Chapter 5
Different Categories of Working Units

When considering permanent plug and abandonment of hydrocarbon wells, location of the well plays a critical role; location can be either onshore or offshore. For onshore wells, the well depth, downhole pressure, and complexity of operation dictate the type of working unit. For offshore wells, type of facility, water depth, downhole pressure, and working unit serviceability are the governing factors for selection of the working unit. The facility can be either platform-based or subsea-based. This chapter will familiarize the reader with different types of working units, for permanent P&A purposes, based on the well location and type of facility (see Fig. 5.1). In addition, to drilling rigs, vessels are also reviewed as a new generation of working unit but as they are not counted as rigs, they are not included in Fig. 5.1.

5.1 Onshore Units

Land wells are the most common drilled hydrocarbon wells. History of the first known land hydrocarbon well, goes back to China where the earliest well was drilled in 347 CE [1]. Accordingly, many oil wells were drilled until 1859, when Edwin L. Drake drilled the first commercially successful oil well. Since then, with the increase of need for energy, drilling activities for hunting hydrocarbons have speeded up and countless wells have been drilled. Subsequently, depth of penetration has been increased and thus, different types of land rigs have been developed. Land rigs are designed based on portability and maximum operating depth and are divided into two main categories: *conventional rigs* and *mobile rigs*.

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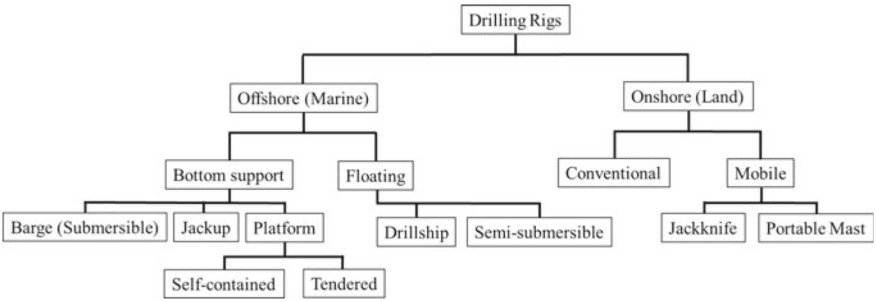


Fig. 5.1 Different working units based on the well location

5.1.1 Conventional Land Rigs

Conventional land rigs are built on location and left on site after the well is completed. The rig can be used for workover activities during the life-cycle of the well. However, due to the high cost of rig construction, mobile rigs were introduced where the derrick can be moved and reused. Figure 5.2 illustrates an onshore rotary drilling rig and its main components.

5.1.2 Mobile Land Rigs

Mobile land rigs are categorized as *jackknife* and *portable mast*. The jackknife, also known as *cantilever derrick*, is assembled on location, on ground, and then raised to vertical position by utilization of the rig-hoisting equipment or the drawworks. The portable mast is usually mounted on wheeled-trucks as a single unit and transported to the location, and raised in the vertical position by using hydraulic pistons on the carrier unit. Different types of land rigs are designed and available, depending on well location, depth of operation, and horsepower requirement. Fit-for-purpose rigs are a class of land rigs specially designed for remote areas where few people wish to venture. These remote areas such as deserts, and arctic areas may have few or no highways.

The main components of a rotary rig are: a power system, a hoisting system, a circulating system, a rotary system, and a well control system [2]. All of these components are necessary for drilling and permanent P&A operations and are therefore, comprehensively discussed in this chapter.

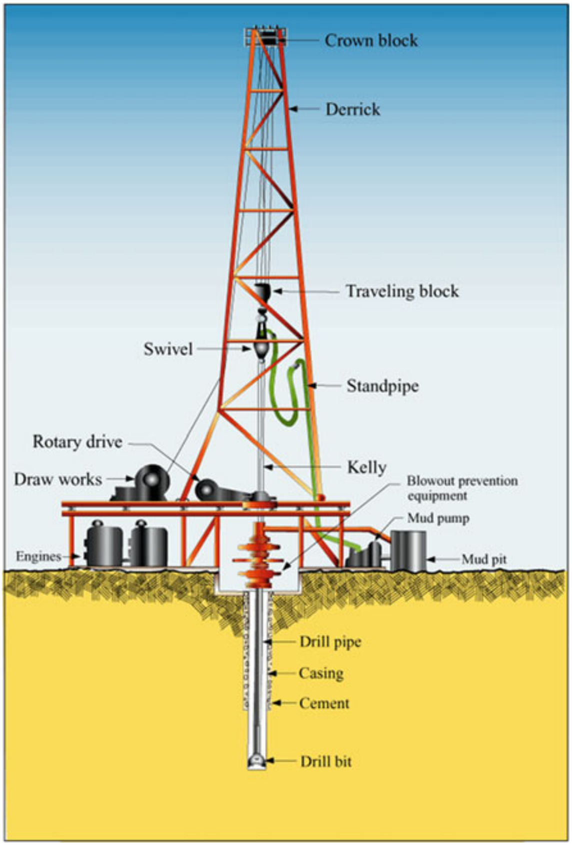


Fig. 5.2 Onshore rotary drilling rig (Taken from Weebly)

5.2 Offshore Units

With the increase in world energy needs for fossil fuels, exploration and production of hydrocarbons have been extended to remote areas such as offshore locations. Although the main intended purpose of a drilling rig and its main systems may not be influenced by well location, the water depth requires modification of land rigs. Consequently, mobile offshore drilling units (MODUs or rigs) or marine rigs were developed and introduced. The main design features for offshore rigs are portability and maximum water depth of operation. Offshore rigs are classified broadly as *floating* or *bottom support*. The floating rigs are categorized as semisubmersible, and drillship. Bottom supported rigs are categorized as barge, jackup, and platform rigs [3].

5.2.1 Submersible/Barge Rigs

These types of rigs are used for drilling at shallow water depths. The operational water depth of these submersible barge rigs is less than 40 (ft) and where there is no severe wave action. The rig is installed on a barge, large pontoon-like structure, and towed to the location. When on location, the pontoons are filled with water, the platform sinks partly or fully, and rests on its anchors. When the drilling operation is completed, water is pumped out and the platform is ready to move to a new location. If the barge rests on the seafloor, then it is counted as a bottom supported drilling rig.

5.2.2 Semisubmersible Rigs

Semisubmersible (see Fig. 5.3) rigs are capable of performing drilling operations while resting on the seafloor as well as being in a floating position. In other words, the drilling rig is on a barge similar to submersible rigs. Compared to submersible rigs (known also as bottle-type semisubmersible rig), the semisubmersible rigs (known as column-stabilized semisubmersible rigs) are designed with good stability and seakeeping characteristics. These types of rigs are usually used at larger water depths where a rig cannot rest on the seafloor. When the semisubmersible rig cannot

Fig. 5.3 A semisubmersible drilling rig towed to location. (Courtesy of Seadrill)

rest on the seafloor, the unit is either *anchored* onto the position or kept on location with dynamic positioning systems. The construction and operational cost of semisubmersible rigs are higher than for submersible rigs.

5.2.3 Drillship

A drillship is a type of floating vessel where the drilling rig is mounted on a merchant ship (see Fig. 5.4). The drillship is usually used for offshore exploration and equipped with advanced dynamic positioning systems. As drillships benefit from the dynamic positioning systems, they are usually much more costly compared to semisubmersible rigs. In recent years, drillships have been used for operation in deepwater and ultra-deepwater areas. There are some generations of drillships, which are equipped with only mooring systems or general dynamic positioning systems that have lower cost compared to semisubmersible rigs. Another challenge for using a drillship is its susceptibility to severe waves, wind and currents. A benefit of using drillships is their efficient mobilization and high speed between drilling locations.

Recently, riserless well intervention vessels have been used for small activities such as coring [4]. These types of vessels are small sized drillships which have the capability to be equipped with well intervention equipment such as coiled tubing units. The cost of these vessels is much lower than cost of other types of rigs; however,

Fig. 5.4 Drillship on location (Courtesy of Seadrill)

Fig. 5.5 A jackup rig on location. (Courtesy of Seadrill)

time spent waiting on weather is higher compared to other types of drilling rigs. The vessels will be reviewed later in this chapter.

5.2.4 Jackup Rig

Jackups are the most common bottom-supported rigs. The rig consists of a barge-type hull (triangular barge form) and three legs, Fig. 5.5. When the rig is in place, legs are lowered to adjust to a given clearance. Jackups are self-contained rigs that can be mobilized and demobilized easily. Depending on their size, they can operate in water depths up to 500 (ft) [5].

5.2.5 Platform Rigs

Platform rigs are usually employed during development phase where an economically viable offshore field is exploited. Many directional wells can be drilled from a platform. Large platforms are capable of accommodating drilling rigs or modular

Fig. 5.6 A platform rig in operation. (AkerBP)

rigs and therefore are known as *self-contained* (see Fig. 5.6). Rig-up time of platform rigs are usually less compared to most of the MODUs as no mooring system nor dynamic positioning system is required. But there are some circumstances when the rig-up time can increase due to waiting on weather.

5.2.6 Tendered Rigs

There are circumstances where the platform is small and not capable of accommodating all the components of a drilling rig or storage facilities. In this situation, a floating vessel is anchored next to the platform (see Fig. 5.7). The floating vessel is known as the *rig tender*. The rig tender can contain storage facilities, many of the rig components and the living quarters.

5.2.7 Vessels

Vessels are small sized merchant ships which offer some basic operations such as well intervention activities and anchor handling. Compared to drillships, the day rate of vessels are much lower. These types of vessels are categorized as light well intervention vessel and anchor handing vessels.

Fig. 5.7 A tender rig in operation while the anchored vessel is in service. (Courtesy of Seadrill)

5.2.7.1 Light Well Intervention Vessels

Light Well Intervention Vessels (LWIVs) have been used for over 25 years in the North Sea. LWIVs are typically monohull, flexible and extremely cost efficient and can be used for a single or multi-well (a campaign) of subsea wells. They can accommodate a wireline unit and coiled tubing unit, Fig. 5.8.

Well integrity and suspension operations including mechanical plug setting, mechanical repair or well maintenance, perforating and setting cement plugs, well-head cutting and removal, logging, Remotely Operating Vehicle (ROV) services, and pumping operations are typical activities which are conducted by use of LWIVs [6]. The future approach for the use of LWIVs is to perform the complete permanent P&A operations. However, there are some limitations to be solved before reaching to the goal, see Table 5.1.

5.2.7.2 Anchor Handler Vessels (AHVs)

Anchor handling operations may contribute 10–20% of the total well costs of off-shore exploration drilling [8]. In a conventional anchor handling operation, the rig's winches are used to tension the anchors. AHV transports and deploys the anchors, connects the required chains, wires and polyester ropes. AHV can pre-lay the anchors before the rig arrives, and more time can be dedicated to drilling or P&A operations.

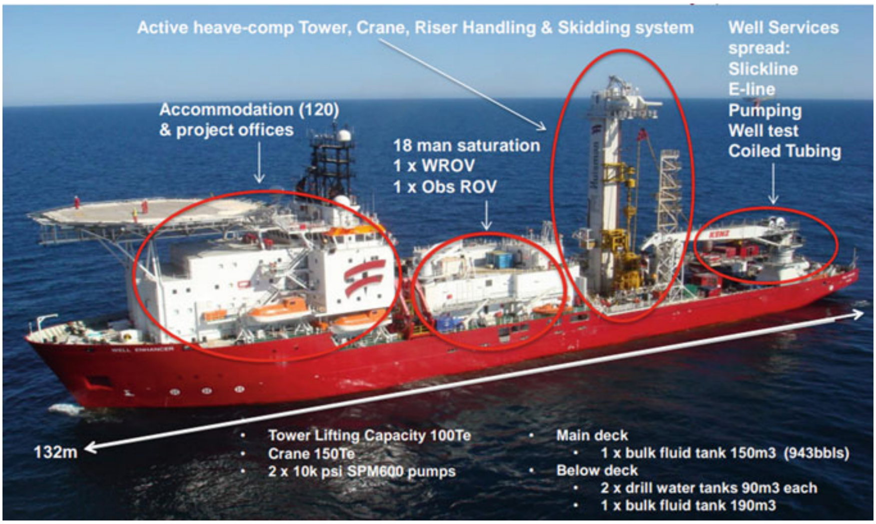


Fig. 5.8 Light well intervention vessel. (Courtesy of Helix Energy Solutions Group)

Table 5.1 Advantages and possible limitations of LWIVs for use in permanent P&A operations [7]

Advantages	Possible limitations
• Equipped with well control package • Wireline operations • Coiled tubing operations • Wellhead cut and removal • Activities for establishment of temporary abandonment • Pipe handling • Cementing adaptor tool • Flexible and cost efficient	• Limited pulling capacity • Waiting on weather is high due to the small size • Unable to work full bore 7-in. • Limited deck space • High motions add more risk

5.3 Types of Offshore Wells

Depending on the field development planning, offshore wells can be completed as either subsea wells or platform wells. Depending on well type, subsea or platform, the plug and abandonment operation will be different. Therefore, it is important to review the major differences between subsea and platform wells.

5.3.1 Subsea Wells

In a *subsea well*, the wellhead, XMT, and production-control equipment are located on the seabed. Subsea wells may be drilled and completed individually, in clusters, or on a template.

Individual subsea wells—An individual subsea well is a well which is drilled and completed as a single well. Every time a well is completed, the drilling unit is demobilized and mobilized to the next well and consequently, associated costs are increased.

Clustered subsea satellite wells—The concept of *clustered subsea satellite wells* is that individual wells are drilled but they are connected to a manifold, Fig. 5.9, and then the manifold is connected to a production unit. In this case, some costs associated with field development are saved because of flow line and control umbilical savings.

Multiwell template subsea wells—The multi-well template is another subsea field development concept where wells are drilled from one location by utilization of a drilling template. In this concept, the drilling unit stays in place while drilling several wells through the template. Therefore, costs associated with demobilization and mobilization will be minimized.

Subsea wells are equipped with *templates*, a large supportive structure which is made of steel. The template is used as a *temporary guide base* and serves as the anchor for guidelines for a permanent guide base. The template has opening(s) which the bit passes through and drilling can be performed, Fig. 5.10. A subsea permanent

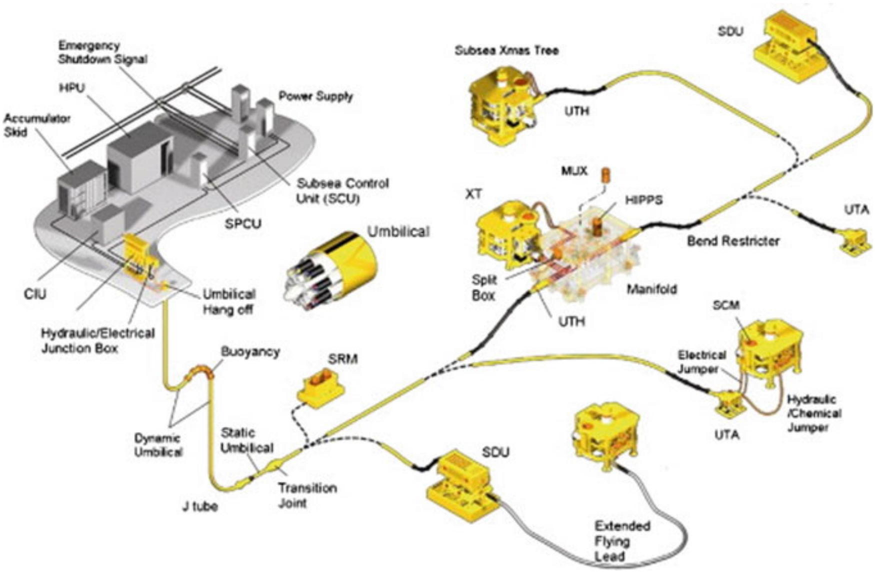


Fig. 5.9 Clustered subsea satellite wells connected to a manifold. (Courtesy of TechnipFMC)

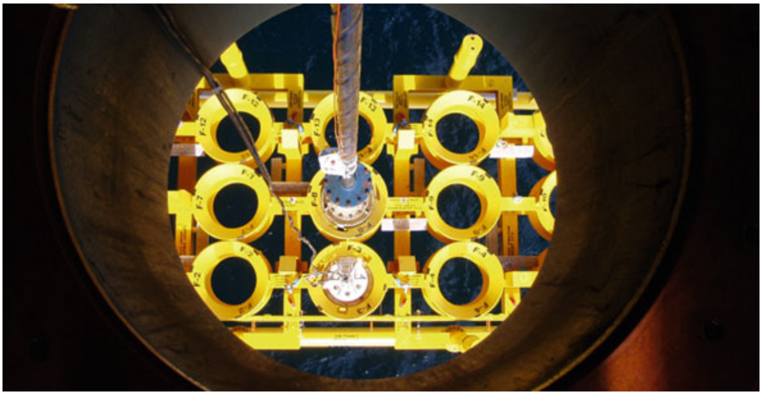


Fig. 5.10 Subsea multi-well template below a moon pool. (Courtesy of Claxton)

guide base is initially used for drilling, hanging off and supporting conductor, wellhead, and subsea tree. In addition, templates provide a base for protective structures. The *permanent guide base* is a steel structure which seats in and is attached to the temporary guide base, Fig. 5.11.

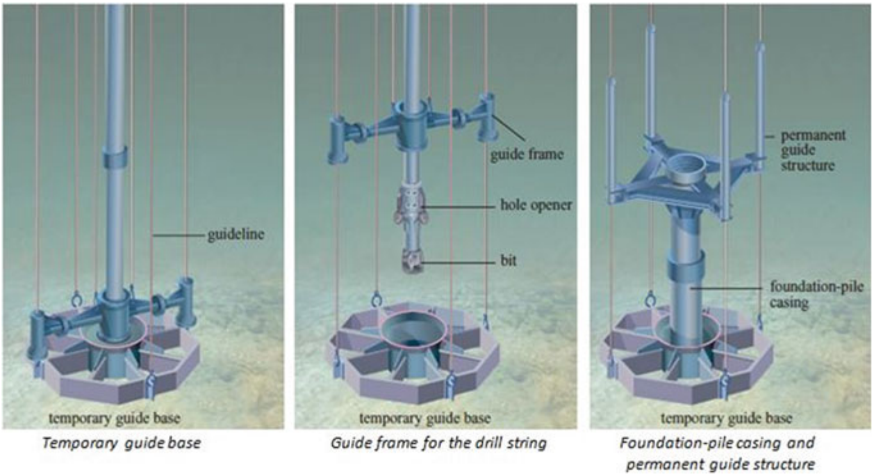


Fig. 5.11 Single-well temporary and permanent guide bases. (Taken from Encyclopedia of Hydrocarbons Eni)

5.3.2 Platform Wells

For a *platform well*, the wellhead, Christmas tree, and production-control equipment are located on the production platform. Platform size depends on number of wells, water depth, and facilities to be installed on top side such as the drilling rig, living quarters, Helipad, etc.

5.4 Types of Offshore Production Units

Offshore production units can be divided into two main categories: bottom supported and vertically moored structures, and floating production systems. Figure 5.12 shows different categories of offshore platforms.

5.4.1 Bottom Supported and Vertically Moored Structures

This category of offshore platforms can be divided into four major types (see Fig. 5.13):

- Fixed platform
- Compliant tower
- Tension leg platform
- Mini-Tension leg platform

Fixed platform—These platform types are, built on concrete or steel legs, or both, and directly anchored to the seabed. They are designed and built for long-term use in moderate water depths up to 400 m. Steel jacket, concrete caisson, floating steel, and floating concrete are various types of fixed platforms. Steel jackets are vertical sections made of tubular steel members, which provides a protective layer around pipes, and are usually piled into the seabed. Fixed platforms typically have a main deck, a cellar deck, and a Helideck which comprise the deck structure. The deck

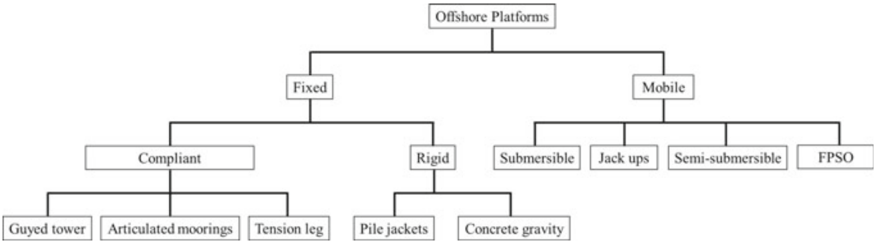


Fig. 5.12 Different categories of offshore platforms

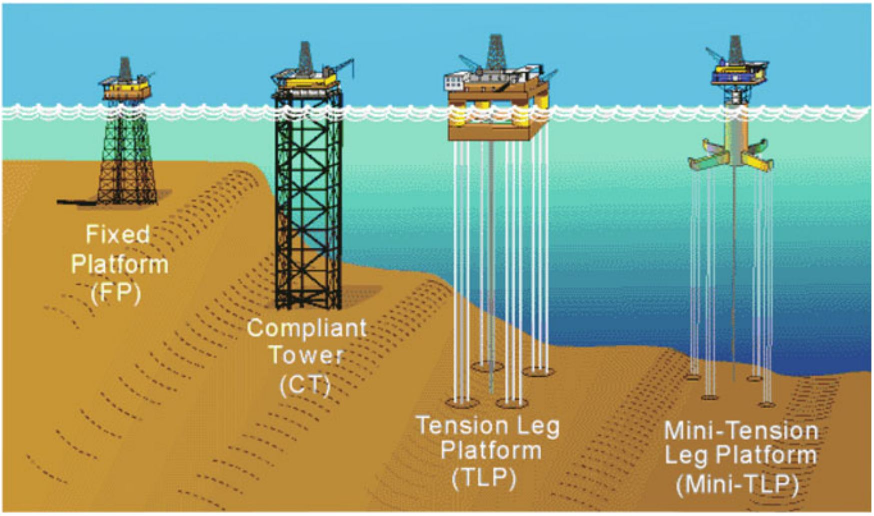


Fig. 5.13 Various types of bottom supported and vertically moored offshore platforms. (Courtesy of BOEM)

structure is standing on deck legs which are connected to the top of the piles. The piles, which are located inside the legs of a jacket, penetrate into soil and are extended above the mean sea level.

Compliant towers—This type of platform is capable of moving along with the external forces acting on the structure. Therefore, a flexibility is given to the structure and it responds to the applied external forces [9]. A compliant tower platform consists of a narrow and flexible (compliant) tower which is supported by piled foundations. The pilled foundations (connected to the sea floor and allowing the structure to move freely with current, waves, and wind) support the deck which accommodates the drilling rig and production facility. However, they are not usually designed for drilling operations but exceptions may exist. The compliant tower platforms are designed and built for deep water depths ranging from 1400 to 3000 (ft). Guyed towers (either piled or spud can foundation), articulated towers, and tension leg platforms are different types of compliant tower platforms.

Tension leg platforms—These type of platforms, known as TLPs, may also be noted as a subcategory of compliant towers as they can move horizontally (see Fig. 5.14). A TLP is a 4-column design whereas each column is moored permanently to the seabed by tethers or tendons. A tether is a vertical steel tube. A group of tethers is called a tension leg, and are designed in such a way that vertical movement of the platform is eliminated. In other words, all the tethers are in pre-tension. This feature allows the wellhead to be placed on deck and connected to the subsea well by use of a rigid riser. As the legs are in tension, the platform is sensitive to topside load variations.

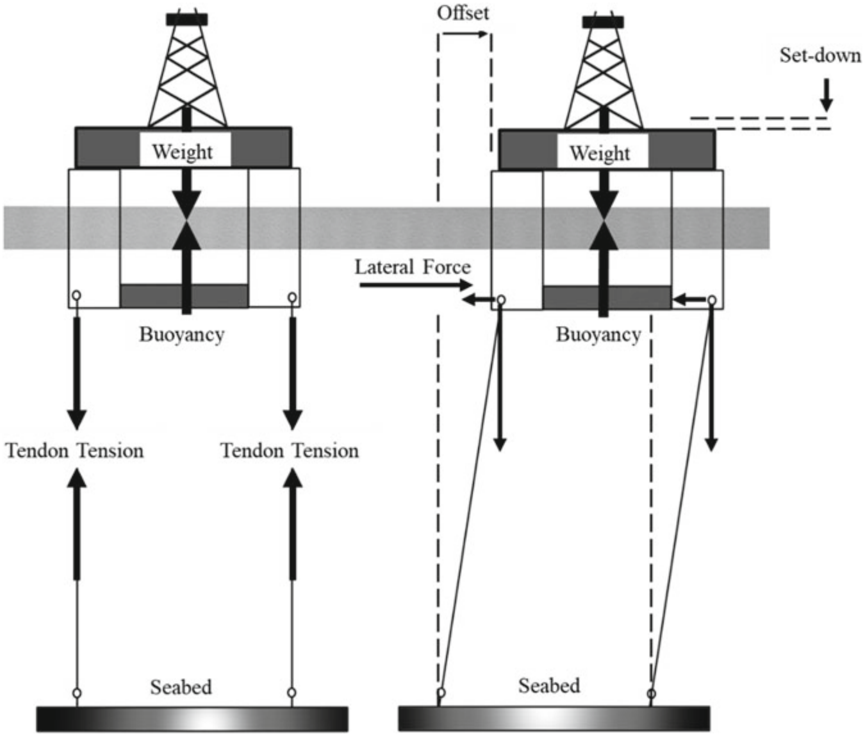


Fig. 5.14 A tension leg platform which is restrained in vertical direction but highly flexible in horizontal plane

Mini-Tension leg platforms—These type of platforms combine the simplicity of a SPAR platform (a floating platform) and favorable features of a TLP [10]. The platform consists of decks, tower, hull, horizontal pontoons, and tethers. Typically, a mini TLP has a low water plane and subsequently experiences less environmental loads and has good response characteristics.

5.4.2 Floating Production Systems

This category of offshore platforms can be divided into three major types (see Fig. 5.15):

- Spar platforms
- Floating production systems
- Floating, production, storage and offloading (FPSO) vessels

Spar platforms—A Spar platform is a type of floating production facility made of a large-diameter, single vertical cylinder (hard tank), which supports a deck on

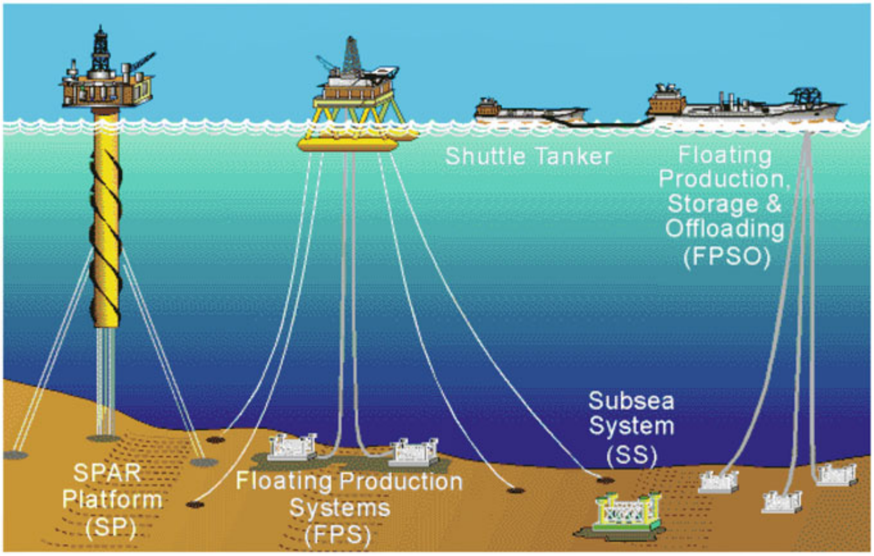


Fig. 5.15 Overview of floating production systems (Courtesy of BOEM)

top. Spar platforms are permanently anchored to the seabed, vertically, by a spread moored system. There are four different types of Spar platforms: classic Spar, truss Spar, cell Spar, and mini-DOC Spar (see Fig. 5.16). One of the major differences of these types is related to size and design of the hard tank. Among these, types, the truss Spar platforms are the most common.

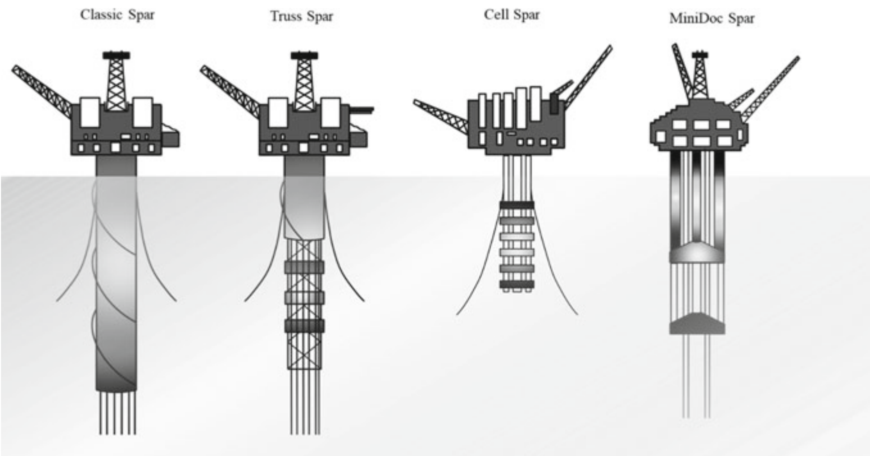


Fig. 5.16 Four different types of Spar platforms

It provides accommodation, crane facilities and usually a drilling rig. The Christmas tree can be either on the seabed (wet tree) or on the platform (dry tree).

Floating production systems (FPSs)—FPSs consist of monohull structures and are equipped with processing facilities. FPSs are moored and can be mobilized and reused after the abandonment of wells. The FPSs are usually used for subsea wells. There are different types of systems and floating, production, storage and offloading systems are a variant.

Floating, production, storage and offloading vessels (FPSO)—FPSOs are a generation of the FPSs. These vessels are ship shaped floaters and do not provide rig or intervention units [11]. The FPSOs are used for subsea wells.

5.5 Manned and Unmanned Platforms

Fixed platforms can be categorized in two types: manned platforms and normally unmanned platforms.

5.5.1 Manned Platforms

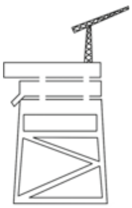
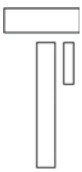
All the offshore construction facilities, which accommodate at least one person routinely for more than 12 h for 24 h periods, are known as manned platforms. Such facilities provide an area for a well intervention unit or supporting drilling rig.

5.5.2 Unmanned Platforms

Unmanned platforms are a type of automated offshore platform which primarily operate remotely and without the continuous presence of personnel. Such platforms are operated remotely from onshore bases. They can be categorized into five different types by considering the number of available wells, helideck availability, fire water system, and crane availability (see Table 5.2).

These types of platforms are small in size and may provide a helipad on top but they do not possess accommodation, except for shelters to address personnel emergencies. If a crane is available, they are usually light-weight and not rated for lifting heavy units such as coiled tubing units. As such platforms are small, when the platform is manned to carry out routine activities such as maintenance and well intervention activities, a supply vessel or jackup unit stands by the platform. The standby unit provides enough deck space and accommodation for personnel on board (POB). When an unmanned platform is manned for activities which require more POB, additional safety measures are necessary as the platform may not provide enough rescue boats or fixed fire water systems.

Table 5.2 Five different types of unmanned platform [12]

Type			Specifications
Type 0:	Complex platform with helideck		• Equipped with fixed fire water system • Equipped with various process equipment including crane (lifting capacity of 50–60 tonnes) • Automated • Allows remote operation for typically 1–5 weeks • Designed for both coiled tubing and wireline operations
Type 1:	Simple platform with helideck		• Supports typically 2–12 wells • Crane is available (lifting capacity of 10–50 tonnes) • No fire water system • Equipped with test separator or multiphase metering • Allows remote operation for typically 2–3 weeks • May be designed for coiled tubing and wireline operations or only wireline operations
Type 2:	Simple platform without helideck		• Supports typically 2–10 wells • Small crane is available (lifting capacity of 1–2 tonnes) • No fire water system • No process facility • Allows remote operation for typically 3–5 weeks
Type 3:	Minimalistic platform		• Supports typically 2–12 wells • No crane • No fire water system • No process facility • Allows remote operation for typically 6 months up to 2 years • All well intervention operations require an offshore support rig
Type 4:	Super minimalistic platform		• Supports typically 1 well • One small deck • Well is connected directly connected to pipeline • All well intervention operations require an offshore support rig

It is a common practice to design and construct simplified offshore installations to keep the initial costs low. Consequently, when considering operational activities for unmanned platforms, some major factors should be considered including: safety-critical systems, deck space, POB, and weather. Due to the design of unmanned platforms, they are not equipped with all of the safety-critical systems such as fixed firewater pumps and larger capacity life boats. The deck space is also very limited due to the compact design of the platforms. Consequently, during operations, a minimum of personnel are permitted to work on unmanned platforms due to safety and emergency response, unless the operation is carried out from a standby working unit. Weather is another major factor to be considered for executing operations on unmanned platforms. Due to constraints including deck space, lifting capacity, etc., an offshore support rig (working unit) is employed to perform the operations. If the employed working unit is not a bottom supported unit, bad weather could cause disastrous consequences such as a collision between the platform and working unit or compromising pressure control procedures. When employing floating working units for intervention and P&A activities, a weather downtime of up to 50% is reported for unmanned platforms in North Sea. However, this depends on the season.

Challenges associated with unmanned platforms can be listed as personnel accommodation, equipment limitations (such as number, size, and weight), and fast crew transfer. Most of these challenges can be overcome by proper selection of a supplementary working unit. Normal anchor handler tug (AHT) vessels, supply vessels, and dynamic positioning vessels are some options besides offshore drilling units [12, 13].

5.6 Mooring Systems for Floating Units

When considering offshore activities, unit motion becomes a critical subject which increases the operation cost and risk. For floating platforms and floating working units, motion means weather downtime and subsequently, weather downtime means increased operation cost. In other words, the primary task of mooring is to reduce the motion of platform or working unit. Fixed platforms and fixed working units do not require mooring system. Studies show that mooring operations can contribute up to 25% of drilling cost. Therefore, an efficient mooring system needs to be considered during P&A of subsea wells or platform wells that may require a complementary floating unit. A mooring system consists of: mooring chain (chain cable) and fiber ropes, windlass, anchors, and mooring winches.

Mooring systems can be either temporary or permanent. A temporary mooring system provides service for relatively short periods of time. The periods can be weeks or months at a time. Most mobile units employed to carry out P&A operations benefit from a temporary mooring system. However, permanent mooring systems provide station-keeping for several years. Typically, permanent mooring systems are utilized to tether floating production facilities. The differences between permanent and temporary mooring systems can be referred to as criteria considered in the design

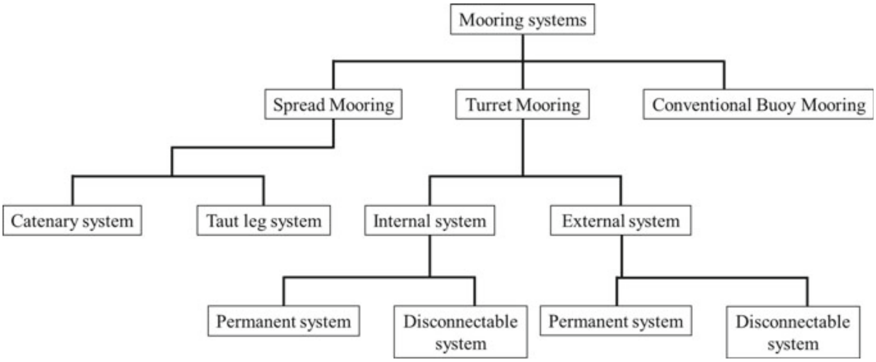


Fig. 5.17 Three main categories of mooring systems

process of the system, type and size of mooring components, type of system analysis, installation methods, and inspection and maintenance philosophy. Generally, mooring systems are categorized into three main categories (see Fig. 5.17): spread mooring systems (Fig. 5.18a), turret mooring systems (Fig. 5.18b), and conventional buoy mooring system (Fig. 5.18c).

5.6.1 Spread Mooring Systems

In this system, mooring lines are spread over multiple points and the system maintains the working unit or platform on location with a fixed heading. In spread mooring systems, two different configurations of mooring line are distinguishable (see Fig. 5.19): catenary system, and taut leg mooring system.

In a catenary system, a parabolic geometry of cables are anchored to the seabed (see Fig. 5.19a). In this configuration, lines are laid down on the seabed and then leave the seabed to the connectors on the unit. Usually, lines are steel chains which subsequently occupy a large space and their transportation is a challenging task. Corrosion of chains is another issue to be considered when utilizing steel lines.

In taut system, lines are stretched between two points; one point on the seabed and another point to the connectors of the unit (see Fig. 5.19b). The lines are polyester ropes which have several advantageous over steel chains. Advantageous include: polyester ropes are lighter and less challenging with regards to accommodation and transportation, they give a softer mooring system, better vortex induced motion response to loop currents, lower product cost, no concerns associated with corrosion, and reduction in mooring pre-tension [14].

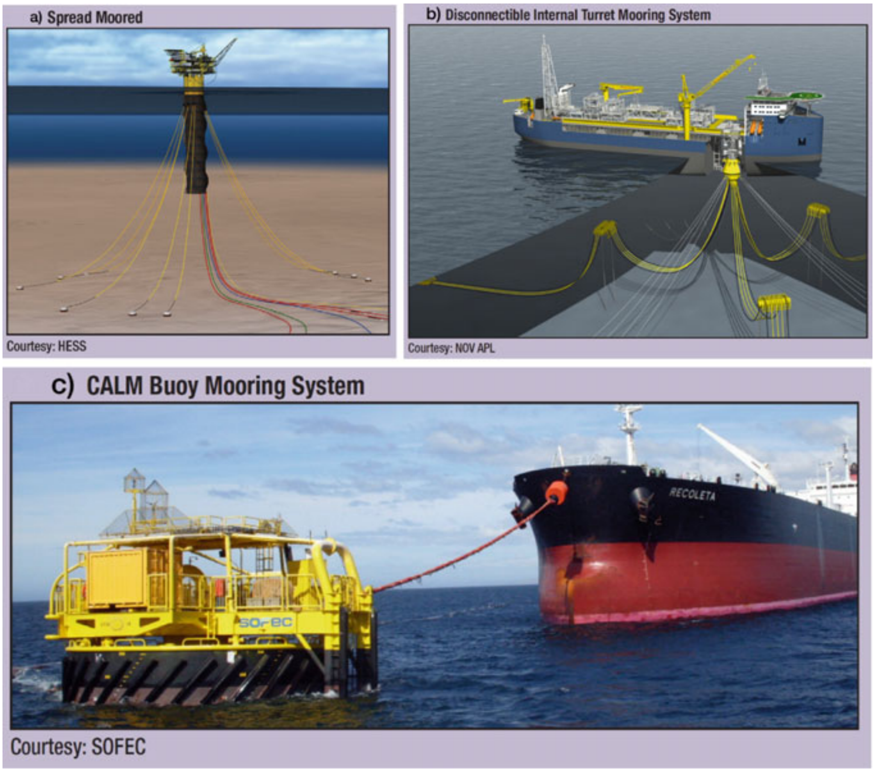


Fig. 5.18 **a** Spread mooring system, **b** Internal turret mooring system, and **c** Buoy mooring system. (Courtesy of Offshore Magazine)

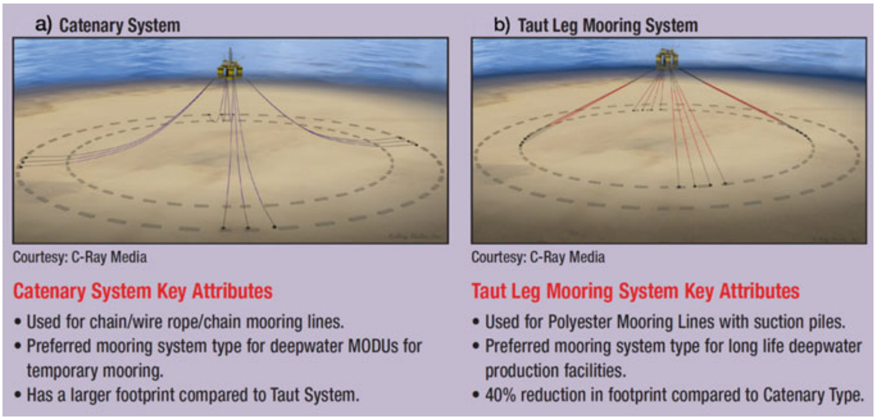


Fig. 5.19 Mooring line configuration used in spread mooring systems; **a** Catenary system, **b** Taut leg mooring system. (Courtesy of Offshore Magazine)

Fig. 5.20 External turret with dry mooring table. (Courtesy of Offshore Magazine)

5.6.2 Turret Mooring Systems

Turret mooring systems are divided into two main categories: internal turret and external turret (Fig. 5.20). Internal turret mooring systems are the most common for extreme design conditions. The internal turret mooring system is positioned inside the hull (see Fig. 5.18b) and it is either permanent or disconnectable [15–17]. Permanent internal turret mooring systems are located in a moonpool. Internal turret mooring systems are designed for moderate to deep water depths and locations where a large number of flexible risers are required. External turret mooring systems are also categorized as permanent or disconnectable. Turret mooring system are usually used for Floating, Production, Storage, and Offloading (FPSO) floating systems and drillships.

5.6.3 Conventional Buoy Mooring System

A conventional buoy mooring (CBM) system (see Fig. 5.18c) typically consists of buoys, mooring legs, and anchor points. A typical CBM consists of 3 to 4 buoys which are moored to the seabed by chain legs, high holding power anchors, or piles.

5.6.4 Offshore Mooring Patterns

There are different types of offshore mooring patterns for temporary and permanent mooring systems, Fig. 5.21. Depending on the intended use of the floating offshore unit, type of operation, and location, different configurations are available.

A mooring line is made of different components (see Fig. 5.22). Manufacturing and selection of the components depends on duration of tethering, size of floating offshore unit, location, water depth, etc. Weight and space allocation for mooring lines is important during the designing process which may influence the mooring configuration.

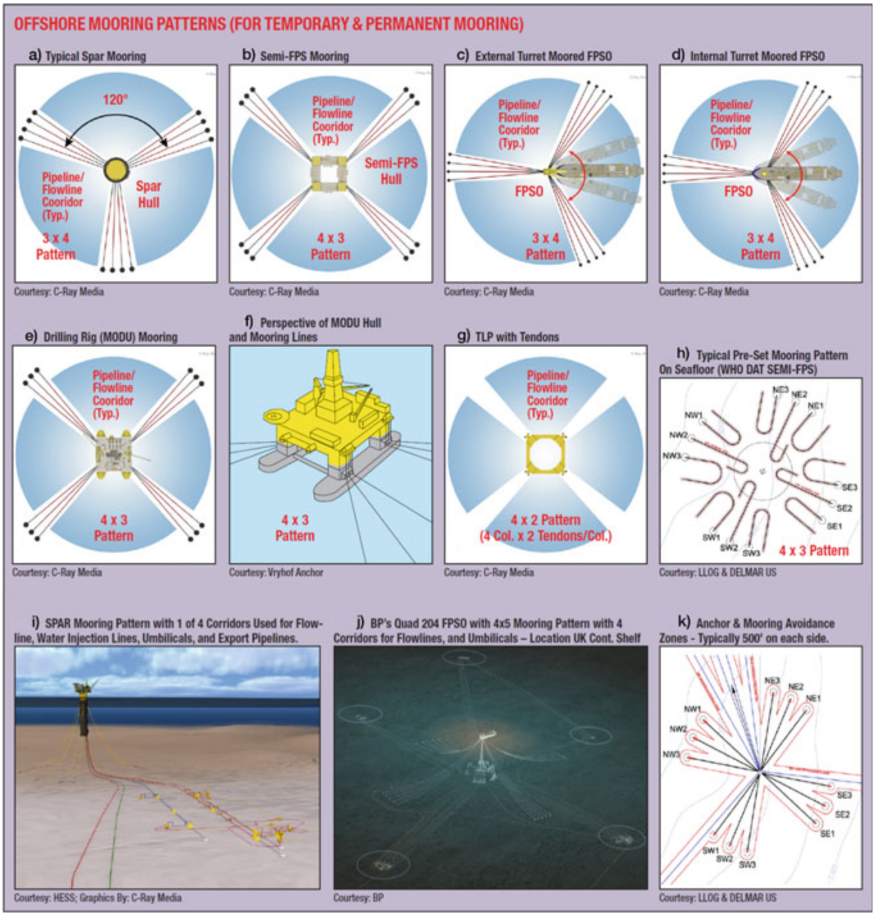


Fig. 5.21 Temporary and permanent offshore mooring configurations. (Courtesy of Offshore Magazine)

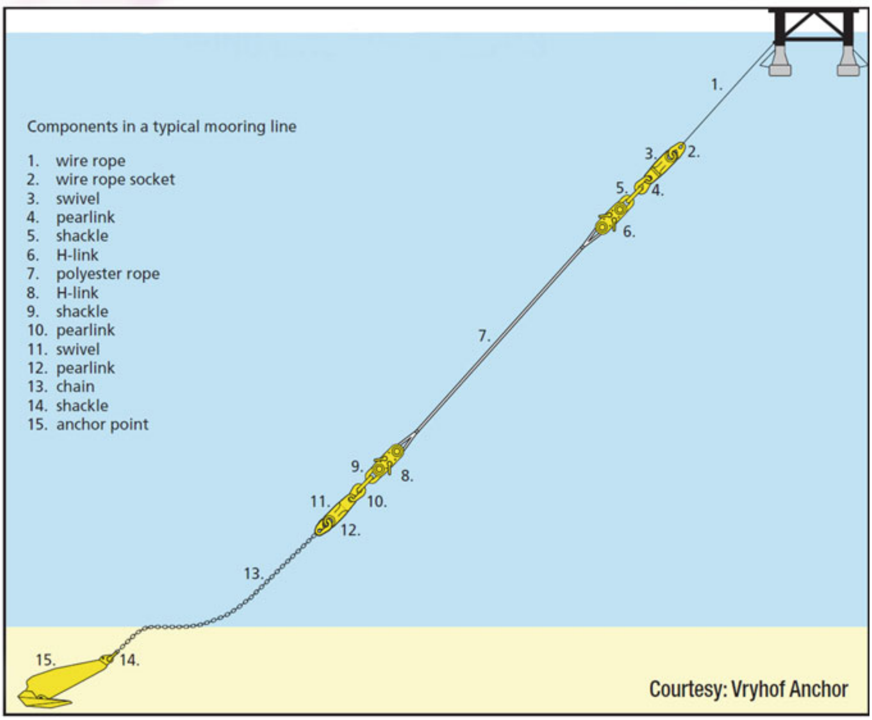


Fig. 5.22 Mooring line components. (Courtesy of Offshore Magazine)

5.6.5 Dynamic Positioning

When thrusters, standalone or in combination with mooring systems, are simultaneously applied to keep the unit in place, it is called "Dynamic Positioning" system or DP system. Such a system provides a highly versatile anchoring system for floating units at deep and ultra-deep locations [18].

5.7 Anchoring Types

Mooring systems need to be anchored to the seabed. The marine ground-anchors are designed based on their capacity for withstanding uplift force and horizontal drag force. There are different anchor types including clump weight, driven pile, drag anchor, suction pile, torpedo pile (drop anchor), and vertical load anchor (see Fig. 5.23).

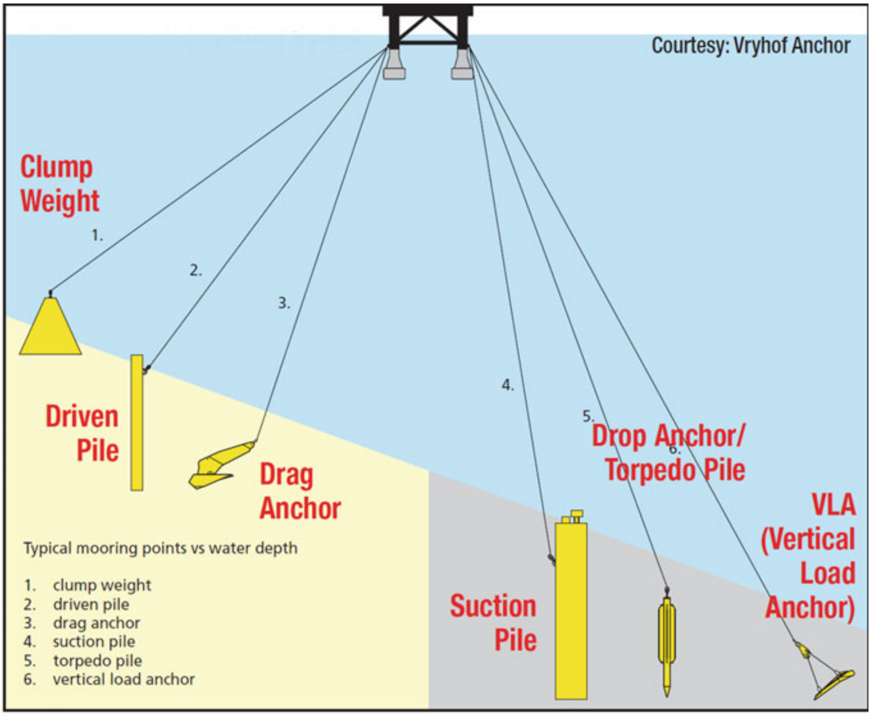


Fig. 5.23 Different anchor types. (Courtesy of Offshore Magazine)

Pre-laid mooring system

In *traditional mooring systems*, the mooring system is established while the working unit is in place. However, due to the day-rate hire cost of the rig, this is not of interest. *Pre-laid mooring system* is a cost efficient alternative scenario. In this approach, prior to mobilizing the working unit, a vessel spreads and establishes the mooring system.

5.8 Moonpool

The moonpool is an open space located in the hull of a vessel or a drillship, which provides access to water entry. The moonpool can have different configurations varying from rectangular to an inverted funnel-like shape, Fig. 5.24. Size, configuration and number of available moonpool can impact the efficiency of a P&A operation as the number of operations which can run simultaneously and crew numbers depend on such factors. When a working unit is in operating mode, at zero speed, the moonpool is opened and a large volume of water known as *entrained water* enters into it. The entrained water has motion which appears as two modes, oscillation and sloshing.

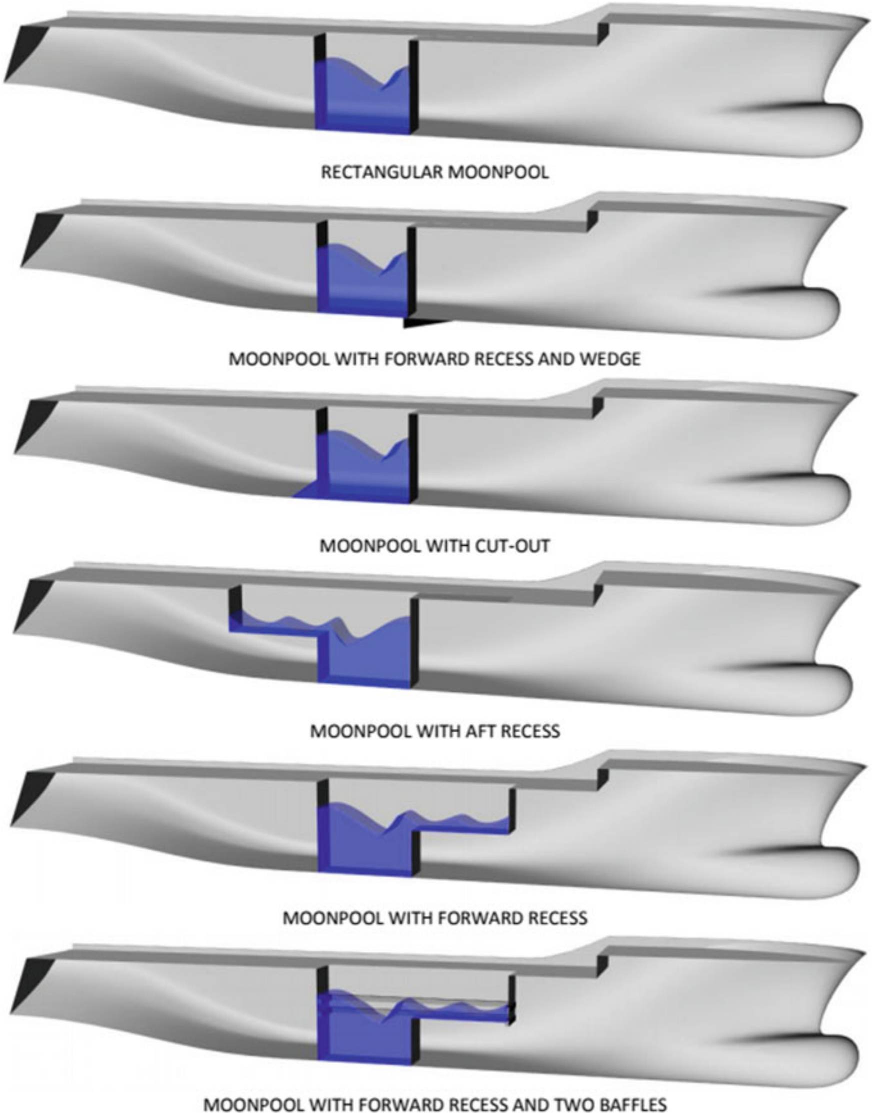


Fig. 5.24 Some types of moonpool configurations. (After Hammargren and Tornblom) [19]

The oscillation mode is when there is a vertical motion of water column. The sloshing mode is when water moves in a longitudinal direction. There are situations where the water motion inside the moonpool can be so strong that the water level reaches the deck and can cause harm to personnel.

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