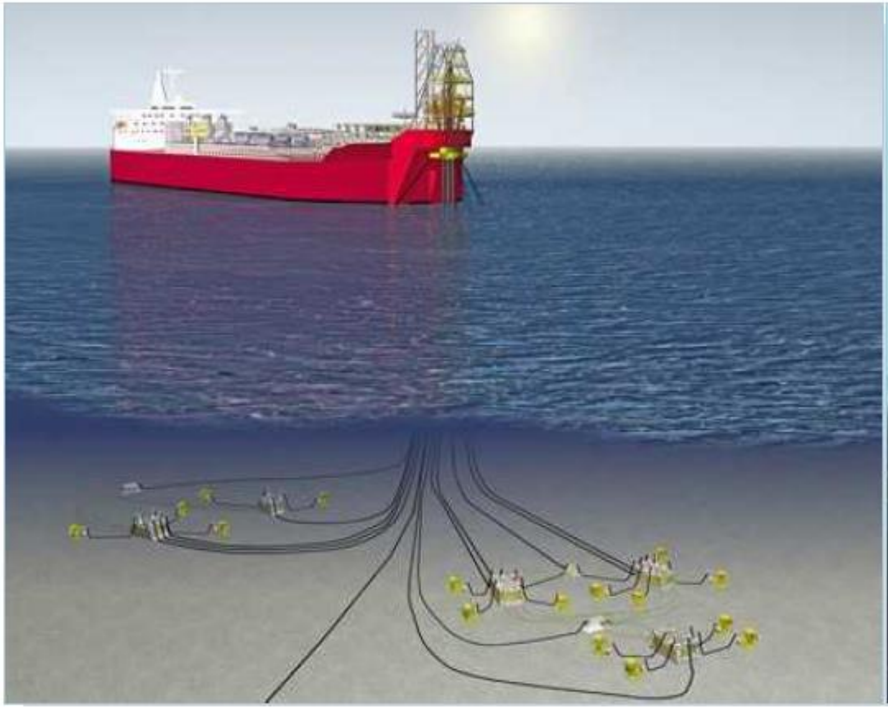
- With its hull structure submerged at a deep draft, the semi-submersible is less affected by wave loadings than a normal ship. With a small water-plane area, however, the semi-submersible is sensitive to load changes, and therefore must be carefully trimmed to maintain stability. Unlike a submersible, a semi-submersible vessel is not supported by resting on the seabed.
- Semi-submersible vessels are able to transform from a deep to a shallow draft by deballasting (removing ballast water from the hull), thereby becoming surface vessels. Usually they are moved from location to location in this configuration.
- The heavy lift vessels use this capability to submerge the majority of their structure, locate beneath another floating vessel, and then deballast to pick up the other vessel as a cargo


Dry transport of 'Thunderhorse' Semi

# Classification of host system
# : Floating type

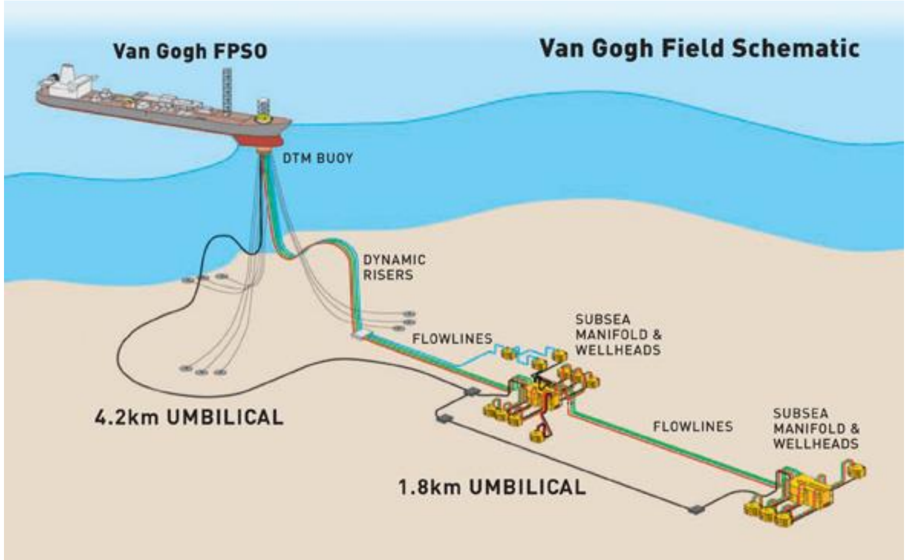
- FPSO (Floating Production Storage and Offloading)

: A **floating production storage and offloading** (**FPSO**) unit is a floating vessel used by the offshore oil and gas industry for the production and processing of hydrocarbons, and for the storage of oil.



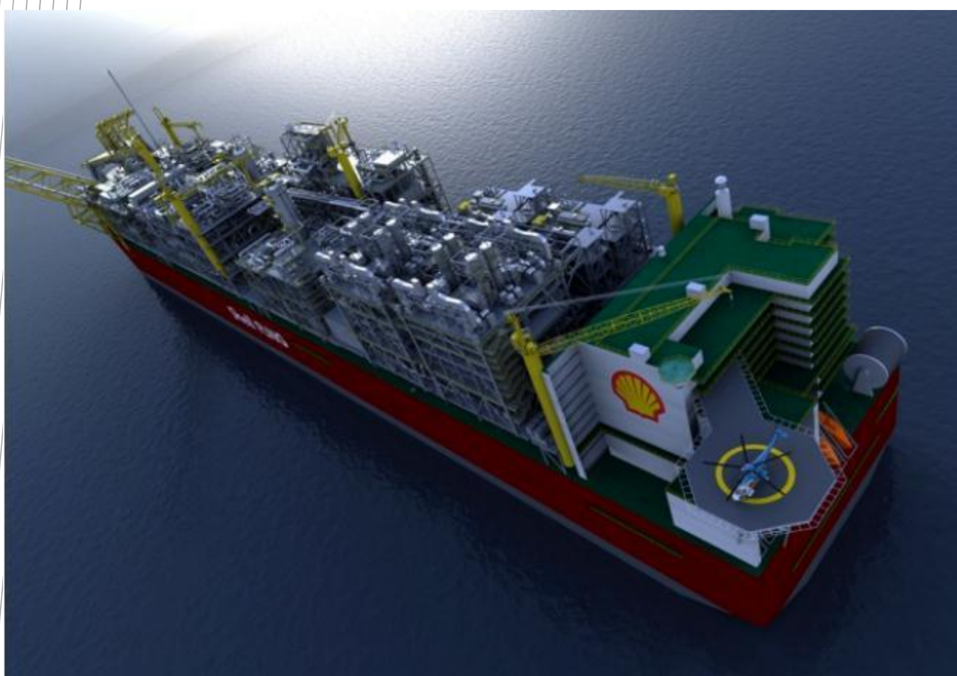

# FPSO (Floating Production Storage & Offloading)

- A FPSO vessel is designed to receive hydrocarbons produced by itself or from nearby platforms or subsea template, process them, and store oil until it can be offloaded onto a tanker or, less frequently, transported through a pipeline.
- FPSOs are preferred in frontier offshore regions as they are easy to install, and do not require a local pipeline infrastructure to export oil.
- FPSOs can be a conversion of an oil tanker or can be a vessel built specially for the application. A vessel used only to store oil (without processing it) is referred to as a floating storage and offloading (FSO) vessel.



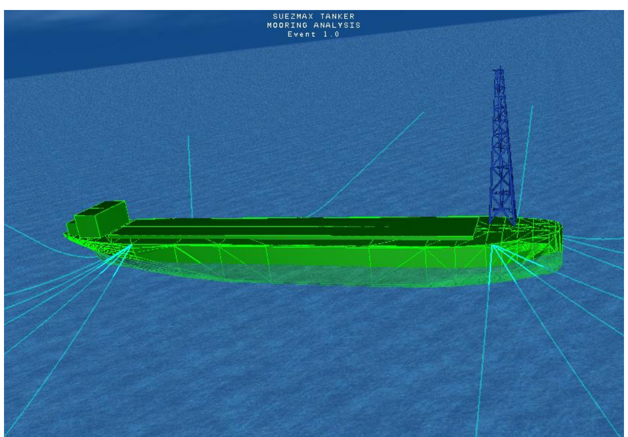
# Example: Pazflor Oil-FPSO

# Example: Prelude FLNG

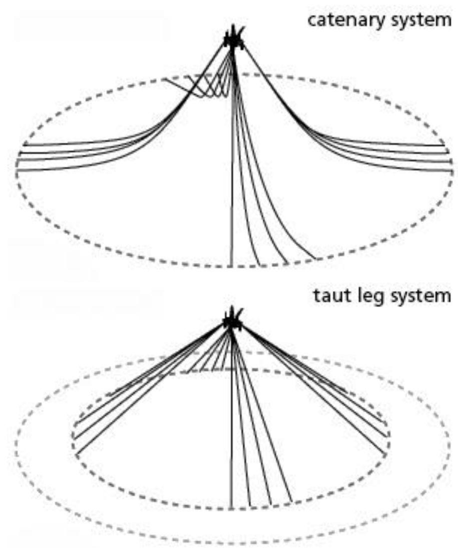


# Spread mooring system

- Spread mooring systems are multi-point mooring systems that moor vessels to the seabed using multiple mooring lines. (www.bluwater.com)
- Catenary Mooring:  the most common mooring system in shallow waters. The catenaries are hanging horizontally at the seabed. Consequently the catenary lengths have to be larger than the water depth and the anchor points in a catenary mooring system are subjected to horizontal forces.
- Taut Mooring: The pre-tensioned mooring lines arrive under an angel at the seabed. Typically the angle between the line and the seabed is between 30 and 40 degrees. The restoring forces are generated by the elasticity of the mooring line.




http://bentley.ultramarine.com/models/Mooring
/tn/Spread%20Moored%20Tanker.png.html




http://www.dredgingengineering.com/m
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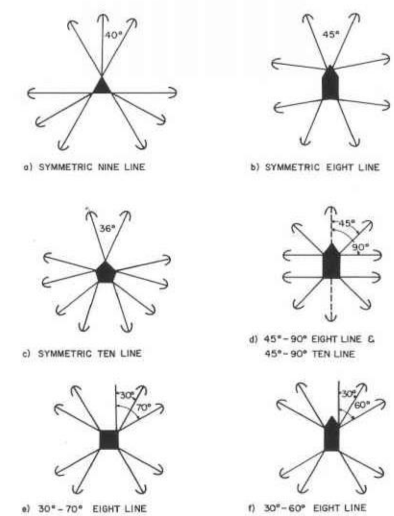
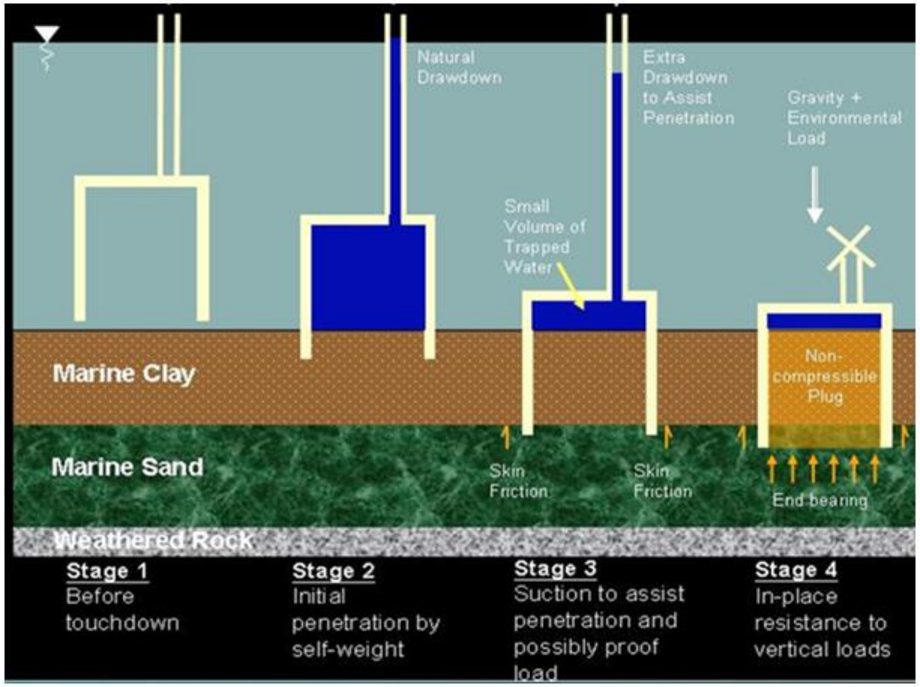



Fig. 1–74 Typical spread mooring patterns.

http://www.netwasgroup.us/offshore/spread-mooring-systems.html

# Anchor

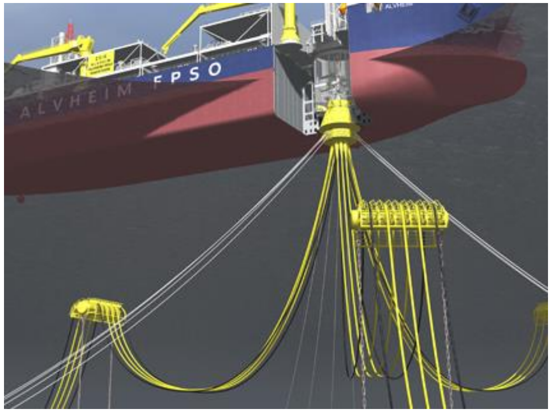
- Suction anchor




http://www.epd.gov.hk/eia/register/report/eiareport/eia_1672009/HKOWF%20HTML%20EIA/HKOWF%20Contents.htm

# Turret mooring system

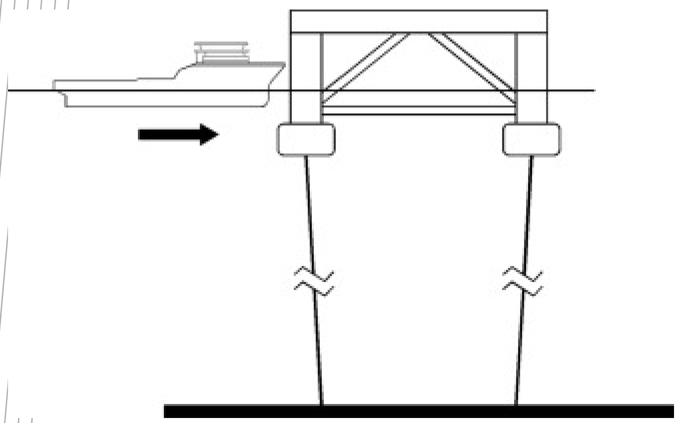
- The single point turret mooring system consists of a turret assembly that is integrated into a vessel and permanently fixed to the seabed by means of a mooring system.
- The turret system contains a bearing system that allows the vessel to rotate around the fixed geostatic part of the turret, which is attached to the mooring system. The turret mooring system can be combined with a fluid transfer system that enables connection of (subsea) pipelines to the offshore unit like a FPSO. The turret mooring system can be located external and internal on the floating unit.
- The disconnectable turret mooring system is often used in an artic environment. If it necessary to disconnect a (subsurface) buoy keeps the mooring lines and risers connected.


http://www.nov.com/fps_landing/products/submerged-turret-production.html

http://www.sbmoffshore.com/what-we-do/our-products/turret-mooring-systems/

# Examples: ship collision with a TLP



- For a Tension Leg Platform (TLP) installation, a surplus of buoyancy in the hull provides the forces needed to carry the vertical load of the installation and to establish axial forces in the tethers. The tensioned tethers are secured to the bottom with suction anchors, gravity anchors, or piles.

- Transverse restoring forces are provided by the tension in the tethers, as increasing tether tension reduces transverse displacements. Due to the large vertical stiffness of the tethers, the system rotates very little around a horizontal axis when the hull is exposed to a transverse force, that is, the installation is upright even for large transverse displacements.
- Consider a TLP installation where the mass of the installation including hydrodynamic mass for transverse dynamic motions can be taken as 160,000 tons. The combined tether tension forces are 300 MN, and the length of the tethers is 600 m. (*Unit: 1 meganewton [MN] = 1000000 newton [N])
- This installation is struck in a central collision by a drifting tanker with a mass plus added mass equal to 100,000 tons and a speed of 2 m/s.

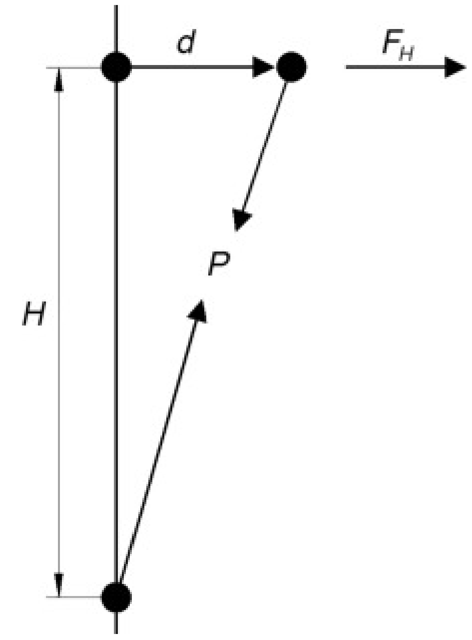
Questions:

(1) Calculate the energy released for crushing of the tanker and/or the TLP structure.

Solution:

First, the restoring forces from the tethers shall be calculated for transverse displacements.

It is seen that for a tension force *P* in the tether system and a transverse displacement *d*, which is small compared with the water depth *H*,




Thus, the stiffness for the horizontal displacement is

$k_{tether}=F_H/d=P/H$

$k_{tether}=300\ MN\ /\ 600\ m = 0.5\ MN/m$

Approximating the installation as a one degree of freedom system for oscillations in the transverse plane, the period can be determined as

$$T = {}^{2\pi}\Big/\sqrt{\frac{k_{tether}}{M_{TLP}}} = {}^{2\pi}\Big/\sqrt{\frac{500}{160{,}000}} = 112.4\ s$$

This period is so long compared with the impact duration for normal ships and installation structures that the motions and thus the restoring forces during the impact can be neglected.

Then, the impact energy released for crushing can be determined from

$$E = \frac{1}{2}\left(\frac{M_{ship}}{1 + \frac{M_{ship}}{M_{TLP}}}\right) \cdot V_0^2 = \frac{1}{2}\left(\frac{100}{1 + \frac{100}{160}}\right) \cdot 2^2 = 123.1\ MJ$$

This is the approximation to the energy that must be absorbed by crushing of structures.

(2) Calculate the maximum amplitude of the sway motion of the struck TLP installation.

Solution.

For an impact with a ship of displacement 100,000 tons and impact speed, $V_{ship}$ = 2.0 m/s, we find that the momentum equilibrium requirement gives the TLP a velocity at the end of the impact, which is

$$V_{TLP} = \frac{M_{ship} \cdot V_{ship}}{M_{ship} + M_{TLP}} = 0.77 \text{ m/s}$$

Now, neglecting damping and assuming that the impact duration is so short that the TLP has not moved during the ship bow crushing period, then the maximum transverse deflection of the struck TLP is found as

$$\delta_{max} = \frac{V_{TLP}}{\omega} = V_{TLP} \Big/ \sqrt{\frac{k_{tether}}{M_{TLP}}} = 13.77\ m$$

This is the approximate value for the maximum amplitude for the struck TLP.

Thank you!