OFFSHORE PLATFORM: SPAR CONSTRUCTION
&
DEVELOPMENT

(FINAL PROJECT REPORT)

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8 May 07

CERTIFICATE

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This is certify that the major project report on ***"OFFSHORE PLATFORM: SPAR CONSTRUCTION & DEVELOPMENT"*** completed and submitted to the **University of Petroleum & Energy Studies, Dehradun** by **Mr. Adil Muneer Khan & Mr. Ashish Kestwal** in partial fulfillment of the requirement for the award of the degree of Bachelor of Technology (Applied Petroleum Engineering), 2003-07, is a bonafide work carried out by them under my supervision and guidance.

To the best of my knowledge and belief the work has been based on investigations made, data collected and analyzed by them & their work have not been submitted anywhere else for any other university or institution for the award of any degree/diploma.

01-05-07

Prof. C.K. Jain

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INTRODUCTION

[1]Drilling for offshore, in some instances hundreds of miles away from the nearest landmass, poses a number of different challenges over drilling onshore. The actual drilling mechanism used to delve into the sea floor is much the same as can be found on an onshore rig. However, with drilling at sea, the sea floor can sometimes be thousands of feet below sea level. Therefore, while with onshore drilling the ground provides a platform from which to drill, at s

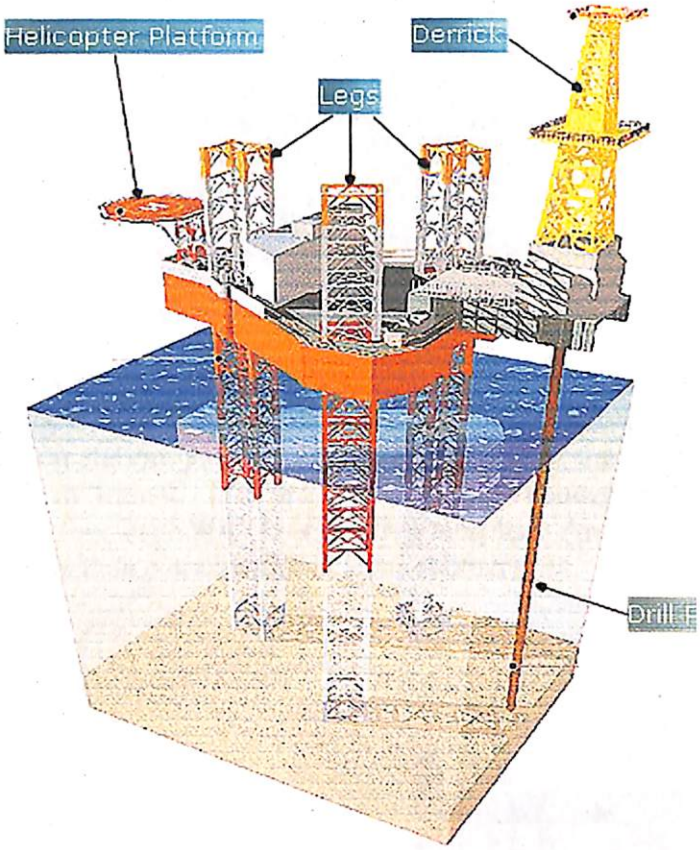
The term platform encompasses many kinds of structures. The structure may be very small over a single well in shallow water, or it may be very large over dozens of wells in deep water. Such a large structure is probably remotely located, necessitating living quarters, communication facilities and transportation installations such as a helicopter pad. It is a virtual village with space at a premium and safety a major concern. The platform is a permanent fixture that will remain in place for the producing life of the wells, and it must be able to withstand any environmental or operational condition that may arise.

Drilling Rigs and Platforms Overview

There are two basic types of offshore drilling rigs: those that can be moved from place to place, allowing for drilling in multiple locations, and those rigs that are permanently placed. Moveable rigs are often used for exploratory purposes because they are much cheaper to use than permanent platforms. Once large deposits of hydrocarbons have been found, a permanent platform is built to allow their extraction. The sections below describe a number of different types of offshore rigs/platforms

Moveable Rigs

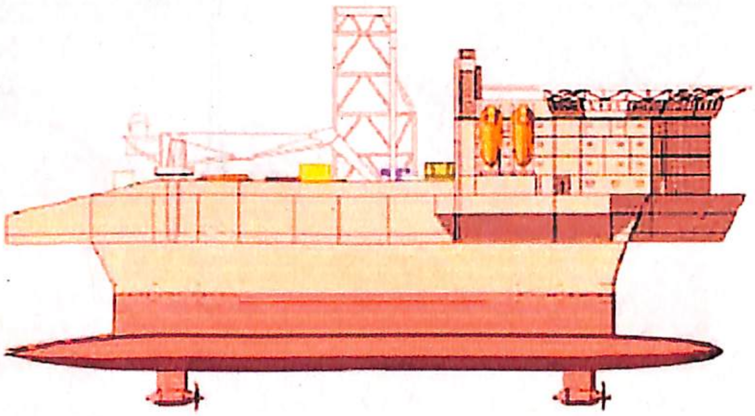
Jack up drilling rig\The Jackup has long leg structures, which it lowers to and into the seabed raising the rig out of the water. The obvious limitation with this type of installation is the depth of water it can operate in. The maximum being about five hundred feet. Many areas of the North Sea are not too deep for this type of installation to operate.



Drilling Barges Drilling barges are used mostly for inland, shallow water drilling. This typically takes place in lakes, swamps, rivers, and canals. Drilling barges are large, floating platforms, which must be towed by tugboat from location to location. Suitable for still, shallow waters, drilling barges are not able to withstand the water movement experienced in large open water situations.

Semi Submersible This type has pontoons and columns that, when flooded with seawater, cause the pontoons to submerge to a predetermined depth. Although it is moved by wave action, it sits low with a large part of its structure under water. It obtains its buoyancy from ballasted, watertight, pontoons located below the ocean surface and wave action. This, combined with eight huge mooring anchors, make it a very stable installation. There can be over one hundred people on board and although smaller than a platform, conditions are usually good. This type of rig makes its money by drilling a hole in the seabed then it moves to the next location. When the rig moves its location, the pontoons are de-ballasted so that the rig can float. Units can be either self propelled or with no propulsion, in which case they are moved using tugs. With advancing technology some semi submersibles can drill in water depths over five thousand feet.

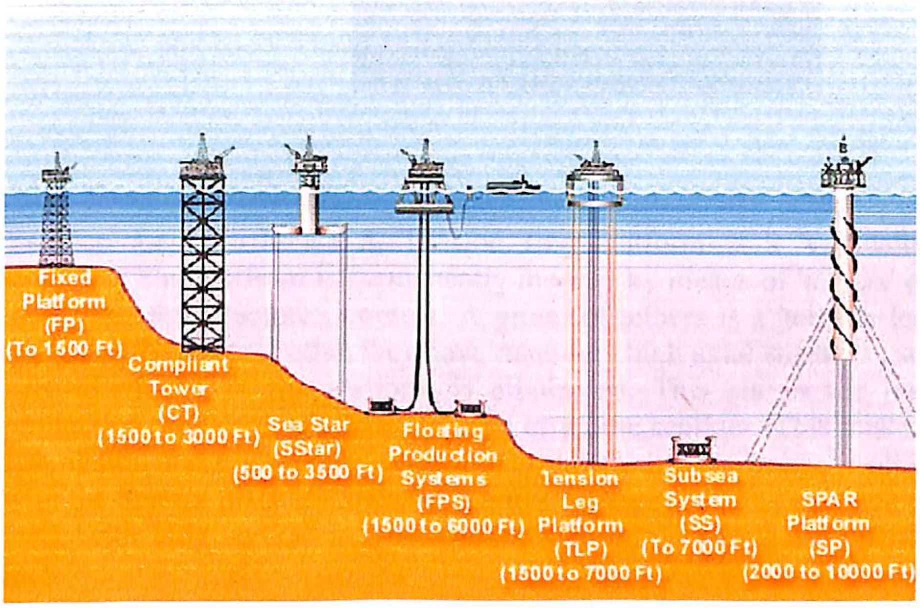
Future Developments It is this lack of transit speed that handicaps a semi-submersible unit in terms of days on station, as a significant proportion of the unit's available time is necessarily taken up in transit. The drawing shows a concept self propelled semi-submersible utilizing the Tri/SWATH (Small-Waterplane-Area Twin-Hull concept), capable of higher speeds than a conventional semi-submersible.



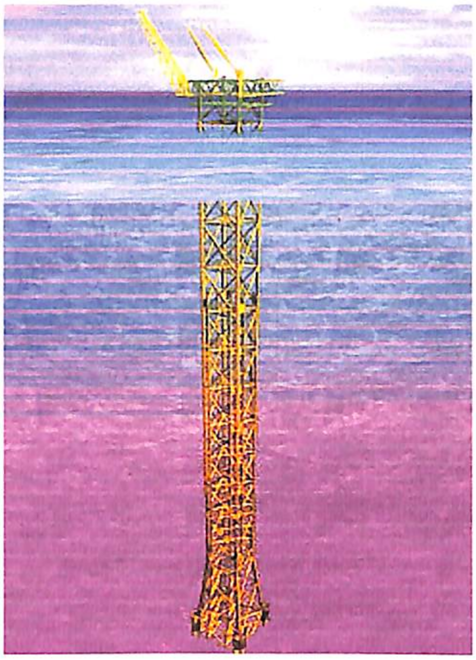
Drill Ship As the name suggests this is a ship equipped for drilling operations. Unlike the semi-submersible and jack up type rigs, it is maneuverable and moves under its own power. They are not as stable as other mobile rigs but, equipped with the latest technology, they cover large areas and are capable of drilling in very deep water. Early ships maintained station by deploying anchors, but modern vessels use DP (Dynamic Positioning). The ships position is determined very accurately by means of satellite signals, land based signals or from underwater sonar beacons. The output from these is linked to the ships propulsion system and continual adjustments by computer are made so as to maintain the ships position. These ships are used for many purposes including drilling for oil and gas or taking sub seabed core samples

Fixed Platforms

Fixed Platforms In certain instances, in shallower water, it is possible to physically attach a platform to the sea floor. This is what is shown above as a fixed platform rig. The 'legs' are constructed with concrete or steel, extending down from the platform, and fixed to the seafloor with piles. With some concrete structures, the weight of the legs and seafloor platform is so great, that they do not have to be physically attached to the seafloor, but instead simply rest on their own mass. There are many possible designs for these fixed, permanent platforms. The main advantages of these types of platforms are their stability, as they are attached to the sea floor there is limited exposure to movement due to wind and water forces. However, these platforms cannot be used in extremely deep water, it simply is not economical to build legs that long.

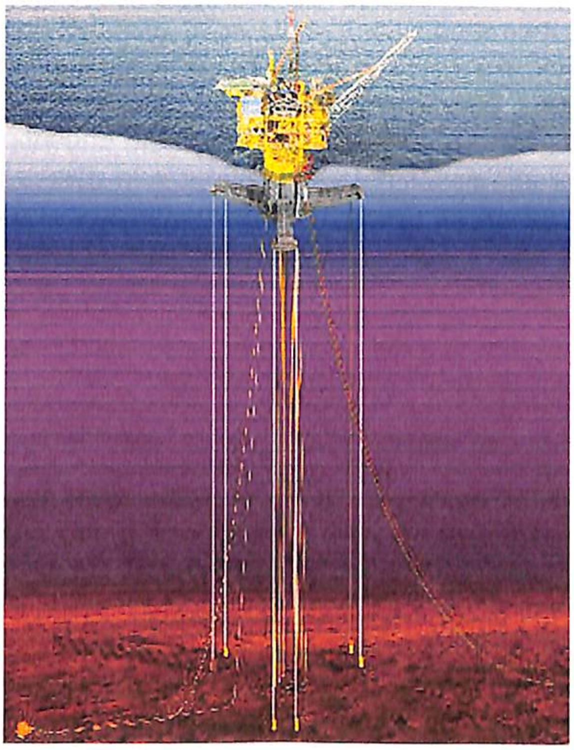


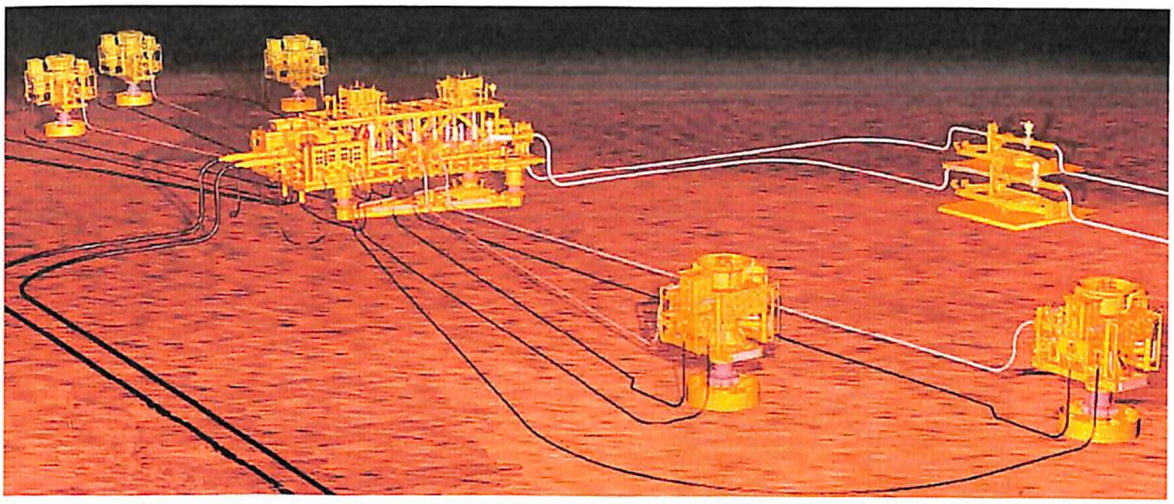
Compliant Towers Compliant towers are much like fixed platforms. They consist of a narrow tower, attached to a foundation on the seafloor and extending up to the platform. This tower is flexible, as opposed to the relatively rigid legs of a fixed platform. This flexibility allows it to operate in much deeper water, as it can absorb much of the pressure exerted on it by the wind and sea. Despite its flexibility, the compliant tower system is strong enough to withstand hurricane conditions.



Tension Leg Platforms A Tension Leg Platform is a 'vertically moored' floating structure. The platform is permanently moored by means of 'tethers' or 'tendons' grouped at each of the structure's corners. A group of tethers is a 'tension leg'. A feature of the design of the tethers is that they have relatively high axial stiffness , such that virtually all vertical motion of the platform is eliminated. This allows the platform to have the production wellheads on deck , instead of on the seafloor. This makes for a cheaper well completion and gives better control over the production from the oil or gas reservoir. As with the Seastar platform, these legs allow for significant side to side movement (up to 20 feet), with little vertical movement. Tension leg platforms can operate as deep as 7,000 feet.

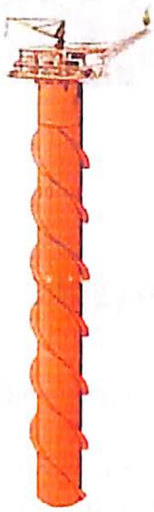
Seastar Platforms Seastar platforms are like miniature tension leg platforms. The platform consists of a floating rig, much like the semi-submersible. A lower hull is filled with water when drilling, which increases the stability of the platform against wind and water movement. In addition to this semi-submersible rig, however, Seastar platforms also incorporate the tension leg system employed in larger platforms. Tension legs are long, hollow tendons that extend from the seafloor to the floating platform. These legs are kept under constant tension, and do not allow for any up or down movement of the platform. However, their flexibility does allow for side-to-side motion, which allows the platform to withstand the force of the ocean and wind, without breaking the legs off. Seastar platforms are typically used for smaller deep-water reservoirs, when it is not economical to build a larger platform. They can operate in water depths of up to 3,500 feet.

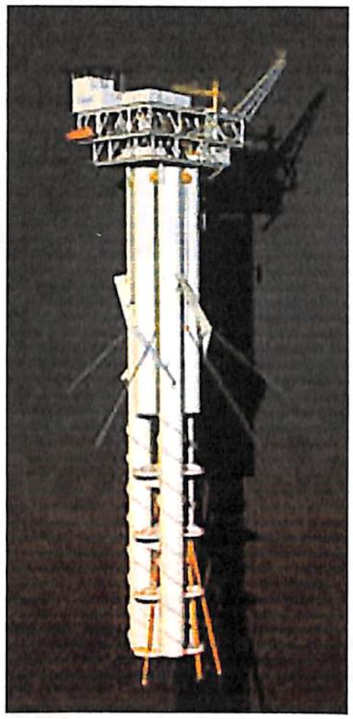




Subsea System Subsea production systems are wells located on the sea floor, as opposed to at the surface. Like in a floating production system, the petroleum is extracted at the seafloor, and then can be 'tied-back' to an already existing production platform. The well can be drilled by a moveable rig, and instead of building a production platform for that well, the extracted oil and natural gas can be transported by riser or even undersea pipeline to a nearby production platform. This allows one strategically placed production platform to service many wells over a reasonably large area. Subsea systems are typically in use at depths of 7,000 feet or more, and do not have the ability to drill, only to extract and transport.

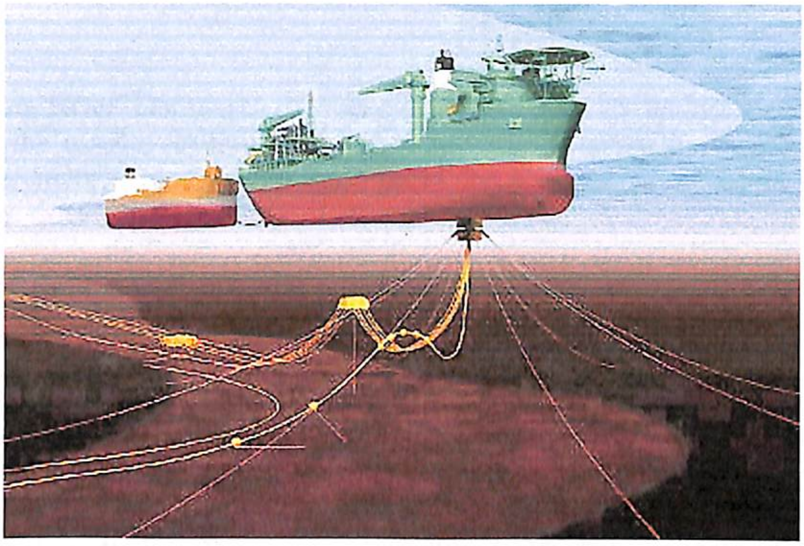
Spar Platforms Spar platforms are among the largest offshore platforms in use. These huge platforms consist of a large cylinder supporting a typical fixed rig platform. The cylinder however does not extend all the way to the seafloor, but instead is tethered to the bottom by a series of cables and lines. The large cylinder serves to stabilize the platform in the water, and allows for movement to absorb the force of potential hurricanes.





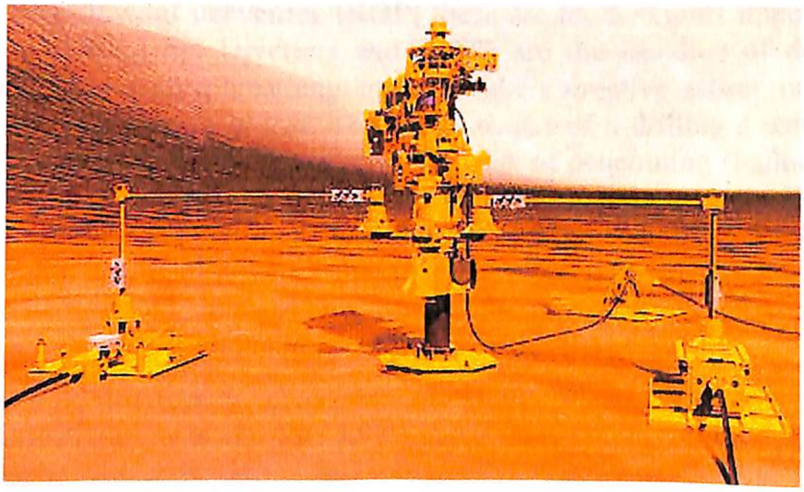
Classic Spar **Truss Spar** **Cell Spar**

Floating Production Systems Floating production systems are essentially semi-submersible drilling rigs, except that they contain petroleum production equipment, as well as drilling equipment. Ships can also be used as floating production systems. The platforms can be kept in place through large, heavy anchors, or through the dynamic positioning system used by drill ships. With a floating production system, once the drilling has been completed, the wellhead is actually attached to the seafloor, instead of up on the platform. The extracted petroleum is transported via risers from this wellhead to the production facilities on the semi-submersible platform. These production systems can operate in water depths of up to 6,000 feet.



Rig Ancillary equipment

The **Wellhead** The Wellhead refers to the topmost point of a well and the structure built over it. This will lie on the seabed. Wellheads include control equipment such as outlets, valves, blowout preventers, casing heads, tubing heads and Christmas trees. On an exploration well there might be just one wellhead, but on a large production field there will be many wellheads all connected together Wellhead refers to the topmost



Marine Drilling Riser The length of steel pipe extended from the BOP stack to the rig is referred to as the marine drilling riser and it provides a return passage for the drilling mud. The riser incorporates a telescopic joint, the top half of which is attached to a tension system

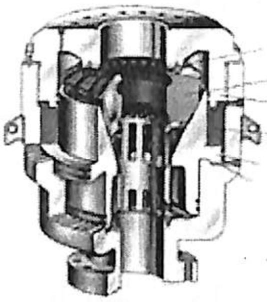
Choke and kill lines A high-pressure pipe leading from an outlet on the BOP stack to the high-pressure rig pumps. During normal well control operations, kill fluid is pumped through the drill string and annular fluid is taken out of the well through the choke line to the choke, which drops the fluid pressure to atmospheric pressure. If the drill pipe is inaccessible, it may be necessary to pump heavy drilling fluid in the top of the well, wait for the fluid to fall under the force of gravity, and then remove fluid from the annulus. In such an operation, while one high pressure line would suffice, it is more convenient to have two. In addition, this provides a measure of redundancy for the operation. In floating offshore operations, the choke and kill lines exit the subsea BOP stack and run along the outside of the riser to the surface.

Marine Riser Flexible Joint A flexible ball joint located between lower riser assembly on the BOP stack and the marine riser can tolerate a certain amount of lateral movement of the rig relative to the wellhead.

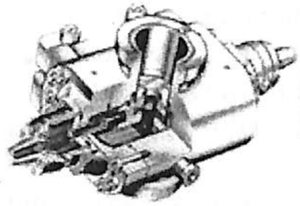
Telescopic Joint The telescopic joint permits relative vertical movement between the stationery lower section of drilling riser which is attached to the seabed and the upper section of drilling riser which is connected to the drilling derrick. It consists of a hydraulic or pneumatically activated packing element, which is located in the top section of drilling riser.

The diverter and blowout preventer [BOP] these are the two most important items of equipment on a drilling rig. Diverters and BOP's are the last line of defence which provide the drill crew with a breathing space to take corrective action, or abandon the installation when well control is lost. The initial stages of a drilling a well are without doubt the most dangerous due to the ever present risk of penetrating shallow gas bearing sands, a hazard which has resulted in numerous fatalities and the complete destruction of both drillships, jackups and semi-submersibles. This primary function of the BOP is to confine well fluids within the well bore. It operates as part of a BOP system which includes the BOP stack, choke and kill valves, choke manifold and a hydraulic powered control unit. There are two types of BOP, ANNULAR & RAM

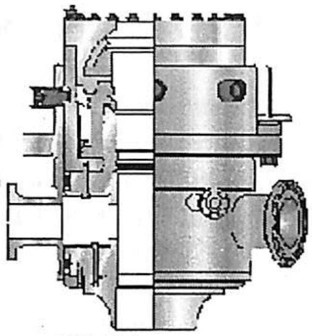
ANNULAR BOP - This type relies on the constriction of a packing element to form a seal around the drill pipe or kelly. The ANNULAR BOP can accommodate considerable changes in diameter and cross section but it typically cannot withstand the high pressures that a RAM BOP can take.



Annular bop



RAM



Diverter

RAM BOP - There four types of RAM BOP- Pipe, Variable, Blind & Blind shear rams. These are primarily used during subsea drilling operations where weather conditions may necessitate the rapid disconnection of the rig from the well. The blind rams incorporate a cutting edge capable of severing the drill string and sealing high pressure, high temperature well fluids within the well bore for an extended period of time. A hydraulically controlled power unit typically provides the fluid power of the rams, and the annular piston used in the annular BOP's.

DIVERTER - The diverter provides a means of diverting an unexpected release of well fluids, primarily gas and occasionally solids, to a location at the extremities of the rig where they can be discharged safely. The diverter is situated on top of the conductor and must permit the passage of the drill bit. During normal drilling operations, the diverter vents are closed and the drilling mud returns flow upwards and into the bell housing then into the shale shaker. Operating the diverter results in the closure of the packing element around the drill string and then opening of the vents, allowing an unrestricted passage to the atmosphere for well fluids.[1]

DESIGN BASIS OF AN OFFSHORE PLATFORM

[2]Offshore structures are used worldwide for a variety of functions and in a variety of water depths, and environments. The most commonly used offshore platforms in the Gulf of Mexico are made of steel, and are used for oil/gas exploration and production. The design and analyses of these offshore structures must be made in accordance with recommendations published by the American Petroleum Institute (API).

The design and analysis of offshore platforms must be done taking into consideration many factors, including the following important parameters:

- Environmental (initial transportation, and in-place 100-year storm conditions)
- Soil characteristics
- American Institute of Steel Construction (AISC) codes, and recommendations
- Intensity level of consequences of failure

The entire design, installation, and operation must be approved by the Minerals Management Service (MMS), a division of the US Department of the Interior. The MMS approval is contingent on a design and analysis done in strict adherence to the API recommendations, and also on possible additional requirements imposed by the MMS

The soil investigation is vital to the design of any offshore structure, because it is the soil that ultimately resists the enormous forces and moments present in the piling, at the bottom of the ocean, created by the presence of the platform in the hostile ocean environment.

The soil can be clay, sand, silt, or a mixture of these.

Each project must acquire a site-specific soil report showing the soil stratification and its characteristics for load bearing in tension and compression, shear resistance, and load-deflection characteristics of axially and laterally loaded piles. This type of report is developed by doing soil borings at the desired location, and then performing in-situ and laboratory tests in order to develop data usable to the platform design engineer.

The soil report should show the calculated minimum axial capacities for piles of the same diameter as the platform design piles. It should also show shear resistance values and pile tip end bearing values. Pile axial capacity values are normally called "T-Z" values, shear values are called "P-Y" values, and end bearing values are called "Q-Z" values.

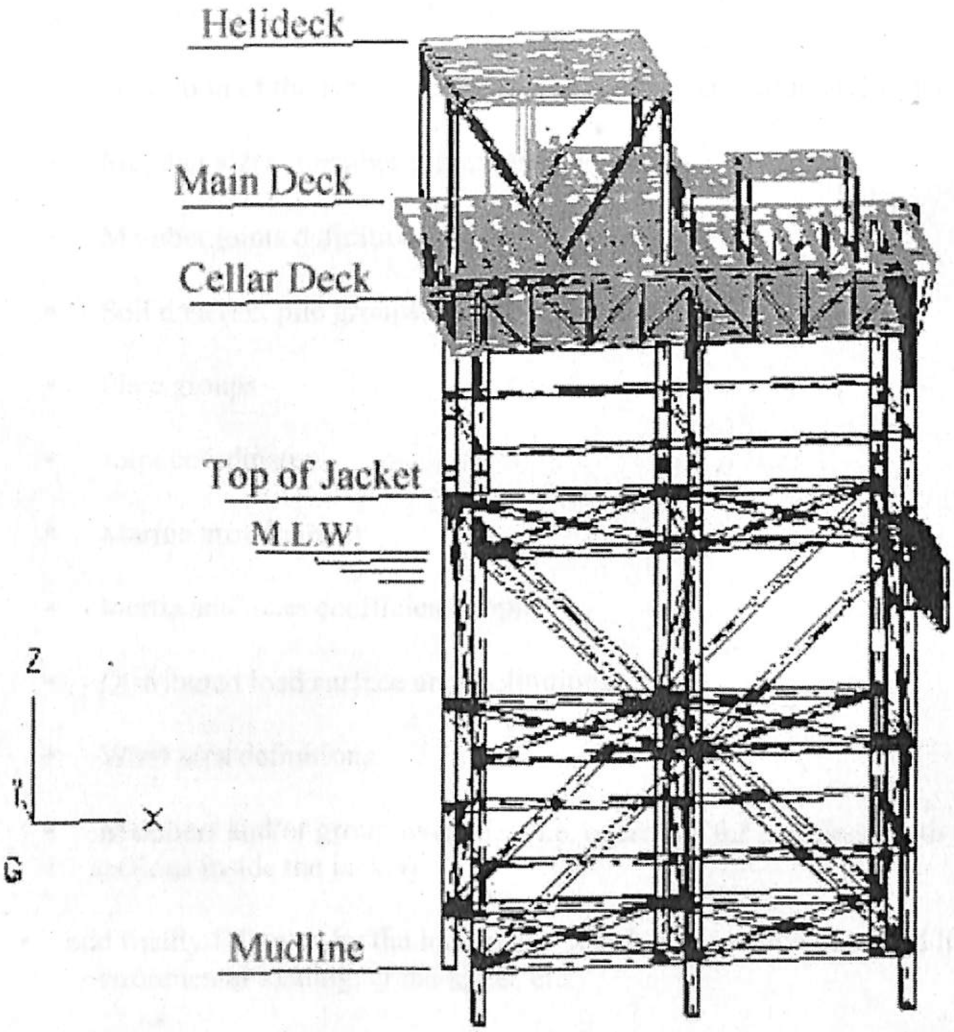
These values, once provided to the engineer by the geotechnical engineers, will be input into the structural analysis model (normally in StruCad or SACS software), and will determine minimum pile penetrations and size. The minimum pile penetration must have a resistance capacity equal to one and a half the maximum design loading on that pile, thus ensuring a factor of safety of 1.5. For operating loads, the FS must be 2.0 for piles. The ratio of the maximum combined stresses to the maximum allowable stresses (Unity Checks) must not exceed 1.0, in the piles or anywhere else in the platform.

Pile penetrations will vary depending on platform size and loads, and soil characteristics, but normally range from about 30 meters to about 100 meters.

The soil characteristics are also used for a pile drivability analysis. Sandy soils are very desirable for axial end bearing, but can be detrimental to pile driving when encountered near the surface. Clay soils are easier to drive piles through but do not provide good support for end bearing, although they provide good resistance to laterally loaded piles.

STRUCTURAL ANALYSIS

To perform a structural analysis of a new or used platform we develop a mathematical model of the structure using normally either of two common software packages developed for the offshore engineering: SACS, or StruCAD.



StruCad Model of offshore oil platform.

A model of the structure should include all principal members of the structure, appurtenances and major equipment

A typical offshore structure supported by piles 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 mudline and into the soil for many tens of meters. 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).

The top of the jacket is placed near the water level where a boat landing will be located for accessing the platform by boat.

The model definition file consists of:

- Definition of the type of analysis, the mudline elevation and water depth.
- Member sizes (member groups and sections).
- Member joints definition.
- Soil data (i.e. pile groups, T-Z, P-Y curve points).
- Plate groups.
- Joint coordinates.
- Marine growth input.
- Inertia and mass coefficients input.
- Distributed load surface area definitions.
- Wind area definitions.
- Members and/or group overrides (i.e. overrides for marine growth for pile sections inside the jacket),
- and finally followed by the load cases, which will include dead and live loading, environmental loading, crane loads, etc.

Any analysis of offshore platforms must also include the equipment weights and/or a maximum deck live loading (distributed area loading), dead loads in addition to the environmental loads mention above, and wind loads. Underwater, the analysis must also include marine growth as a natural means of enlargement of underwater projected areas subject to wave and current forces.

ON-SITE INSTALLATION

All the structural sections of an offshore platform must also be designed to withstand the lifting and installation stresses.

The jackets must be designed to be self supporting during installation. Consequently they must have "mudmats" at the bottom horizontal brace level which will be resting on the mudline. The mudmats are sections of the bottom of the jacket structure covered by stiffened plates to allow the weight of the jacket to be supported by the top layer of the soil at the ocean floor (the mudline). The mudmats are generally located adjacent to the jacket leg connections for obvious structural reasons.

The piles must be designed to withstand the stresses during installation. The installation of the piles is done above the waterline after the jacket has been lowered to the mudline. The piles are installed in sections. The first section must be long enough to go from a few meters above the top of the jacket leg to the mudline. The second section must be field welded to the first section at an elevation slightly higher than the top of the jacket legs. At this stage the second section is standing up to a height that is calculated depending on the size and weight of the pile driving hammer (which is placed on top of the pile sections), because the pile section is behaving like a cantilevered beam. All subsequent sections have to be designed as a cantilevered beam for the same reason.

When all the piles have been driven to the required design penetration they will be trimmed at the design "top of pile" elevation. The jacket will then be welded to the piles about 1.0 meters or less below the top of the piles.

The deck structure, whose legs will have "stabbing guides" at the bottom, will be lowered to fit on top of the piles, and will be welded to the piles.

Any riser or other operational pipes will then be field installed onto the platform.[2]

SPAR PLATFORMS

INTRODUCTION:-

[3]A spar is a deep-draft floating caisson, which is a hollow cylindrical structure similar to a very large buoy. Its four major systems are hull, moorings, topsides, and risers. The spar relies on a traditional mooring system (that is, anchor-spread mooring) to maintain its position. About 90 percent of the structure is underwater. Historically, spars were used as marker buoys, for gathering oceanographic data, and for oil storage. The spar design is now being used for drilling, production, or both. The distinguishing feature of a spar is its deep-draft hull, which produces very favorable motion characteristics compared to other floating concepts. Low motions and a protected center well also provide an excellent configuration for deepwater operations. Water depth capability has been stated by industry as ranging up to 10,000 ft.

The hull is constructed by use of normal marine and shipyard fabrication methods. The number of wells, surface wellhead spacing, and facilities weight determine the size of the centerwell and the diameter of the hull. In the classic or full cylinder hull forms, the upper section is compartmentalized around a flooded center well containing the different type of risers. This section provides the buoyancy for the spar. The middle section is also flooded but can be economically configured for oil storage. The bottom section (keel) is compartmentalized to provide buoyancy during transport and to contain any field-installed, fixed ballast. Approximate hull diameter for a typical GOM spar is 130 feet, with an overall height, once deployed, of approximately 700 feet (with 90% of the hull in the water column).

The first Spars were based on the Classic design. This evolved into the Truss Spar by replacing the lower section of the caisson hull with a truss. The Truss Spar is divided into three distinct sections. The cylindrical upper section, called the "hard tank," provides most of the in-place buoyancy for the Spar. The middle truss section supports the heave plates and provides separation between the keel tank and hard tank. The keel tank, also known as the "soft tank," contains the fixed ballast and acts as a natural hang-off location for export pipelines and flowlines since the environmental influences from waves and currents and associated responses are less pronounced there than nearer the water line.

A lateral catenary system of 6 to 20 lines keeps the spar on location. The mooring lines are a combination of spiral strand wire and chain. Because of its low motions, the spar can use a taut mooring system at a reduced scope and cost compared with a full catenary system. Each mooring line is anchored to the seafloor with a driven or suction pile. The hullend of the line passes through a fairlead located on the hull below the water surface, then extends up the outside of the hull to chain jacks at the top, usually 50 ft or more in elevation. Excess chain is stored in the hull. Depending on hull size and water depth, the moorings can vary in number up to 20 lines and contain 3,700 ft of chain and wire. Starting at the seafloor, a typical mooring leg may consist of approximately 200-ft long, 84-inch diameter piles; 200 ft of 4¾-inch bottom chain; 2,500 ft of 4¾-inch spiral strand wire; and 1,000 ft of 4¾-inch platform chain. The footprint created by the mooring system can reach a half-mile or more in diameter measured on centers from the hull to the anchor piles.

The topsides configurations follow typical fixed platform design practices. The decks can accommodate a full drilling rig (3,000 hp) or a workover rig (600-1,000 hp) plus full production equipment. Production capacities range up to 100,000 BOPD and 325 MMcfgpd. The type and scale of operation directly influence deck size. The larger topsides would be consistent with drilling, production, processing, and quarters facilities, and could also include remote wells/fields being tied back to the spar for processing. Total operating deck load, which includes facilities, contained fluids, deck structural and support steel, drilling/workover rig, and workover variable loads, can be 6,600 tons or more. Crew quarters on a production/workover spar may accommodate 18 workers, while a full drilling and production facility may house 100 people.

There are three basic types of risers: production, drilling, and export/import. Production – Each vertical access production riser is top tensioned with a buoyant cylinder assembly through which one or two strings of well casing are tied back and the well completed. This arrangement allows for surface trees and a surface BOP for workover. The drilling riser is also a top-tensioned casing with a surface drilling BOP, which allows a platform-type rig to be used.

Export/import risers can be flexible or top-tensioned steel pipe or steel catenaries. Production risers consist of a conventional subsea wellhead at the mudline and a tieback connector with a stress joint for taking the stresses associated with environmentally imposed displacements. The seafloor pattern (footprint) depends on the number of risers. For example, a riser pattern may consist of 16 risers in a parallel 8 by 2 pattern, on 15-ft centers within each row and 20 ft between rows, thus having a rectangular footprint approximately 100 ft long by 20 ft wide. Other patterns (e.g., circular or square) are available. An example production riser for a spar could be either a single or dual-bore (concentric pipe) arrangement. Low motions of the spar allow the use of the economical steel catenary riser technology for subsea production trees.

Installation is performed in stages similar to those of other deepwater production systems, where one component is installed while another is being fabricated. Installation schedules heavily depend upon the completion status of the hull and topsides.

Prior to the delivery of the hull to location, a drilling rig might predrill one or more wells. During this time, export pipelines are laid that will carry production either to another platform (host) or to shore after processing. A presite survey is performed and includes the following: onbottom acoustic array installed for the mooring system, identified obstructions removed, anchor pile target buoys preset, and a final survey of the mooring lay down area performed. Once on location, a derrick barge installs the anchor piles and mooring system. The installation of the anchor piles is performed using a deck-mounted lowering system designed for deepwater installations and an underwater free-riding hydraulic hammer with power pack. Remotely operated vehicles (ROV's) observe the hammer and umbilical as the pile is lowered and stabbed into the seafloor.

In conjunction with pile installation, the mooring system is laid out and temporarily abandoned. A wire deployment winch with reels specifically designed for this type of work handles each wire. An ROV monitors the wire lay-down path as the derrick barge follows a predetermined route until it reaches the wire end on the deployment reel. The end of the mooring wire is then connected to an abandonment/recovery line and marked for later use in attaching the mooring system to the hull.

To date, all GOM spar hulls have been built in Finland. Upon completion of the hull, it is shipped to the Gulf of Mexico on a heavy-lift vessel such as the Mighty Servant III. Because of its size and length it is necessary to divide the spar hull into two sections. Upon arrival at an onshore facility, the sections are connected together using a wet mating technique, which allows for lower cost and ease of handling and positioning, and eliminates the need for special equipment. The hull is then ready for delivery to location.

Depending on the proximity of the onshore assembly location to the open sea, smaller tugs (2,000 to 4,000 hp) may be used first to maneuver the hull into deeper water, and then larger oceangoing tugs (7,000 hp) tow the spar to its final destination.

A derrick barge and a pump boat await arrival of the hull on site. The barge and boat up-end the hull. While the hull is being held loosely in place, the pump boat fills the hull's lower ballast tank and floods the centerwell. The hull self-up-ends in less than two minutes once it is flooded. Next, the derrick barge lifts into place a temporary work deck brought to the site on a material barge. Tasks performed using the temporary work deck are basic utility hook up, mooring line attachment, and riser installation.

The hull is positioned on location by a tug and positioning system assistance. Then the mooring system is connected to the hull. After the mooring system is connected, the lines are pretensioned. Then the hull is ballasted to prepare for the topsides installation and removal of the temporary work deck.

Topsides are transported offshore on a material barge and lifted into place by the derrick barge. An important characteristic is that the derrick barge can perform the lift in dynamic positioning mode. The topsides consist of production facilities, drilling/workover rigs, crew living quarters, and utility decks. Installation of miscellaneous structures such as walkways, stairways, and landings are also set in place by the derrick barge.

The last pieces of equipment to be installed are buoyancy cans and the associated stems. The cans are simply lifted off the material barge and placed into slots inside the centerwell bay. Next, the stems are stabbed onto the cans. To prepare for riser installation, the cans are ballasted until the stem is at production deck level.[3]

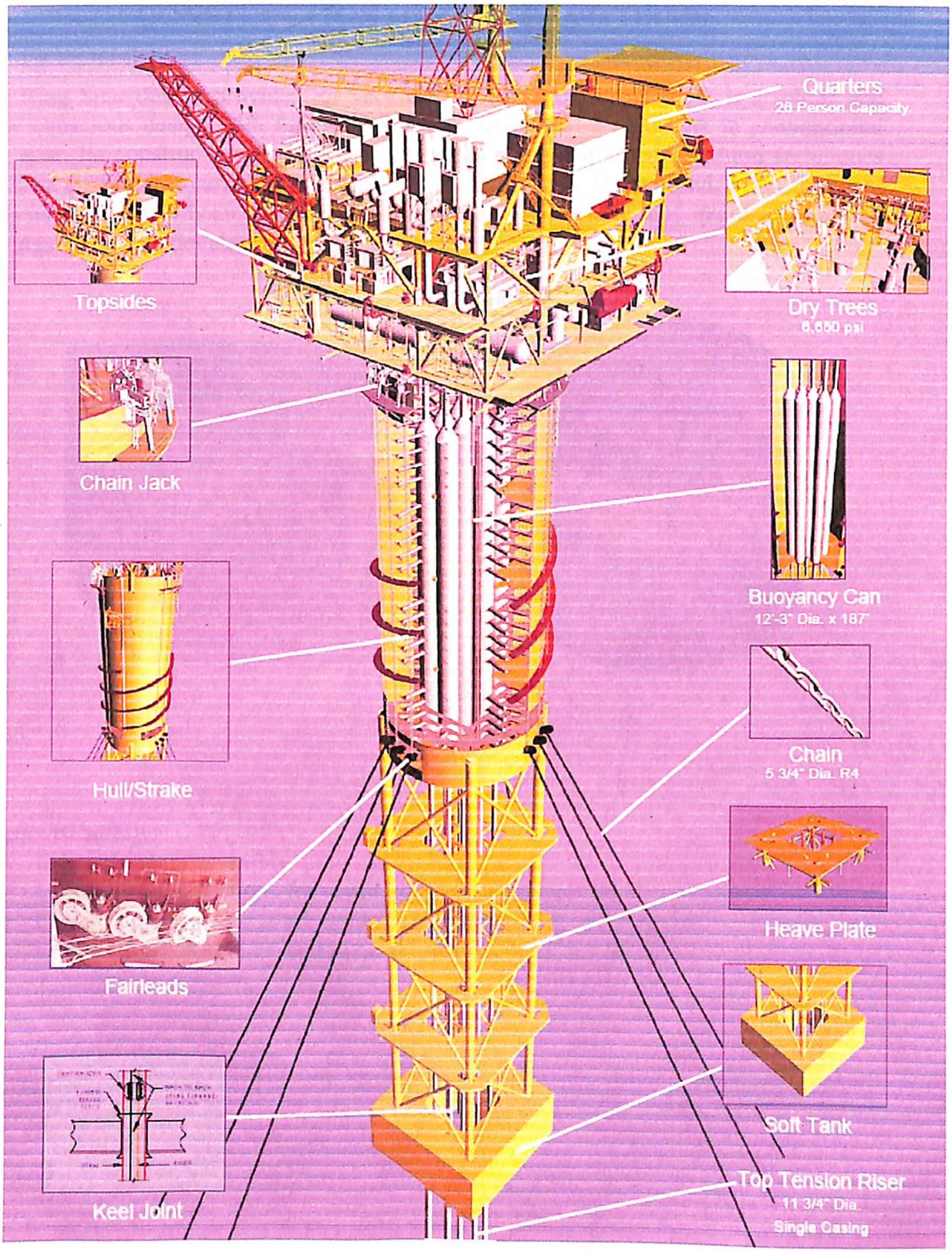
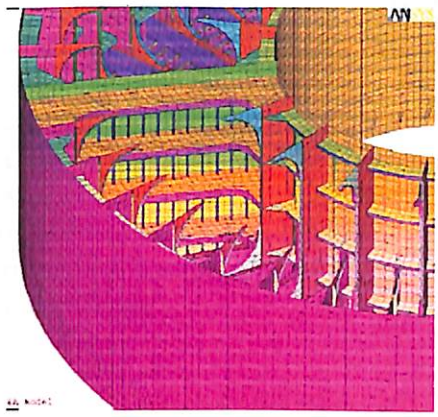
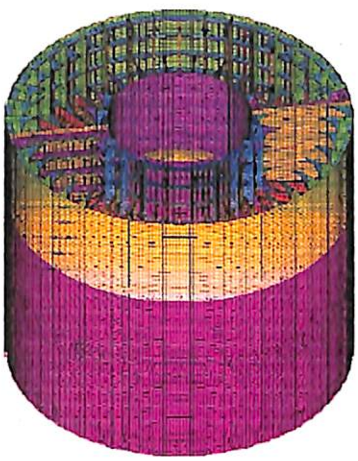


FIGURE SHOWING ALL THE COMPONENTS OF SPAR PLATFORM

CONSTRUCTION OF SPAR PLATFORMS

[4]The Ring Spar design provides for very cost effective construction. It is a robust and safety conscious design with lighter and fewer pieces than a hard tank in conventional truss spar. Its construction friendly concept enables innovative construction techniques that save time and money. The maturity of the design is well advanced. Finite Element Analysis (FEA) has been performed on numerous load cases and detailed structural drawings have been developed.



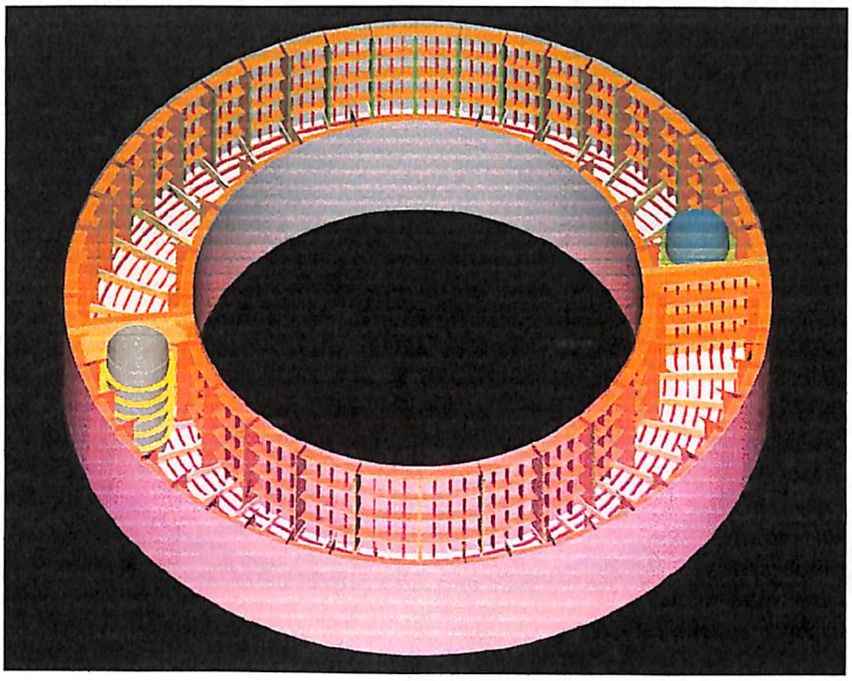


- Improved safety
  - Increased shop assembly
  - Large open top sections for ventilation, crane access
  - Fewer compartments to access during operating life
  - Less air work during assembly on skidways

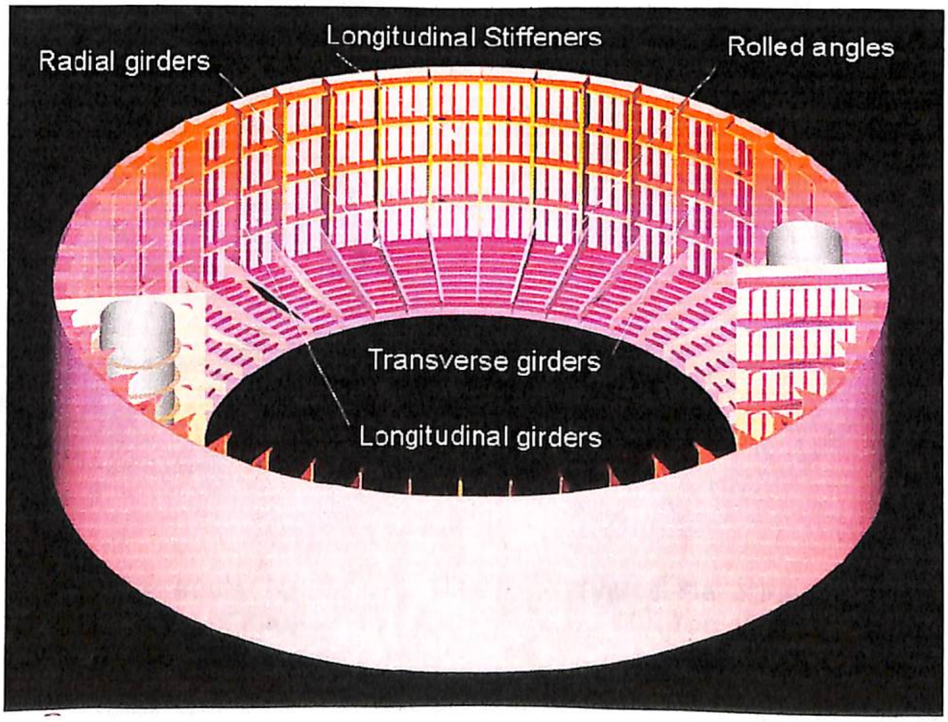
- Retains hydrodynamic characteristics of 13 proven Truss Spar designs
  - Tested, calibrated, proven hydrodynamic form;
  - Exterior looks and acts the same
- Focus on enhanced constructability
  - Simplified framing patterns
  - Easier fit-ups

STEPS INVOLVED IN CONSTRUCTION

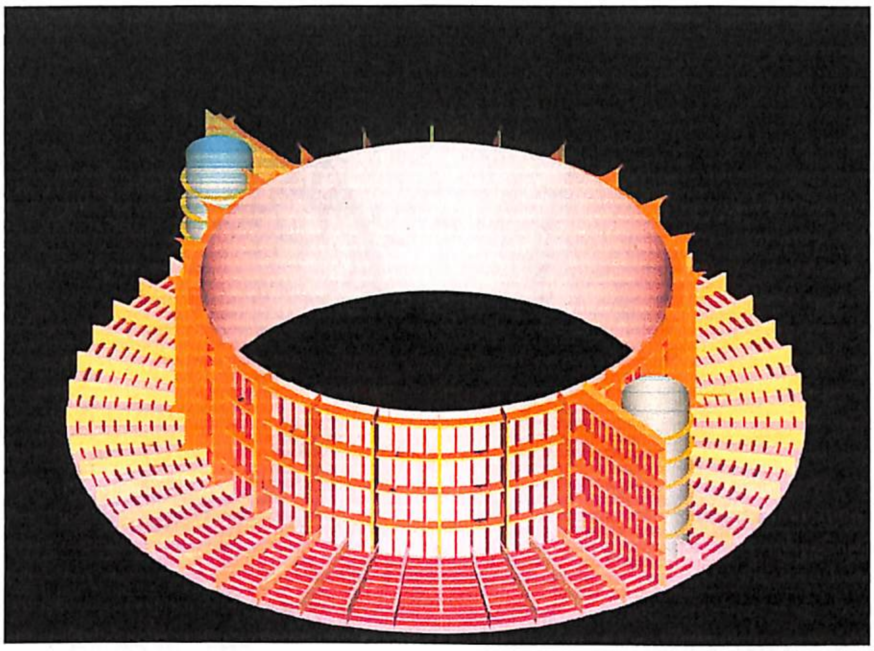
1) *Ring Spar* Hard Tank Framing Scheme –One Full Module



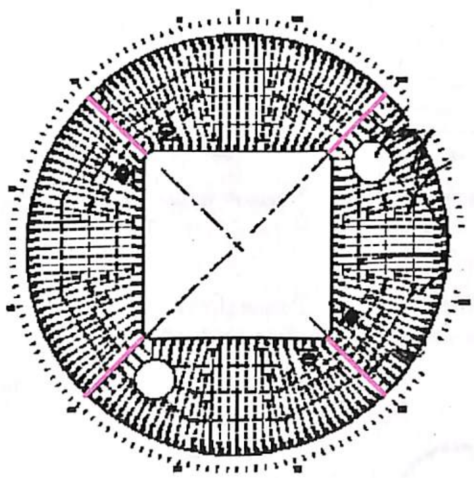
2) *Ring™Spar*Hard Tank Framing Scheme –Outer Shell Stiffening



3) *Ring™Spar*Hard Tank Framing Scheme –Centerwell Stiffening

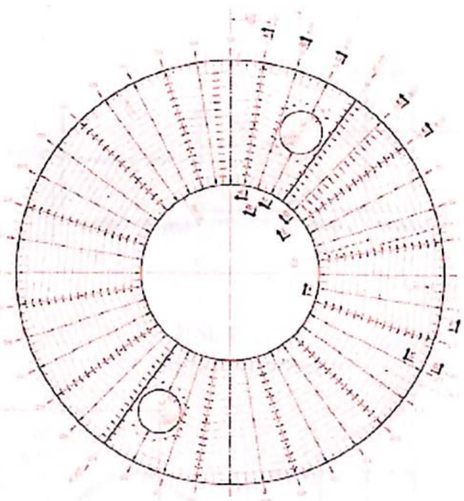


4) *Ring Spar* Hard Tank Framing Scheme –Flat Stiffening



Typical Flat Stiffening
(On Underside of Flat)

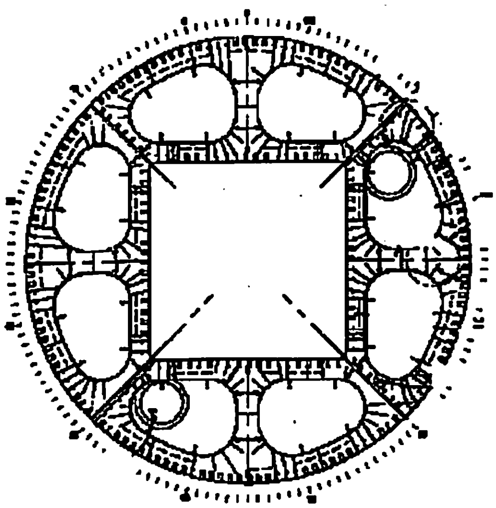
Traditional Truss Spar



Typical Flat Stiffening
(On Top of Flat)

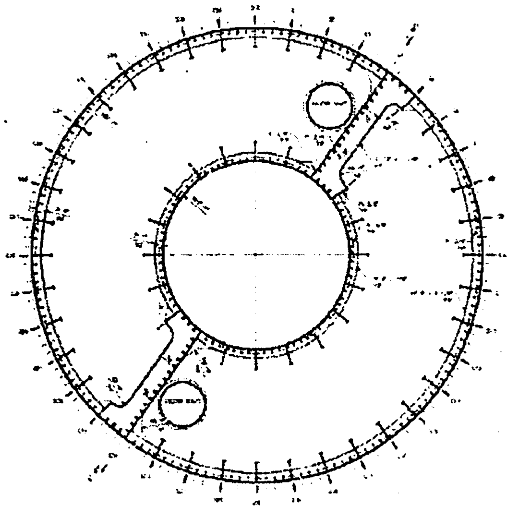
Ring™ Spar

5) *Ring™Spar*Hard Tank Framing Scheme –Section Between Flats



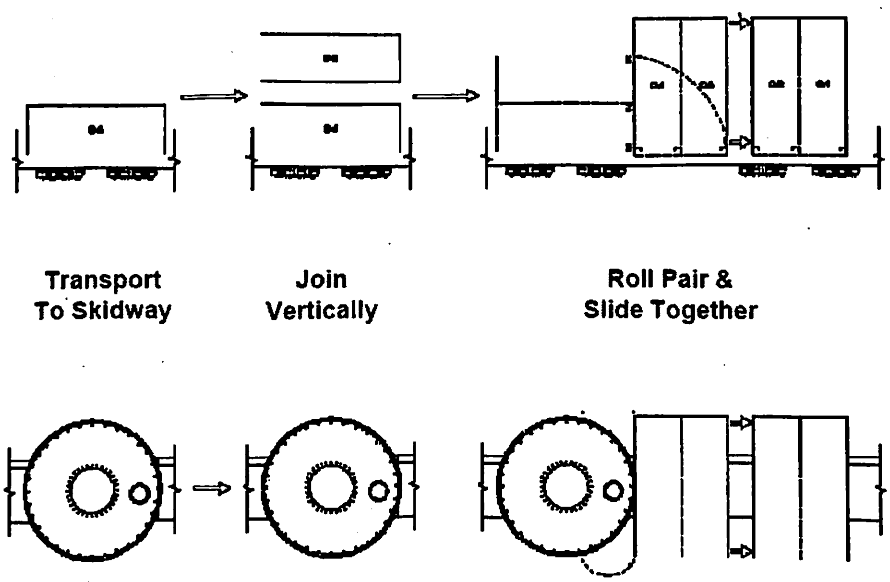
Typical Ring Frames
Between Flats

Traditional
Truss Spar



Typical Section
Between Flats
Ring™ Spar

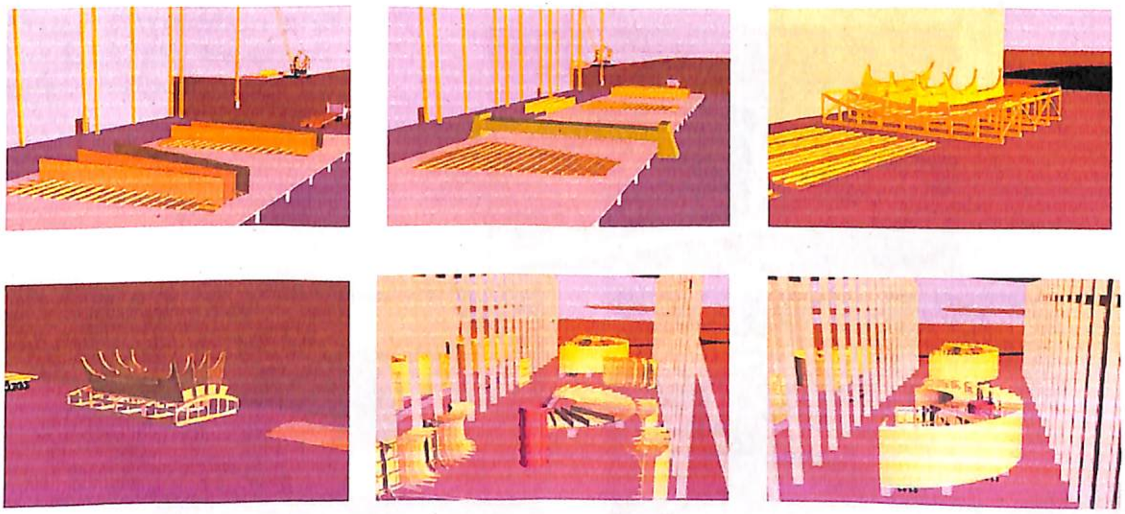
6) *Ring Spa* Hard Tank Assembly Sequence –Joining Rings On Skid ways



7) Traditional Truss Spar Construction –Preparing To Fit-up Quadrant Section

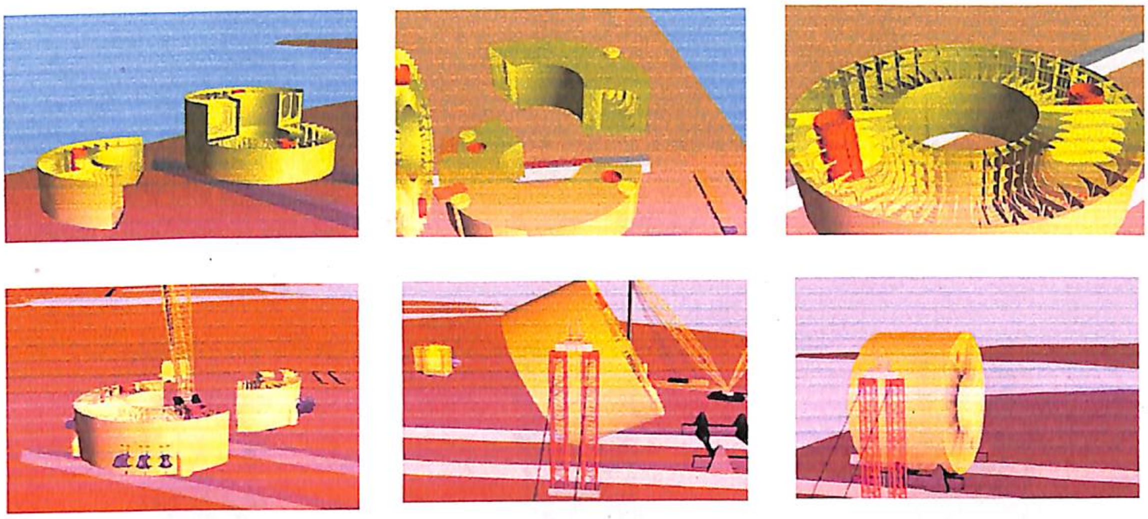
8) *Ring™Spar*Animated Fabrication Sequence

In the workshop....



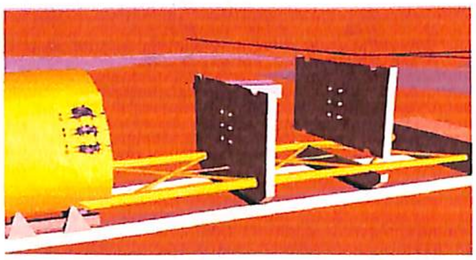
9) *Ring™Spar*Animated Fabrication Sequence

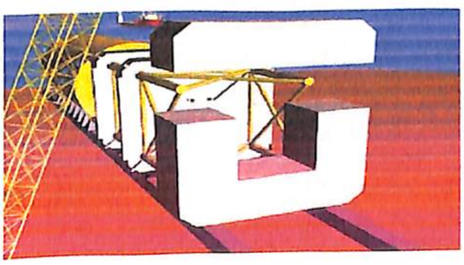
In the assembly area....

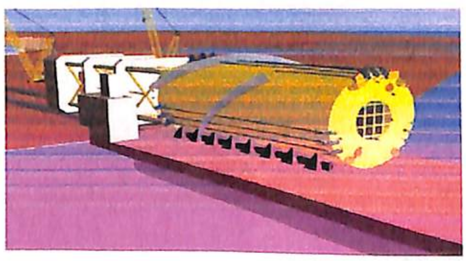


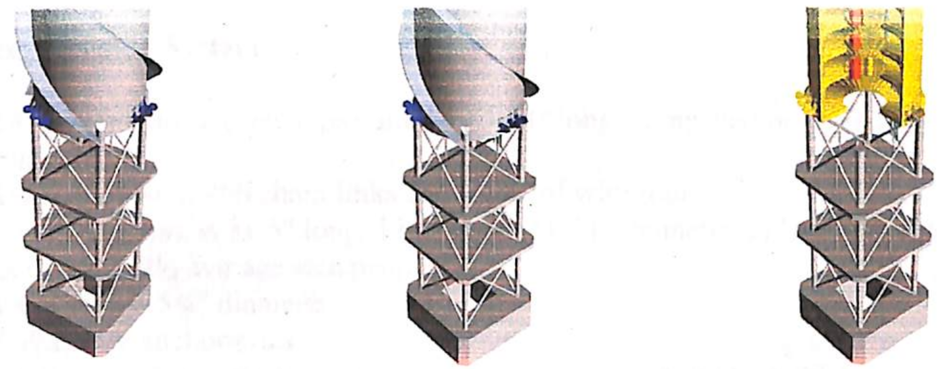
10) *Ring™Spar*Animated Fabrication Sequence

Truss installation and
loadout and tie down
preparations....









[5]COMPONENTS SPECIFICATION OF NEPTUNE SPAR PLATFORM:-

Statistics: Hull

1st drilling and production spar ever built

- 122' Diameter—could almost fit an entire baseball field inside
- Could hide the Washington Monument inside the well bay
- 705' long, exceeds the height of many skyscrapers.
- Weighs 28,700 tons, as much as 12,000 Suburban trucks
- 58' x 58' well bay
- 20 well slots

Statistics: Mooring System

- 14 mooring lines, each approximately 3000' long, composed of chain and wire rope
- Total of about 8,400 chain links & 28,000' of wire rope
- Each chain link is 31.5" long, 17.6" wide, 5¼" in diameter and weighs 426 lbs—as much as 2½ average size people
- Wire rope is 5¼" diameter
- 8' diameter anchor piles
- Seafloor anchor pattern encircles an area equivalent to 264 city blocks

Statistics: Topsides

- 55,000 barrels/day oil capacity
- 72 million standard cubic feet/day gas capacity
- 9 megawatt electric power capability—enough for a small city
- 35 million standard cubic feet/day gas injection
- Weighs about 17,000 tons, as much as 7,100 Suburban trucks
- 110-person sleeping capacity
- Deck area about the size of 2½ football fields

Statistics: Risers & Subsea Wellheads

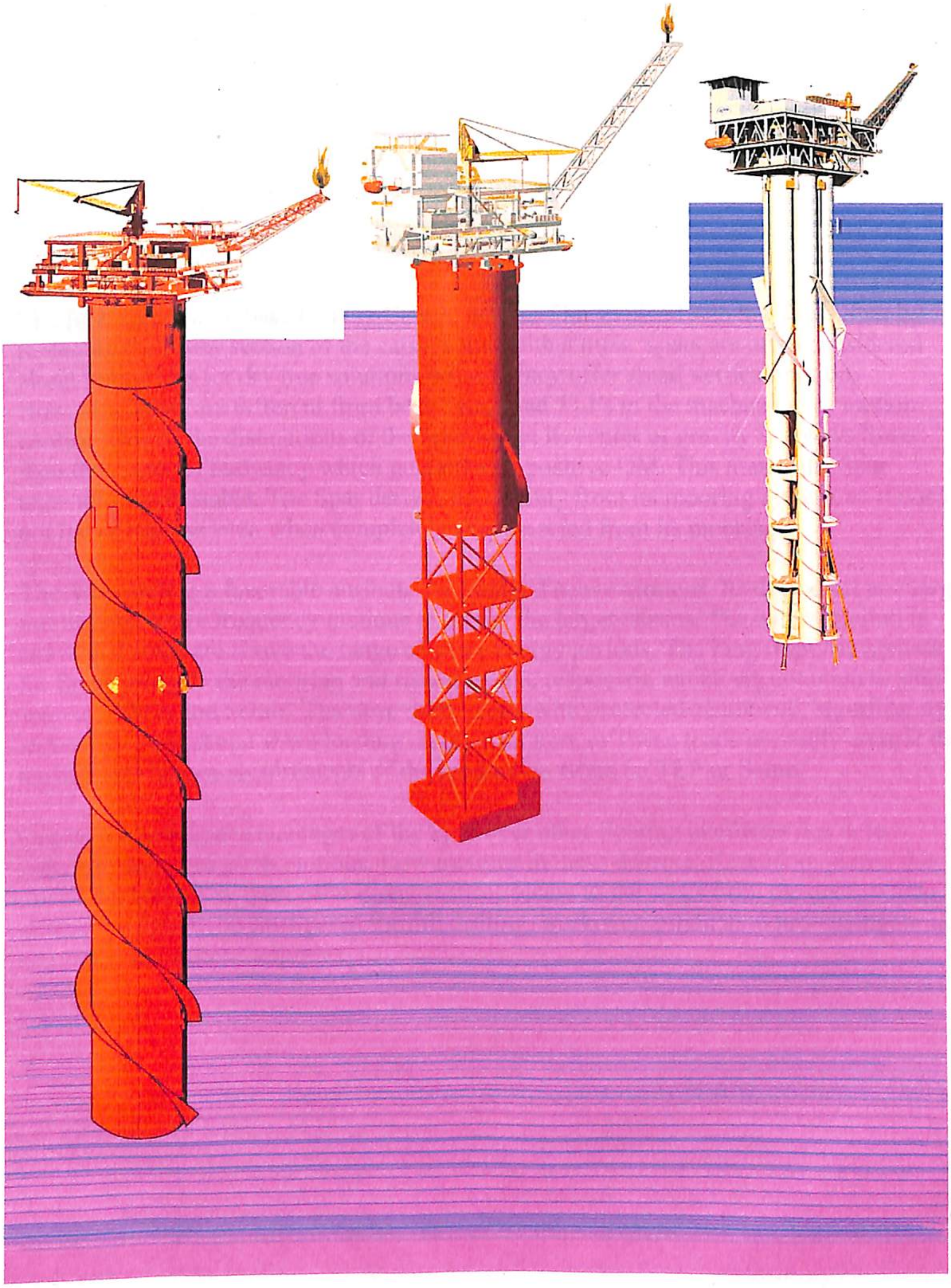
- Up to 20 Production risers, 2 export pipeline risers, and 1 drilling riser
- Each approximately 2,650' long to span from seafloor wellheads to the topsides
- 20 subsea wellheads & 2 export riser bases on seafloor arranged in 140' diameter circle with 20' spacing.[5]

TYPES OF SPAR PLATFORM

[6]Classic Spar
In 1996, Kerr-McGee pioneered the use of spar technology in deepwater field development at its Neptune field, in the Gulf of Mexico, in 1,930 feet. The classic spar is a large, cylindrical hull moored in a vertical position. The innovative spar production system offers a stable platform that can accommodate dry trees, and support workover and drilling operations. The world's first spar floating production facility was installed at the Kerr-McGee-operated Neptune field in 1996. Kerr-McGee Global Producer IV is in 1,930 feet of water in the Gulf of Mexico's Viosca Knoll block 826.

Truss Spar
In 2002, Kerr-McGee deployed the second generation of spar technology, the truss spar, at the Nansen and Boomvang fields in more than 3,000 feet of water in the gulf, marking another industry milestone. This new design replaces the lower portion of the cylindrical hull with an open truss structure reducing size and cost. Kerr-McGee achieved first production from its third truss spar at the Gunnison field in the deepwater gulf in December 2003. Kerr-McGee installed its fourth truss spar over the Constitution field in 5,000 feet of water.

Cell Spar
In 2004, Kerr-McGee deployed the third generation of spar technology, the cell spar, marking another industry first. The cell spar's advantage — ease of fabrication and flexibility — makes it a more cost-efficient design, providing another option to reduce the reserve threshold for economic development of deepwater fields. Red Hawk achieved first production in July 2004. The Red Hawk cell spar was fabricated at Gulf Marine Fabricators yard in Corpus Christi, Texas. The cell spar's hull is formed by seven hollow tubes, each 20 feet in diameter, used to provide both stability and buoyancy for people, production equipment and related systems.



11) Ring Spar Advantages

Offshore Platform: Spar Construction & Development

In the field

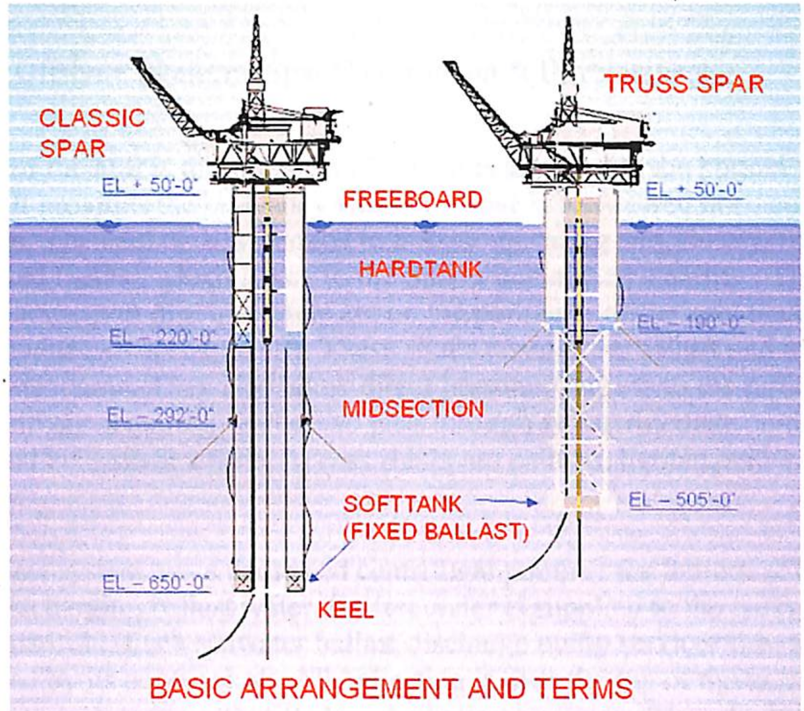
In the field

Spar Technology

The first **Spars** were based on the Classic design. This evolved into the Truss Spar by replacing the lower section of the caisson hull with a truss. Spars are often considered along with TLPs for dry tree solutions because they offer small vertical motion. However, Spars are different from both Semis and TLPs in the mechanism of motion control. One of the distinctions of the Spar is that its center of gravity is always lower than the center of buoyancy which guarantees a positive GM. This makes the Spar unconditionally stable. The Spar derives no stability from its mooring system, so it does not list or capsize even when completely disconnected from its mooring.

The deep draft is a favorable attribute for minimal heave motions. Its deep draft and large inertia filter wave frequency motions in all but the larger storms. The natural period in heave and pitch are above the range of wave energy periods. The long response periods for Spars mitigate the mooring and riser dynamic responses, which are common to ship shaped FPSOs and Semis. The deep draft, along with protected centerwell, significantly reduce the current and wave loading on the riser system These loads normally control the tension and fatigue requirements of the production risers on TLP or Semis

One of the principal advantages of the Spar over other floating platforms lies in its reduced heave and pitch motions. Low motions in these degrees of freedom permit the use of dry trees. Dry trees offer direct vertical access to the wells from the deck, which allows the Spar to be configured for full drilling, workover, production processing, or any combination of these activities.[6]



Truss Spar Concept

[7]The Truss Spar is divided into three distinct sections. The cylindrical upper section, called the "hard tank," provides most of the in-place buoyancy for the Spar. The middle truss section supports the heave plates and provides separation between the keel tank and hard tank. The keel tank, also known as the "soft tank," contains the fixed ballast and acts as a natural hang-off location for export pipelines and flowlines since the environmental influences from waves and currents and associated responses are less pronounced there than nearer the water line.

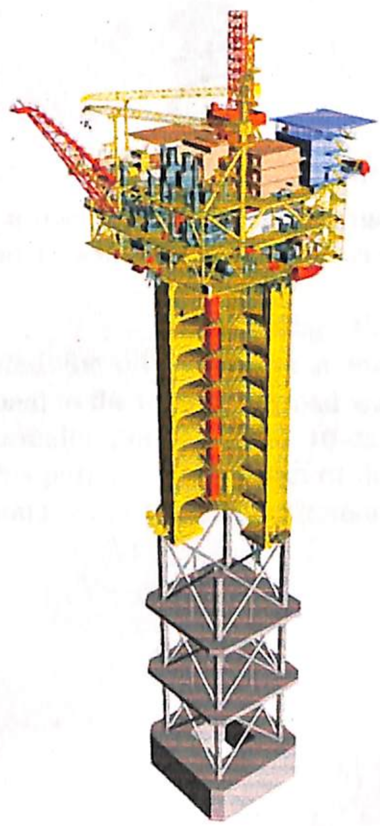
In the original designs, the Hard Tank architecture is the same in the Classic and Truss Spar designs FloaTEC, LLC has recently developed a Ring Spar architecture for the Hard Tank. This architecture offers a more fabrication-friendly option with reduced fabrication costs. Horizontal decks and radial bulkheads divide the hard tank spaces into tanks and voids. The lower set of tanks is configured to contain seawater ballast, which can be increased, decreased, or moved between tanks to correct for major changes in topsides weight, topsides eccentricity, SCR weight, or hull flooding resulting from damage. A ring of additional voids is provided at the waterline area. These are used during topsides installation and prior to TTR installation.

The trussed mid-section of the hull is an X-braced space frame constructed of tubular members and flat plates called "heave plates." The heave plates increase the added mass in the vertical direction and thereby increase the natural heave period of the Spar and bringing it above the range of periods in the wave energy. In a Truss Spar, they also increase heave damping.

The third section of the hull is the "keel tank," which is attached to the bottom of the truss at the keel. It provides the buoyancy while the Spar is wet-towed horizontally to site for installation. The keel tank is flooded to initiate upending and, finally, receives the field-installed, fixed ballast, which is key to the Spar's unmatched stability. The porches for the steel catenary export pipeline risers are on the perimeter of the keel tank.
The Spar hull includes two access shafts. These shafts contain the ballast and utility piping and instrumentation. They also allow direct personnel access to the piping and to every void tank without requiring workers to pass through an intermediate compartment. Only one void need be open at a time. Access shafts are painted, lighted, and vented, as required, for entry.

The seawater ballast system has a dedicated centrifugal pump at the bottom of each access shaft for discharging ballast water. Ballast water is supplied to the tanks from the utility seawater manifold. Each seawater ballast discharge pump services the same two ballast tanks served by its access shaft. All ballasting is over the top of the hull, so that ballast tanks have to be intentionally filled by the ballast operator. This eliminates the possibility of inadvertent flooding, which can occur if a sea-chest system is used.

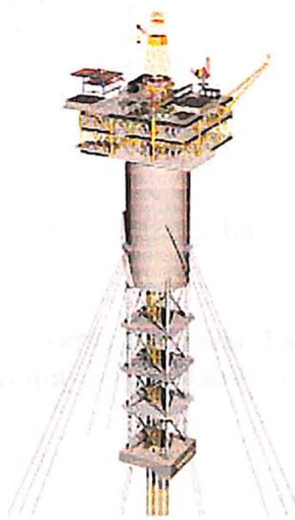
LLC's Innovative Ring™ Spar Concept Improves on the Traditional Truss Spar



Truss spar hull construction methods typically involve fabrication of quadrant sections, often necessitating time consuming and complex construction techniques. In an effort to develop a more construction friendly design, FloaTEC, LLC spent a number of years working with its fabrication yard personnel to come up with a better design. This resulted in FloaTEC, LLC's innovative Ring™ Spar concept - a robust and construction friendly truss spar design. The design provides for very efficient and cost effective construction. It is a safety conscious design with fewer pieces than the hard tank on a conventional truss spar, and its construction friendly concept enables innovative fabrication methods to be used. Details of this new innovative design can be downloaded by clicking on the links below.[7]

SPAR PLATFORMS: DEVELOPMENT

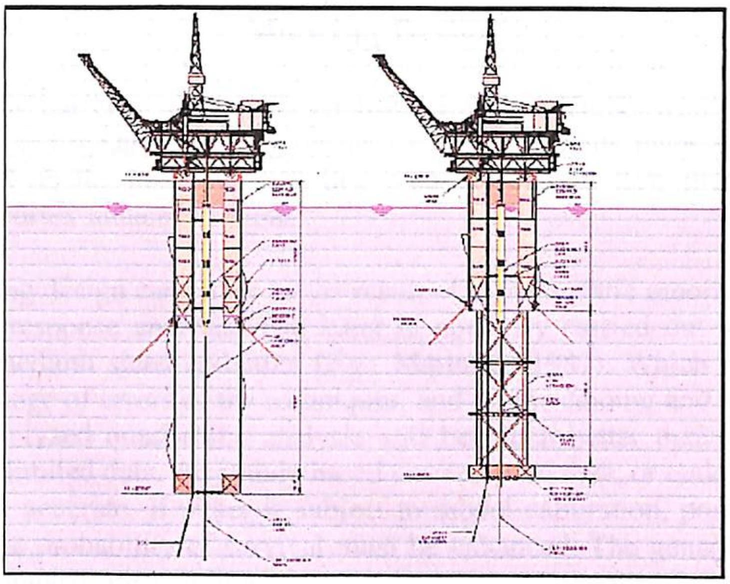
[8]The basic form of the spar platform, the classic spar, is a deep-draft, caisson-type, floating structure with a fully compartmented upper section that is buoyant and with 2 lower sections that are flooded. The lowest compartments in the upper buoyant section are configured for variable seawater ballast to maintain draft and trim under varying topside loading conditions. The hull uses standard ship-type plate and stiffener construction and contains an open centerwell (moonpool). The applicable water depth range is considered to be from 1,500 ft. to 10,000 ft., although shallower and deeper depthsare achievable.



Stationkeeping is provided by lateral, catenary anchor lines which are attached to the hull near its center of pitch for low dynamic loadings. Because of the very favorable interaction of the hull and mooring system, a spar uses a taut catenary system of chain and wire, terminating at the sea bed in piled anchors, installed by driving or suction techniques. This system has much shorter scopes than conventional full catenary arrangements and is correspondingly more economical.

Rigid Steel production risers are located within the centerwell where the protected water allows each riser to be supported in tension by its own buoyancy module. This riser arrangement permits the use of surface (dry) trees at the deck level. The very favorable motions of a spar platform permit the use of steel catenary risers for both export pipelines and import flowlines from remote well sites.

Using the normally flooded center section, a spar can be configured for oil storage at a low marginal cost. Since the size of the hull is usually proportional to the topside payload and the corresponding production throughput, the hull can normally store an 8- to 10-day supply of oil without increasing the diameter or draft for this purpose. This aspect of the spar's design makes it suitable for shuttle tanker turn around, even from rather remote locations.



Finally, a spar platform is relatively insensitive to water depth and very insensitive to seabottom topography and geology, so it is a very good candidate for relocation several times during its 20- to 40-year design life.

The result is a system that, compared to other systems for very deep water, has been shown to cost less to build and install, to have greater flexibility, and to have more favorable motions when subjected to the offshore environment.

Spar Characteristics

-Applicable in 1,500 ft. to 10,000 ft. water depths
-Cost relatively insensitive to water depth, most competitive in very deep water
-Hull cost is relatively insensitive to deck payload
-Platform motions are mostly lateral (minimal heave)
-Uses standard shipyard and offshore deck construction
-Hull is initially transported by towing in a horizontal, self-floating position
-Wells can be pre-drilled or drilled from the platform
-Production risers are steel pipe with surface trees
-Hull can be configured for significant liquids storage if this is advantageous
-Particularly applicable in remote locations which lack infrastructure
-Economical to relocate to other sites, in both deeper and shallower water.

Mooring Design

For a spar, currents will usually control the design. Unlike wind and wave, which results in mean and dynamic loading on the structure, currents loads tend to produce a large mean load on the hull that is in-line with the current flow plus transverse hull motions due to vortex induced motions.

A mooring design can either be the result of a quasi-static mooring analysis, or of a full dynamic response analysis. The latter is normally carried out using proprietary software on a medium sized computer (e.g., Marintek, 1987). Which is better depends largely on the range of errors of the techniques, and on the amount and accuracy of input data. A well analyzed quasi-static analysis will be much better than a dynamic study performed with limited data. Any study based on measured data, or tank trials will also in general be more accurate. If either is subject to model calibration, post-monitoring and analysis, then the probability of survival must be enhanced. The general steps in quasi-static mooring analysis are as follows:

(i) The mooring geometry and mooring excursion/force equations are defined.
(ii) The mean environmental force is applied to the system, and the excursion (offset) calculated.
(iii) The periodic wave forces, and response amplitude is now applied to the system.
(iv) The line tensions resulting from this maximum excursion are now calculated.
(v) These line tensions are now compared with the minimum breaking load of the riser components.
(vi) The maximum peak anchor loads are calculated for each line, and direction.
(vii) A safety factor (generally 2) is introduced in to the line strengths.
(viii) The maximum peak line loads are recalculated with 1 line broken, or after a line failure.
(ix) If the proposed mooring specification fails the safety factor test, then a new specification is tried.

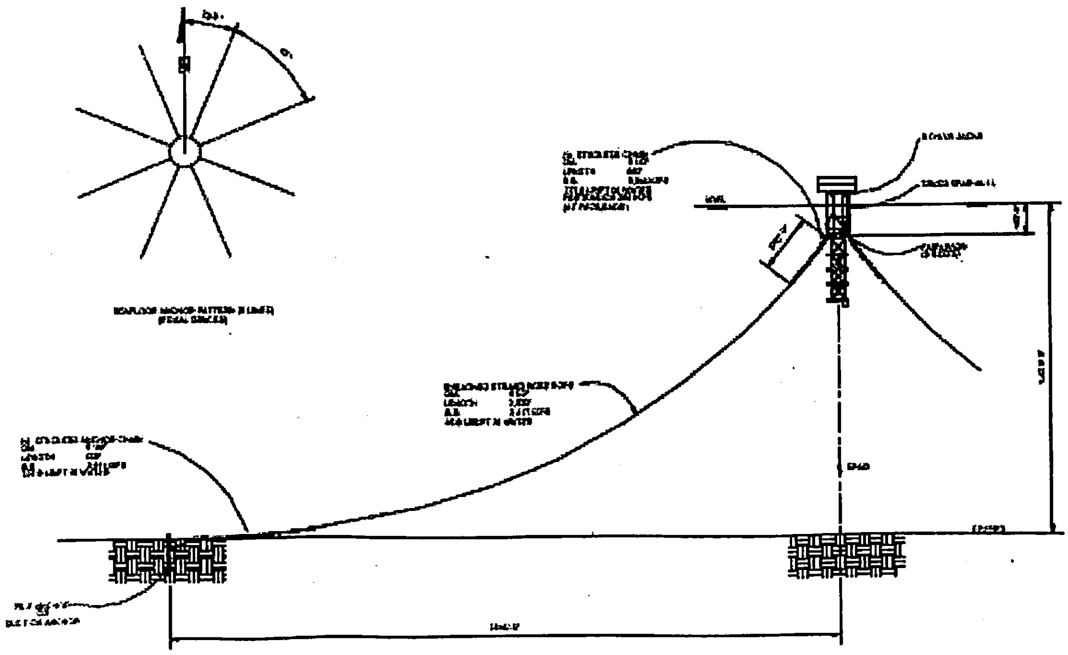
This type of mooring analysis is most common, and documented by many sources. In addition, it is endorsed by a number of insurance classification societies. However, it is open to errors through the lack of sufficient, or accurate data, and particularly through under-estimating wave climate. Also, a mooring system which may survive, could still be so "stiff" that fish stocks are killed through abrasion, or nets torn, during violent storms.

Spar Mooring

Taut Mooring

The mooring system for the spars built till date consists of a chain-wire-chain taut catenary system. A "taut" mooring is defined as one in which the anchor loads have an uplift component for all load condition, i.e. the anchor chain or wire never lies on the seabed.

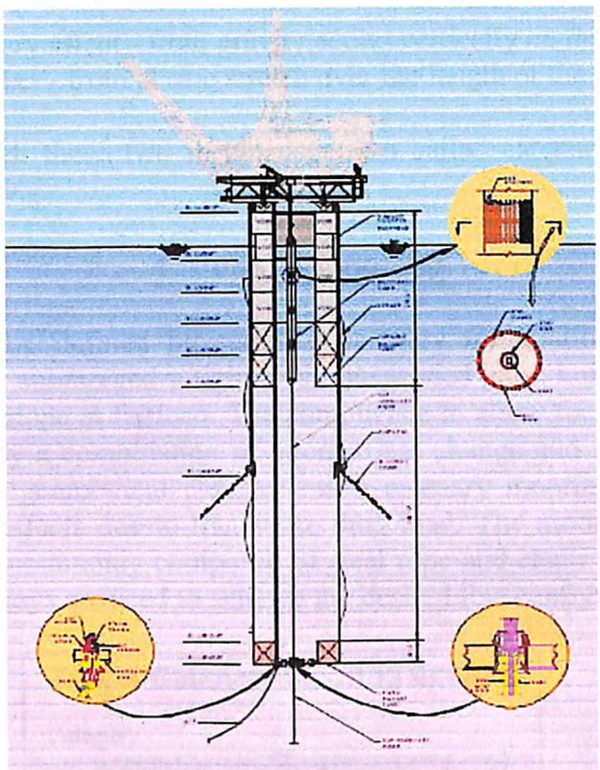
The spar motions are small enough, even in the 100-year hurricane, that the taut system can be used without synthetic mooring lines. The taut system saves a considerable length of wire and chain needed for a conventional catenary mooring.



Mooring Lines

The platform chain is tensioned using chain jacks or windlasses, which are installed on the periphery of the upper deck of the hull. The chain runs from the chain jack to a fairlead, which is located from up to 350 ft below the mean waterline. The length of platform chain is determined by the amount chain, which needs to be pulled in or paid out to maneuver the spar.

The midsection of the mooring system consists of a spiral strand wire rope or polyester line. For long life the steel strand is typically sheathed with a urethane coating. the lower end is attached to a length of anchor chain. The length of chain and the mooring tension is selected so that the wire will not make contact with the sea bottom except under the most extreme condition.



Anchoring

The anchor chain is connected to a piled or suction anchor which can sustain uplift and lateral loads. The pile padeye is usually about 50 ft. below the mudline, so that the bending moment from the mooring forces is minimized.

Mooring

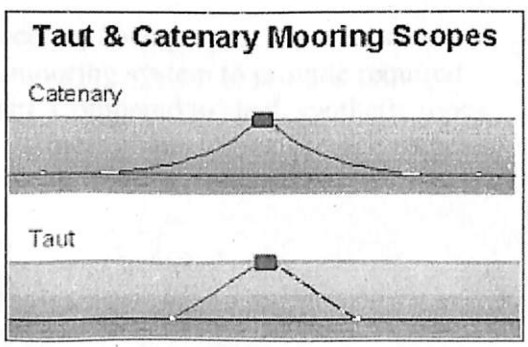
Mooring systems are compliant systems. They provide resistance to environmental loading by deforming and activating reaction forces. Mooring systems work as spring mechanisms where displacement of the floater from a neutral equilibrium position causes a restoring force to react to the applied loading. The tension spring effect of mooring lines derives from two mechanisms:

- hanging catenary effect - from gravity acting vertically on the line
- line elastic effect - from elastic stretch over the length of the line.

Mooring systems with these two mechanisms are called catenary moorings and taut moorings, respectively.

Catenary mooring

Catenary moorings are defined by standard catenary formulations, which relate the following parameters: submerged weight of the suspended lines, horizontal mooring load, line tension and line slope at fairlead. The compliance to allow for wave-induced floater motions is ensured by a combination of geometrical change and axial elasticity of the lines. The large line geometrical changes make catenary mooring systems subject to significant dynamic effects due to transverse drag load. The mooring lines in catenary mooring systems are commonly composed of steel rope and chain segments. Sometimes clump weights and buoys are used to achieve the desired line configurations.



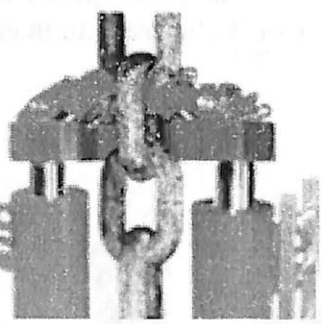
Taut mooring

In a taut mooring system the lines are nearly straight between the anchor and fairlead. The vertical forces are taken up as anchor and vessel reactions directly. The compliance to allow for wave-induced floater motions is provided mainly by line elasticity.

The transverse geometric changes in taut mooring systems are not as large as in catenary systems, thus dynamic effects due to transverse drag loads are moderate.

Synthetic rope mooring

Synthetic ropes have recently been proposed and used as mooring lines in a taut mooring system to provide required elasticity and low weight. Compared to steel, synthetic ropes exhibit more complex stiffness characteristics (e.g. hysteresis), which may induce important dynamic effects.



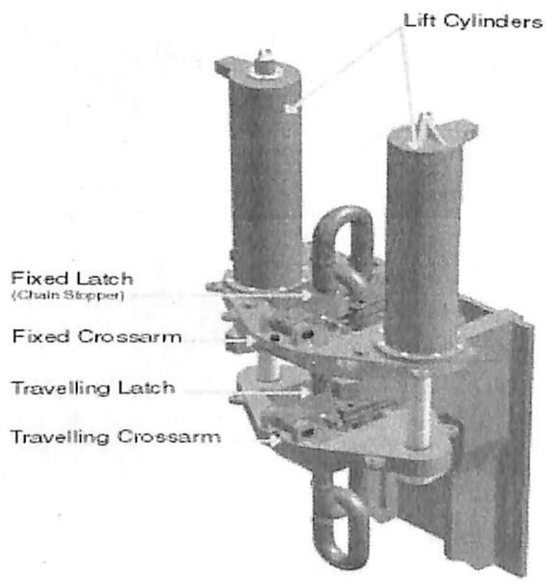
Tensioning system

One of the safest and most efficient ways to lift, tension, or move heavy loads using chain, is the linear chain jack, as shown in the picture below.

As the word "Linear" in the product's name implies, the chain is always lifted, pulled, or tensioned in a straight line. There are no induced link bending stresses and interlink wear inherent when jacking the chain and simultaneously bending it around a shoe or chainwheel.

The Linear Chain Jack has a significantly reduced footprint when compared to other devices such as windlasses or winches. This reduces the amount of sometimes crucial deck space required to. The Linear Chain Jack has been designed such that the chain is always mechanically held by either the Fixed or Traveling latches. This makes it impossible for the chain to be released inadvertently due to loss of hydraulic power or operator error. Its hydraulically based power source allows it to be incorporated into a multi-unit system for the safe, efficient, and synchronized movement of extremely heavy loads exceeding 30,000 metric tons.

- The design is kept simple with few moving parts. This results in low initial, operating and maintenance costs.
- Chain is mechanically held at all times.
- All parts can be easily removed for preventative maintenance or repairs.
- The latches cannot be released while under load.
- Simplified foundation structural design.



Evaluate mooring alternatives

The most common tension member lines used are synthetic fiber ropes and wire rope. Synthetic lines have the advantage of easy handling and some types have stretch, which can be used to fine tune static and dynamic mooring behavior and aid in load sharing between tension members. Wire rope has the advantage of durability.

Synthetic Fiber Ropes

Mooring lines are formed by weaving a number of strands together to form a composite tension member. Lines are made of different types of fiber and various constructions. The size and type of synthetic line specified in a given design will depend upon parameters such as those shown in table below.

Wire Ropes

Wire rope is composed of three parts: wires, strands, and a core. The basic unit is the wire. A predetermined number of wires of the proper size are fabricated in a uniform geometric arrangement of definite pitch or lay to form a strand of the required diameter. The required number of strands are then laid together symmetrically around a core to form the rope. Refer to NAVSEA NSTM 613 for additional information.

Factors considered for selection

PARAMETER
Safety
Break strength
Diameter
Weight
Buoyancy and hydrodynamic properties
Ease of handling
Equipment to be used
Stretch/strain properties
Load sharing between lines
Dynamic behavior
Reliability
Durability
Fatigue
Exposure
Chaffing/abrasion
Wet vs. dry condition
Experience
Ability to splice
Ability to provide terminations
Inspection
Cost
Availability

- **Some important issues**

1.Polyester rope stiffness is a function of many variables unlike spiral strand. For a spar, currents will usually control the design. As a result, the static stiffness of the polyester rope become much more important than the dynamic stiffness.

2.To date the largest polyester rope ever made and put into a service is 1000 tonnes with 1250 tonnes ropes being produced.

3. The last issues is development of adequate assurance that the mooring could be safely operated over the field life.[8]

SPAR PLATFORMS: TECHNICAL DESCRIPTION

[9]A spar is a deep-draft floating caisson, which is a hollow cylindrical structure similar to a very large buoy. Its four major systems are hull, moorings, topsides, and risers. The spar relies on a traditional mooring system (that is, anchor-spread mooring) to maintain its position. About 90 percent of the structure is underwater. Historically, spars were used as marker buoys, for gathering oceanographic data, and for oil storage. The spar design is now being used for drilling, production, or both. Figure 4.1 is an outboard and inboard profile drawing of the classic spar.

The distinguishing feature of a spar is its deep-draft hull, which produces very favorable motion characteristics compared to other floating concepts. Low motions and a protected centerwell also provide an excellent configuration for deepwater operations.

Listed below are some spar features:

- Water depth capability has been stated by industry as ranging up to 10,000 ft
- Full drilling and production capabilities
- Direct, vertical access production risers (surface production trees)
- Surface blowout preventer for drilling and workover operations
- Steel catenary risers (import and export)
- Inherently stable – center of buoyancy is located above the center of gravity
- Favorable motions compared with other floating systems
- Traditional construction (steel or concrete hull)
- Cost insensitive to water depth
- Potential oil storage
- Relocation over a wide range of water depths
- Conventional drilling and process components used[9]

TECHNICAL DESCRIPTIONS

[10]**Hull.** The hull is constructed by use of normal marine and shipyard fabrication methods.

The number of wells, surface wellhead spacing, and facilities weight determine the size of the centerwell and the diameter of the hull. In the classic or full cylinder hull forms, the upper section is compartmentalized around a flooded centerwell containing the different type of risers.

This section provides the buoyancy for the spar. The middle section is also flooded but can be economically configured for oil storage. The bottom section (keel) is compartmentalized to provide buoyancy during transport and to contain any field-installed, fixed ballast. Approximate hull diameter for a typical GOM spar is 130 feet, with an overall height, once deployed, of approximately 700 feet (with 90% of the hull in the water column).

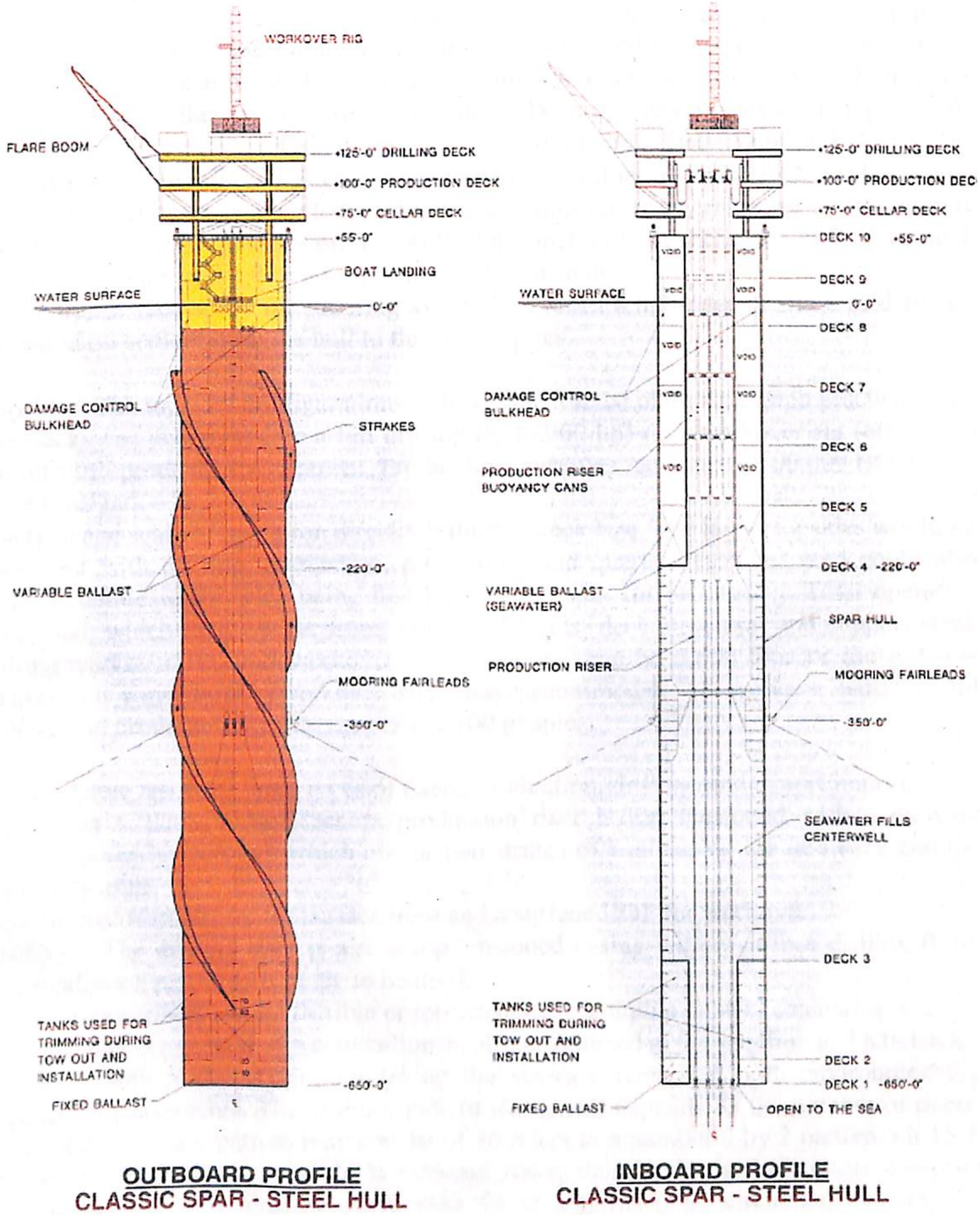


Figure 4.1: Courtesy of Spars International Inc.

Mooring. A lateral catenary system of 6 to 20 lines keeps the spar on location. The mooring lines are a combination of spiral strand wire and chain. Because of its low motions, the spar can use a taut mooring system at a reduced scope and cost compared with a full catenary system. Each mooring line is anchored to the seafloor with a driven or suction pile. The hullend of the line passes through a fairlead located on the hull below the water surface, then extends up the outside of the hull to chain jacks at the top, usually 50 ft or more in elevation. Excess chain is stored in the hull. Depending on hull size and water depth, the moorings can vary in number up to 20 lines and contain 3,700 ft of chain and wire. Starting at the seafloor, a typical mooring leg may consist of approximately 200-ft long, 84-inch diameter piles; 200 ft of 4¾-inch bottom chain; 2,500 ft of 4¾-inch spiral strand wire; and 1,000 ft of 4¾-inch platform chain.
The footprint created by the mooring system can reach a half-mile or more in diameter measured on centers from the hull to the anchor piles.

Topsides. The topsides configurations follow typical fixed platform design practices.
The decks can accommodate a full drilling rig (3,000 hp) or a workover rig (600-1,000 hp) plus full production equipment. Production capacities range up to 100,000 BOPD and 325 MMcfgpd.
The type and scale of operation directly influence deck size. The larger topsides would be consistent with drilling, production, processing, and quarters facilities, and could also include remote wells/fields being tied back to the spar for processing. Total operating deck load, which includes facilities, contained fluids, deck structural and support steel, drilling/workover rig, and workover variable loads, can be 6,600 tons or more. Crew quarters on a production/workover spar may accommodate 18 workers, while a full drilling and production facility may house 100 people.

Risers. There are three basic types of risers: production, drilling, and export/import.
Production – Each vertical access production riser is top tensioned with a buoyant cylinder assembly through which one or two strings of well casing are tied back and the well completed.
This arrangement allows for surface trees and a surface BOP for workover.
Drilling – The drilling riser is also a top-tensioned casing with a surface drilling BOP, which allows a platform-type rig to be used.
Export/import risers can be flexible or top-tensioned steel pipe or steel catenaries.
Production risers consist of a conventional subsea wellhead at the mudline and a tieback connector with a stress joint for taking the stresses associated with environmentally imposed displacements. The seafloor pattern (footprint) depends on the number of risers. For example, a riser pattern may consist of 16 risers in a parallel 8 by 2 pattern, on 15-ft centers within each row and 20 ft between rows, thus having a rectangular footprint approximately 100 ft long by 20 ft wide. Other patterns (e.g., circular or square) are available. An example production riser for a spar could be either a single or dual-bore (concentric pipe) arrangement. Low motions of the spar allow the use of the economical steel catenary riser technology for subsea production trees.[10]

PROCESS DESCRIPTIONS

[11]**Installation Overview.** Installation is performed in stages similar to those of other deepwater production systems, where one component is installed while another is being fabricated. Installation schedules heavily depend upon the completion status of the hull and topsides. Listed below are the order of events for a typical spar installation:

- Well predrilling (drilling vessel)
- Export pipelines laying
- Presite survey; transponder array deployment; anchor pile target buoys set
- Anchor pile and mooring line settings
- Hull delivery and upending
- Temporary work deck setting
- Mooring and pipeline attachment
- Mooring lines pretensioning
- Hull ballasting and removal of temporary work deck
- Topsides delivery, installation, hookup, and integration
- Buoyancy can installation

Prior to the delivery of the hull to location, a drilling rig might predrill one or more wells. During this time, export pipelines are laid that will carry production either to another platform (host) or to shore after processing. A presite survey is performed and includes the following: onbottom acoustic array installed for the mooring system, identified obstructions removed, anchor pile target buoys preset, and a final survey of the mooring lay down area performed. Once on location, a derrick barge installs the anchor piles and mooring system. The installation of the anchor piles is performed using a deck-mounted lowering system designed for deepwater installations and an underwater free-riding hydraulic hammer with power pack. Remotely operated vehicles (ROV's) observe the hammer and umbilical as the pile is lowered and stabbed into the seafloor.

In conjunction with pile installation, the mooring system is laid out and temporarily abandoned.A wire deployment winch with reels specifically designed for this type of work handles each wire. An ROV monitors the wire lay-down path as the derrick barge follows a predetermined route until it reaches the wire end on the deployment reel. The end of the mooring wire is then connected to an abandonment/recovery line and marked for later use in attaching the mooring system to the hull.

To date, all GOM spar hulls have been built in Finland. Upon completion of the hull, it is shipped to the Gulf of Mexico on a heavy-lift vessel such as the Mighty Servant III. Because of its size and length it is necessary to divide the spar hull into two sections. Upon arrival at an onshore facility, the sections are connected together using a wet mating technique, which allows for lower cost and ease of handling and positioning, and eliminates the need for special equipment. The hull is then ready for delivery to location.

Depending on the proximity of the onshore assembly location to the open sea, smaller tugs (2,000 to 4,000 hp) may be used first to maneuver the hull into deeper water, and then larger oceangoing tugs (7,000 hp) tow the spar to its final destination.

A derrick barge and a pump boat await arrival of the hull on site. The barge and boat up-end the hull. While the hull is being held loosely in place, the pump boat fills the hull's lower ballast tank and floods the centerwell. The hull self-up-ends in less than two minutes once it is flooded.

Next, the derrick barge lifts into place a temporary work deck brought to the site on a material barge. Tasks performed using the temporary work deck are basic utility hook up, mooring line attachment, and riser installation.

The hull is positioned on location by a tug and positioning system assistance. Then the mooring system is connected to the hull. After the mooring system is connected, the lines are pretensioned. Then the hull is ballasted to prepare for the topsides installation and removal of the temporary work deck. Topsides are transported offshore on a material barge and lifted into place by the derrick barge. An important characteristic is that the derrick barge can perform the lift in dynamic positioning mode. The topsides consist of production facilities, drilling/workover rigs, crew living quarters, and utility decks. Installation of miscellaneous structures such as walkways, stairways, and landings are also set in place by the derrick barge.

The last pieces of equipment to be installed are buoyancy cans and the associated stems. The cans are simply lifted off the material barge and placed into slots inside the centerwell bay. Next, the stems are stabbed onto the cans. To prepare for riser installation, the cans are ballasted until the stem is at production deck level.[11]

LATET DEVELOPMENTS IN SPAR PLATFORMS

1. [12]Replacement ofmain circular geometry by helical strikes to overcome the problem of vibrations while operation.

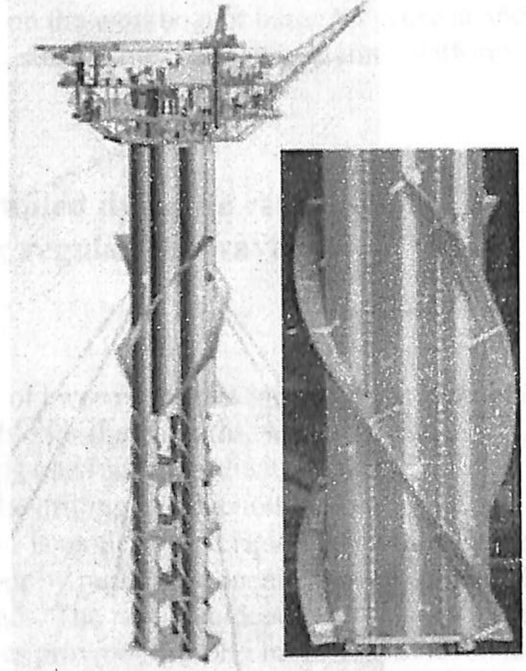


Figure 1.1: *Sample spar platform. Vibration problem solved by modifying the main circular geometry by helical strikes.*

2. Telescoping Spar Platform

Exploratory oil drilling, sea floor mining and sunken object location in deep water require extensive floating platforms. These platforms are susceptible to wave action often causing operations to be suspended. Spar platforms are being used but their length is excessive and they are very difficult to deploy and retrieve.

The researchers at The Johns Hopkins University Applied Physics Laboratory have developed a telescoping spar platform. This unique invention allows for the platform to be manufactured on land and loaded onto a workboat or barge. Once on location is dropped into the water and the telescoping mechanism and variable location buoyancy chamber are deployed. After completing this operation the spar is anchored to the seabed by cables. This forms a stable wave independent platform in medium to deep water. At the conclusion of the exploration the telescoping mechanism is retraced and the spar platform is loaded back on the workboat or barge for reuse at another location. This design offers a compact, simple, inexpensive operating platform.

3. Nonlinear coupled dynamic response of offshore Spar platforms under regular sea waves:-

Oil and gas exploration of large reservoirs in deep water has accelerated the need to explore structures suitable for these depths, which operate more economically in deep water. A Spar platform is one such compliant offshore floating structure used for deep water applications for the drilling, production, processing, storage and offloading of ocean deposits. The Spar is modeled as a rigid body with 6 degrees-of-freedom, connected to the sea floor by multicomponent catenary mooring lines, which are attached to the Spar at the fairleads. The response-dependent stiffness matrix consists of three parts: (a) the hydrostatics provide restoring force in heave, roll and pitch; (b) the mooring lines provide the restoring force which are represented here by nonlinear horizontal and (c) vertical springs. An unidirectional regular wave model is used for computing the incident wave kinematics by Airy's wave theory and force by Morison's equation, The response analysis is performed in time domain to solve the dynamic behavior of a moored Spar platform as an integrated system using the iterative incremental Newmark's Beta approach. Numerical studies are conducted for several regular waves.[12]

CONCLUSION

In a bid to utilize our petroleum resources to their fullest, more and more focus has to be given to the deepwater and ultra deep water zones. Working in those high risk zones, it is crucial to be well equipped with the world's best technology. Here comes, the importance of the spar technology, enabling us to extract oil from the zones seemingly unfeasible to work at. In the Gulf of Mexico alone, most of the platforms doing operations are fully based on the spar technology. They are well equipped to withstand the hostile and problematic environmental conditions of the Gulf of Mexico. In addition to that, many offshore areas of Brazil have been extracted of oil making use of the spar technology. Last but not the least we look forward to further modify the spar platforms in use so as to make them more efficient for the same investment.

Signature ?,