

METALLIC OFFSHORE PLATFORMS – PRODUCTION CHRONOLOGY AND FUTURE SOLUTIONS

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ABSTRACT

The article, after a short historic setting and an attempt to definitions and classifications, will be articulated around three chapters following the chronology of the realization (studies, manufacturing, installation) of the metallic offshore platforms and will end on a fast review of the solutions of the future. The demand for energy continues to rise asking for inexpensive energy solutions. A large mettalic structure used to house workforce and machinery (offshore platform) extract, process and ship or pipe the oil and natural gas to the hore, can be fixed to the ocean bottom, depending on the circumstances, or could be an island or can float.

Keywords: offshore platforme, jack-up, assembling, loading, installation

1. INTRODUCTION

It was not until 1946 that the first steel piles were used. The construction was carried out on site and the works were done over several weeks. In 1947 the basic concept appears, then it is resumed at several thousand copies: prefabrication of the support in shore-based steel, barge transport, crane placement, batteries steel beaten through the legs. The water depth was only 6 m, but it is 30 km from the coast, and the installation work only lasts nine days. 1955 sees the invention of peripheral piles (skirt piles). The story then accelerates quickly: in 1957 appears the first jacket "launched"; in 1959, a platform is set up in 60 m of water; in 1989, was reached a depth of water of 416 m, with support from 45,000 t (seven times the weight of the Eiffel Tower); finally, 1993 saw the setting up of a structure with legs stretched in 870 m water depth.

Historically, the goal was to have of an emerged work surface, in shallow water

depths bigger and bigger. But what work to get here?

Exploration drilling first! We are then dealing with mobile platforms that are not set up at the place of work only for a few weeks or a few months. Three kinds of supports are used by the drillers, according to the height:

- Jack-up, for shallow water depths (up to 100 or 120 m). A jack-up is a stool with three or four legs that can get up or down with big racks playing on the horizontal part of the stool (the drill bridge):

- lowered, resting at the bottom of the water, the legs ensure good stability; on the bridge out of water, the derrick of drilling works safely.

- Raised, legs, clearly protruding above of the bridge, allow the latter, which is then floating, to move with tugs carrying it to a new drilling site.

- "Semi-submersibles" for bigger depths of water (up to 500 m), are floating supports. In fixed position for the drilling, they are anchored: the drillers settle the weak "excur-

sion" (1 to 2 m) around the target of drilling. When moving from one drilling site to another, they are most often self-propelled.

- "Dynamic position vessels" for very big depths of water. These boats are equipped with side engines which, in the drilling position, are actuated automatically in order to counter environmental efforts (wind, current) and to stay in a near-fixed position. There is no more anchoring.

The present article does not concern these mobile platforms, but only the fixed platforms, installed for the life of the field discovered through exploration drilling that was just mentioned.

Platforms perform a variety of functions: production drilling; effluent treatment (separation of gas, oil, water); utilities (supply of electrical energy, for example); injection of water, gas, compression of gas; living quarters; flares. So, we can find on a field, depending on its size and depth of water, a platform by function or multiple functions grouped on a single platform.

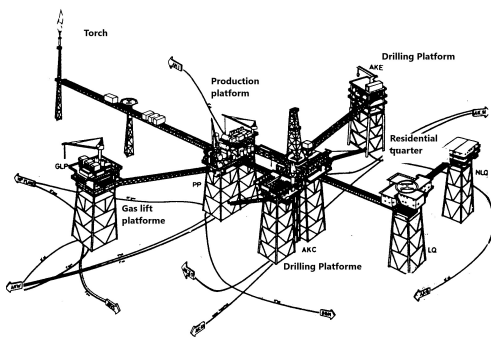


Fig.1. Field example

The nature of foundations introduces two kinds of fixed platforms:

- Platforms with gravity supports: one (or more) bay at the foot of the platform is filled with sand and ensures stability (if soil conditions permit) after the set up. This principle has made the success of concrete platforms, all gravitational. Of the 15,000 to 20,000 existing platforms in the world today, only about thirty are in concrete, mainly in the Norwegian part of the North Sea.

- Platforms with tubular lattice support (the jacket) and piles that are the subject of the rest of this article.

This paper concerns the immersed part of the support. The original system "bridge +piles" is historically limited, saw it, at shallow water depths and quiet areas.

Piles subjected, on the one hand, to vertical stresses due to the weight of equipment installed on the work platform and, on the other hand, the horizontal forces due to the swell and the current, are thus exposed to the risk of buckling as soon as their slenderness (function directly proportional to the length) becomes big. With the increase in water depths and the increase in charges, it has become imperative to decrease the free length of the piles, in other words to counteract them.

The installation under water of such bracing being very difficult, if not impossible, a separate entity, often called jacket, was designed. It is manufactured and installed in one piece, then put the piles into the corner tubes (the "Legs"). But this jacket offers often important screens (to swell, current, wind), mainly in the upper part; he then becomes necessary to resume the moment of reversal at the bottom, usually by embedding the piles which take up the vertical effort.

The classification of fixed metal platforms "pilled" will settle next:

- depending on the environmental conditions:

- easy, mostly in warm seas: gulf from Guinea, Persian Gulf, Indonesia, etc.,
- average, in temperate zones: south of the sea North, Western Mediterranean, etc.,
- severe, especially in cold areas: North Sea, Baltic Sea, Tierra del Fuego, etc.

- depending on the depth of the water:

- less than 30 m,
- between 30 and 150 m,
- beyond 150 m.

- depending on the number of legs:

- 3 legs,
- 4 legs,
- 6 legs,
- 8 legs.

For these last two categories, as we will see below, could be distinguish the true legs and the false legs, in depending on the method of manufacture or transport (in position vertical or horizontal), or the type of installation (launch, lifting or floating), or the type of batteries.

The following is rather geared towards the platforms of eight legs subjected to medium or severe environments in water depths of the order of 100 m.

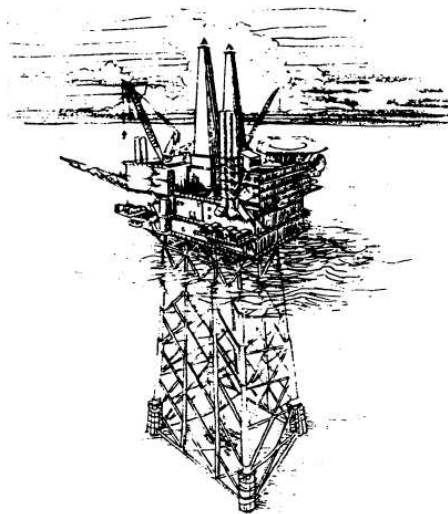


Fig.2. Platform with 8 legs

2. STUDIES

2.1. THE LOADS

The calculation of a fixed platform requires a large number information:

- Nature, size, weight (empty, in operations and in test conditions) and the arrangement of the different equipment.
- Normal, exceptional and accidental work overloads.
- The weather-oceanographic data:
 - water depth,
 - tide height,
 - exceptional elevation of storms,

- amplitude and wave period under normal conditions (return period of one year) and in extreme conditions (period back 50 or 100 years),
 - surface current and its variation according to the depth,
 - normal and exceptional wind speed,
 - extra thickness of marine concretions (shellfish, etc.) depending on the depth,
 - seismic zone.
- The characteristics of the soil at the surface and the height of the piles, the subsidence possibilities (ie soil subsidence due to reservoir depression), the instability risks of the surface layer ("mudslide").
 - The shelf life of the platform.

2.2. THE BASIC CALCULATION

One of the software commonly used to calculate platforms is a general program of three-dimensional structural resolution developed for the Massachusetts Institute of Technology (MIT) called STRUDL (STRUcture Design Language). This software has been perfected, developed by the centers research and / or engineering.

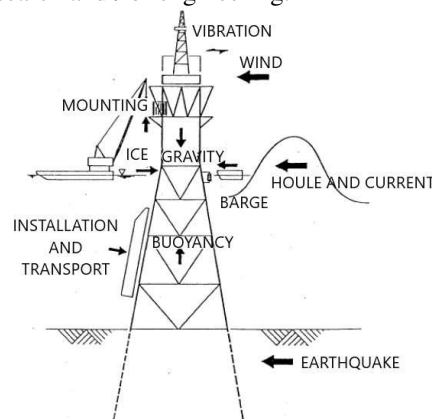


Fig.3. Loads on a platform

This calculation has three main steps:

1. The definition of the geometry of the structure, with, for all the nodes, their spatial coordinates and their conditions to limits (free node, support node, links between nodes), and the definition of the mechanical characteristics of all cylindrical bars struc-

ture. It should be noted that the buried part of piles is represented by a stiffness matrix taking into account the properties of the soil and batteries.

2. The definition of charges. We saw that they were many, and their combinations should be treated with warning. The wave directions are first selected (from three to six or eight) in order to have the most load cases unfavorable for the piles and the jacket.

The following different charges are also taken in account:

- vertically:
 - the weight of the structure and accessories,
 - the buoyancy of Archimedes on submerged tubes,
 - the weight of the extra thicknesses of marine concretions,
 - gravity loads due to superstructures;
- horizontally:
 - the wind loads on the emergent part of the platform and on the superstructures,
 - the loads due to the swell and the current on the main structures enlarged by the thicknesses of concretions and "ancillary" structures such as wharf, dampers, anodes, tubes, drill conductors, effluent supply or discharge pipes,
 - the loads due to the accidental impact of boats in the upper part of the platform,
 - the expenses due to the considering of the possible earthquakes.

3. The output of the results preceded by several automatic checks (via the "plotter" and the "scan on") for to detect possible errors of geometry, units, commands.

The analyzes define:

- displacements,
- the support reactions,
- the efforts at different points of each bar,
- checking the constraints,
- punching verification of the nodes,
- the fatigue check of the knots.

2.3. COMPLEMENTARY CHECKS

Static and possibly dynamic analyzes are iterative based on the results (and changes in section), but also the evolution of the charges, the conditions of manufacturing, loading, transportation and installation.

For large platforms it is a bit complicated, because it must count three iterations.

In addition to these calculations, checks should be made to consider the following phases:

- manufacture (for example, rotation in a vertical position panels built horizontally: the "roll-up"),
- the loading on the barge of transport (sliding of the structure based on several nodes of the main members launching beams integrated into the structure),
- transport (stability and strength of the solidarized structure on the barge subjected to dynamic forces),
- installation (by launching, lifting).

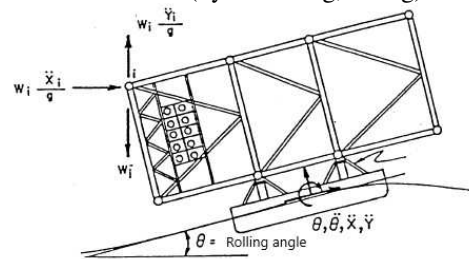


Fig.4. Transport of a platform

It is also necessary to consider the constraints by fatigue during transport and during the life of the structure. Reinforcements on the right knots (oversize, stiffeners) are then decided to limit the damage due to fatigue.

Moreover, the calculation of piles, conducted in parallel, leads often to changes in the design of the structure: it is necessary to check that the lateral and axial reactions of the soil are doing well, friction and / or peak, calculated efforts.

2.4. MULTIDISCIPLINARY DESIGN

The calculation of a platform thus involves simultaneously six technical disciplines:

- oceanography for the determination of environmental marine values,
- geotechnics for the specification of soil characteristics and depth, as well as for the selection of threshing hammers,
- the study of the resistance of materials for calculations static or dynamic structure,
- metallurgy for the choice of grades and qualities of steel,
- naval architecture for buoyancy checks and stability when towing, launching and ballasting,
- marine operations for the selection of barges transport, launching and / or lifting gear.

3. MANUFACTURING

3.1. STEEL

By simplifying a lot, three features can define the steel used: high thicknesses, 40 to 100 mm, even 130 mm; a yield strength of 360 MPa (current value), 420 MPa, or 500 MPa; a very low temperature resilience (-40 or -50° C) to avoid brittle fracture problems.

These steels are traditionally of the "normalized" type. Tempered-tempered or accelerated-cooling steels are also encountered (more promising in the future because of their lower price and their implementation - basically the welding is easier and more economical).

In addition, areas with a high demand for thickness require steels with good characteristics in cross-machine direction (Z steel with a minimum of 35% necking) to avoid lamellar tearing problems.

In addition to thermal stress relieving treatments are imposed for complex highly stressed nodes or at thick layers. This requirement leads to cutting the structure into subassemblies which can be introduced into

an oven so as to minimize the number of welds to be stripped on site.

3.2. THE NODES AND PREFABRICATION

The knots in mechano-welded implement welds on thick sheets are difficult to access and to control.

The technique of molded steel nodes ("casting nodes") has been developed in recent years. It tends to develop for large platforms like the North Sea. The mono block knot is cast in a mold made especially.

The advantages of these molded nodes, compared to the nodes mechanically welded, are obvious: weight gain when they are designed with a more compact geometry; better adapted forms to the constraints; better resistance to fatigue and suppression of internal stiffening (circles, diaphragms).

This type of knot appeared first for the ears lifting modules. It is now generalizing for the knots, in areas where fatigue is critical.

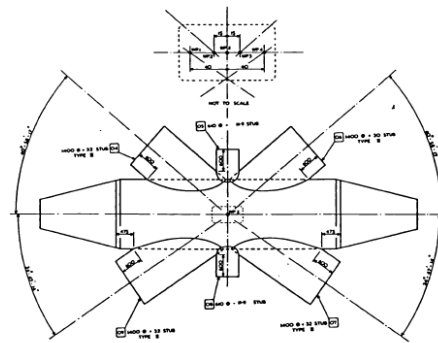


Fig.5. Node example in welded construction

The building blocks of the platform (knots, tubes, piles, anodes, etc.) are first prefabricated. They can be subcontracted in different workshops. The whole is then conveyed on an assembly yard located at the seaside.

In parallel with this prefabrication, the works of preparatory civil engineering: essentially, the two beams slip that will support the set to jacket lots of its assembly, and whose spacing must correspond to that of launch beams of the barge.

3.3. THE ASSEMBLING

The structure is made horizontally. The lattice girders are first assembled horizontally, laterally to skidding beams and then the most often by 112 length, as indicated by the "mounting phases".

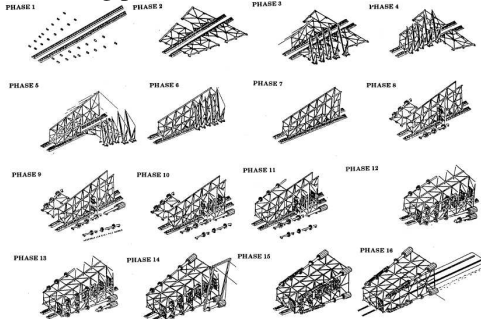


Fig.6. Mounting phases



Fig.7. Assembling

Lifting (the "roll-up") is carried out by a set of four to ten cranes + winches. This operation is delicate, each flat-form lattice board being very heavy and very flexible (temporary reinforcements are sometimes necessary). Each crane is maintained at computational load level. Successive rotations are weak (a few degrees). At each stage, cranes stop. The charges are then rebalanced, and each crane is advanced to reposition itself in line with the load. The operation lasts several hours to bring the panel to 10° from the vertical position. Load control is then ensured by the guyding winches that will bring the panel to its final vertical position and maintain it until the first connecting elements are welded.

The connecting elements of the peripheral piles with the platform ("bottles") are the heaviest (600 to 2,000 t) and include the most works. They are raised last.

Main structure completed, finishing work can then be carried out: fixation of "risers", "tubes", ballast control piping, piles guides, possible floatation tanks, etc.

Between the beginning of manufacture and the loading, it take a period of 18 to 24 months.

A detailed analysis of tasks and subcontracting is necessary and must consider the inevitable unforeseen events (strikes, delays supply, repairs, bad weather). The planning must consider the existence of the weather window in which the installation generally positions: May to August. Any delay may result in a delay from the general program to the season next; that's why very important penalties are always provided.

3.4. THE LOADING

The loading of the jacket on the barge of transport and launch is the last stage of manufacturing. It's a delicate operation: it is a matter of dragging a package by translation of several thousand tons of land on a support floating. The horizontality of the whole must be controlled in considering the combined action:

- the tide that provides additional buoyancy to rising tide,
- ballasting the compartments of the barge to ensure his level and / or his plate.

In practice, we try to use the rising tide and complete the operation in six hours. In some cases, simplifies the procedure by placing the transport barge on the bottom water previously compacted and adjusted.

The main equipment used for this operation are: a double de-ballasting pump system to get capacities of the order of 15.000 to 20.000 m³/h, slip equipped with Teflon to reduce the coefficient of friction, a thrust system whose ability revolves around 2,000 / 3,000 t.

4. INSTALLATION

4.1. TRANSPORTATION

The jacket set up on the barge must be effectively secured: the whole must indeed be able to cross sea conditions often lenient.

Flat-bottomed barges used for this type of transport are very stable: their metacentric radius is very large compared to that of traditional boats. But the center of gravity of transported loads is also abnormally high compared to barge bridge, and stability calculations are to be conducted before determining the transport barge.

The sizing thus calculated may require several hundred tons of tubes to bond the main chords from the jacket to the barge, to the right of its main diaphragms. These the last are to be verified and strengthened in many cases.

4.2. THE LAUNCHING

This operation is performed in a favorable weather window, after cutting the lashing elements. Two techniques are compete and condition the design of the platform:

- Launching: The jacket is pushed with jacks or pulled with cables until the articulated arm ("rocker-arm") at the end of the barge takes over the weight of the jacket and topple it to Skin. Verifications are carried out beforehand (either by the calculation, either through model tests) to determine:

- constraints in the structure during launch,
- the trajectories of the jacket and the barge,
- the maximum depth reached by the jacket,
- the final equilibrium position.

They lead to play on buoyancy parameters: shuttering of frames, addition of floats.

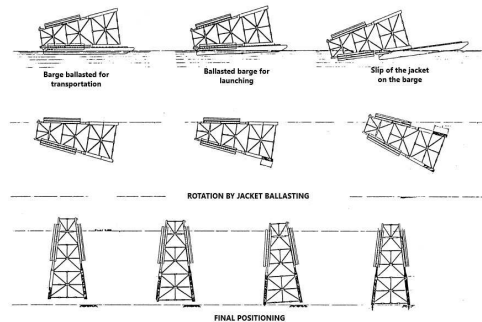


Fig.8. Launching phases

At the end of the launch, the jacket is horizontal and barely emerges from the surface of the water. The successive ballastings, again controlled by the computation and on model, will straighten gradually to the vertical position at its final location.

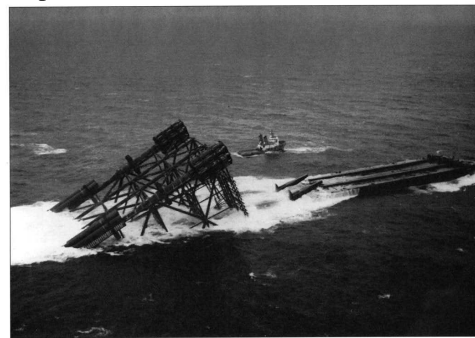


Fig.9. Jacket launching

To save time on production, the installation is more and more often over wells previously drilled. They are then protected by a structure (the "template") which will serve as a guide for the jacket during its final positioning.

- Lifting: The jacket is lifted directly from the transport barge by lifting barges with capacities up to 2x7,000 tons.

The structure is immersed horizontally with, in general, several chords closed to make it float temporarily. It is then taken up by slings located in head, straightened while the chords are ballasted, and positioned at its final location.

Lifting at sea poses a dynamic problem that must be control: the crane and the load rest on supports floating animated own movements. When setting the tension of the

slings, the relative movements of the supports can lead to significant dynamic efforts.

The recent appearance of cranes with a nominal power of 6 to 7,000 t mounted in pairs on a barge allows, considering safety factors and decreases in capacity depending on the arrow, to lift "parcels" of 10,000 t. Lifting accessories, shackles, slings reach exceptional dimensions (cables 600 mm in diameter, for example, for slings) and require special lifting accessories. Their setting up, especially in water, is long and delicate.

4.3. THE FOUNDATIONS

In order to ensure a good foundation when setting up, stabilizing floors ("mud-mat") in wood, steel or aluminum are provided during manufacturing at the lower level of the jacket. Their surface is a function of the nature of the superficial soil meet. This temporary foundation allows to set up in good conditions the final deep foundations ensured by batteries.

These are of three types:

- The main cells, installed in the frames of the jacket over their entire length, directly support the legs bridge receiving superstructures and modules. The jacket is then hanging overhead on the piles through a welded joint.

- Inserted piles which, when they are deemed necessary by the calculation (increase of the inertia of all) or geotechnical (difficulty of driving threshing hard floor), are installed inside the main batteries (after drilling) and bonded with them, either by welding at the head, or by concreting the annular space if the inserted pile does not do not go back to the surface.

- The peripheral piles (skirt piles) that are arranged around the main legs of the jacket and do not go back up to its summit. The structure of the jacket works then like a recessed console in the ground.

The installation of the piles is a result of handling: threshing or drilling, additional pile length jointing until the pile reaches the required depth and lift determined by the cal-

culatation. They are then partially united bottom of the jacket dam cylinders bottles mentioned above, using the technique of concrete injection or expansion mechanical type Hydra-Lok.

The threshing hammers used are of two types:

- steam (and therefore aerial), energies up to 3000 KNm,
- hydraulic (mostly underwater), which avoid the set up staple piles and make it possible to have vertical piles.

The structure is then ready to receive its bridge and its superstructures.

The installation times are very variable: if the phase of launching is short (a few hours), setting up the piles depends on their number, the nature of the soil, the conditions weather, construction hazards, and it varies from a few days to several weeks.

5. TRENDS FOR THE FUTURE

We will consider the following three themes of reflection:

5.1. SAVINGS LINKED TO THE LIMITATION OF WORK AT SEA

Once the jacket is installed, it is necessary to ask the crane the different parts of the superstructure, i.e. the Module Support Frame and modules, and then connect modules between them (the "hook-up"). This work done offshore, is long, expensive and dangerous.

Rather than having a superstructure in several pieces, it can be designed in one block manufactured and tested on the ground.

If the weight of this "integrated bridge" of several thousand tons is excessive to be able to be posed with the new barges very large capacity or by the available lifting means in the area concerned, it may be placed on the support by ballasting of the barge (the "mating").

Support must be suitable for this installation method. In shallow water, in the delta

areas of Indonesia for example, it consists only of battered stacks and receives a built-in bridge that connects the batteries and provides stability from the whole; in greater depth of water, as in Middle East, the jacket is designed to receive between her legs the barge in charge of the integrated bridge: the horizontal level of upper bracing is lower than normal, and leg spacing is more important than usual.

The same principle pushes to study the use of a jack-up not only drilling, but also production, and permanently installed on "crushed" low height seats in the ground. As pointed out above, the jack-up bridge arrives fully equipped flotation system on the production site: sea are limited to foundation work.

5.2. REDUCED WEIGHT OF STRUCTURES

Any weight gain is economically favorable. This follows from:

- the use of steels with a very high yield strength (450-500 MPa), but, unfortunately, the current criteria at the fatigue are not advantageous,
- even more systematic use of cast nodes,
- the reduction of the number of anodes thanks to the generalized painting on the entire platform, except the welds to be inspected,
- the stabilization floors of the aluminum jacket,
- devices to reduce the swell to the swell, in particular due to the concretions,
- the "inserts" in the legs with concreting of the ring finger "Leg-insert" to improve accidental impact resistance boats in the tidal zone.

5.3. GREAT DEPTHS

The extrapolation of the traditional jacket+piles+superstructures system seems to have reached its limit with the development of Bull Winkle by 410 m of water depth.

Beyond that, three options seem possible:

- Remove the support and develop the field via automated underwater systems ... Some operators, in Brazil for example, have made this drastic choice.

- Remove the moment of embedding at the foot of the platform and have only one articulation or semi-articulation. It's the principle of flexible structures ("compiler towers"). They are slimmer, much lighter, and accept distortions controlled but not insignificant. In some cases, the effort head is picked up via anchored side cables. The vertical forces are transmitted through the reticulated structure to a fixed base. Only one platform of this type has been so far built.

- Reverse the direction of efforts in the legs using a once again the principle of Archimedes to realize a platform with stretched legs (TLP = Tension Leg Platform). The bridge is a sort of floating caisson, pulled down by tie rods working in traction. Two platforms of this type exist, one at sea north by 147 m of water depth, the other in the Gulf of Mexico by 526 m depth, and three others are in the process of construction (one of them will be the world record, with 870 m in depth).

6. CONCLUDING REMARKS

From this short review, it can be retained:

- the multidisciplinary aspect of this technique,
- the importance of orders of magnitude (weight, dimensions, costs)
- the rapid evolution towards the great depths of water.

Based on water depth considerations and deck equipment necessary to perform its service, each platform type is chosen. In shallow water depths (up to 150m) the jackup platforms are used while the fixed template (jacket) platforms may vary in size and height, and can be used in water depths up to about 300 meters, but commonly less than 150 meters. Semi-submersible platforms are

used in water depths up to 1800 meters and the Tension Leg Platforms are used in water depths greater than 300 meters. The SPAR platforms are used in very deep water exploration.

Considering the importance of the time factor in fabrication and installation, may also be studied more expensive platforms and procedures.

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