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THE WELLHEAD BARGE

A VERSATILE SOLUTION FOR MILD DEEPWATER CONDITIONS

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1. ABSTRACT

The Wellhead Barge (WHB) is a wellhead platform solution developed by Bouygues Offshore (BOS) and its partners Sedco-Forex and 2H Engineering for the development of deepwater fields in mild conditions.

This solution is based on a spread moored barge supporting the facilities required for drilling, completion and work over, partial production facilities and accommodating production risers with surface trees in a central well-bay. The WHB is linked by import / export lines to a main process centre.

The WHB has been developed for West Africa and Indonesia. It takes full advantage of the mild wave conditions and the directionality of the sea states.

The paper will present the main features of a WHB designed to accommodate up to 24 surface trees and equipped for autonomous drilling.

Technical topics will include general deck layout, well-bay area and drilling equipment definition, production riser preliminary design and installation principles, mooring system and drilling availability.

Finally, the advantages of the solution will be presented together with the reasons why the WHB should be very effective in terms of CAPEX and OPEX.

2. INTRODUCTION

BOUYGUES OFFSHORE is currently involved in two EPCI contracts for ELF Angola. Work covers firstly the FPSO and secondly the flowlines, risers and umbilicals for the deep water GIRASSOL field offshore ANGOLA in 1300 m water depth.

SEDCO FOREX is a pioneer and leader offshore drilling in particular in the drilling of deepwater wells with surface BOP (Blow Out Preventer).

This advanced technology allows to drill conventional deepwater wells with the BOP being located at the surface of the water instead of on the sea-bed, thus saving considerable drilling time.

Such unique technology has been developed offshore Indonesia's deepwater acreage, with over 30 wells drilled with surface BOP stack. The current water depth record for drilling with surface BOP is 4370 ft and has been achieved with the Semi-submersible SEDCO-602 in June 1999.

2H Engineering is an independant-engineering consultancy that specialises in riser system design and particularly the development of riser systems for deep and ultra deep water floating production.

BOUYGUES OFFSHORE and SEDCO-FOREX with the assistance of 2H ENGINEERING have developed barge solutions with surface trees: the Multifunction Barge (MFB) and the Wellhead Barge (WHB), dedicated to the deepwater fields in mild environmental areas.

Both the WHB and the MFB will use the surface BOP drilling technology as a direct application of the new technology already developed offshore Indonesia.

3. THE MULTIFUNCTION BARGE

The Multifunction Barge (MFB) is an FPSO with surface wellheads and drilling facilities. This solution which has been under development since 1995, takes advantage of the benign sea conditions to offer a shallow draft production support with surface wellheads, and a conventional catenary mooring system. (BP-Amoco, ELF, EXXON, SHELL and STATOIL have brought a technical and financial contribution to the development of the MFB).

Development work of the MFB for water depths varying from 1500 m to 3000 m is now complete (hull, moorings, hull systems, drilling equipment, wellbay area, riser design, static and fatigue analysis of risers, risers installation method…).

The MFB has been developed to be the central platform of a deepwater field gathering the functions of drilling, production with surface trees, treatment, storage and offloading facilities (directly or through a buoy).

4. FROM THE MFB TO THE WHB

Based on the same design principles as for the MFB but with reduced functions (no crude oil storage, little –or no- production equipment, minimum utilities) the Wellhead Barge (WHB) has a far smaller hull size. The Wellhead Barge (WHB) is proposed for mild environment areas, providing only support for the surface wellheads and drilling functions. However, the large deck and its high payload capacity permits the installation of some production equipment should the fluid properties require, such as first stage of separation.

The wellhead barge is a satellite remotely controlled spread moored barge providing:

- Drilling through high-pressure riser and surface BOP.
- Autonomous Drilling operations.
- Vertical free-standing production risers with surface trees protected within a central wellbay.
- Well control and testing with limited treating facilities.
- Connections to the central facility.

Some wells may be entirely pre-drilled to start production as early as possible. Drilling of the other wells will be performed after production start-up.

The wellhead barge presented in this document is designed for 24-production risers and 1,200 m water depth.

Thanks to the low sensitivity of the concept to the topsides load, the barge can be alternatively adapted to the following without major changes :

- Perform drilling operations with tender assistance.
- Upgrade the wellhead barge into a production unit with full treating facilities.

5. THE WHB SOLUTION

The WHB provides the same advantages as other wellhead platforms such as the TLP or the SPAR, allowing use of surface wellheads and trees.

The WHB can be constructed entirely in a dry dock, be commissioned at a quay near an area with suitable labour resources, and then be towed to the site without major offshore hook-up work. On site, well pre-drilling for the 30" and 20" casings can be performed from a conventional deepwater drilling rig before arrival of the barge or from the barge itself if more economical. After installation on site and connection to the host platform, the well drilling can start quickly and the first oil will be produced immediately after tieback and completion of the first well (see figure 1).

6. DESCRIPTION OF THE WHB

The use of a barge type floater for drilling and production operations is particularly suited to Indonesia where environmental conditions are mild and waves largely unidirectional.

6.1. Deck Layout

The spacious deck area is designed for an uncongested topsides arrangement, with a simple interface between the topsides and the hull (see figure 2). The large size of the barge deck permits :
Reduction in the number of deck levels which simplifies the topsides design, facilitates construction and minimises the risks related to the installation;
Uncongested topsides arrangement, resulting in convenient unit operation and control, as well as a high safety level;
Maximum separation of hazardous areas from normally manned areas, including accommodation and Temporary Safe Refuge (TSR);
Ample allowance for topsides late definition and for future changes (retrofits, tie-ins, etc.) due to the exceptional stability and lack of sensitivity to changes in weight and centre of gravity of topsides facilities.

The production equipment is split into two main zones. One is at the bow adjacent to the living quarters with low risk modules, and one is at stern with more hazardous equipment such as the flare (see table 2).

The drilling area with the moonpool is located in the middle of the deck, from port side to starboard. This arrangement minimises the vertical relative motions between the risers and the hull. Wide areas around the moonpool are available for easy handling of the drilling facilities, the storage of drill pipe and casing, and for mud tanks.

The hull has a low sensitivity to topsides weight increase. This allows flexibility in the amount of processing equipment to be installed on the WHB. This is due to the large floating area and to the freeboard in excess of requirements.

6.2. High Pressure Production Risers and Riser Stroke

The wellbay of the WHB is designed for drilling operations and for the installation and accommodation of 24 risers in two longitudinal rows. Drilling operations will be performed on pre-drilled wells. To avoid interference with surrounding wellhead trees and to improve safety, the BOP is located away from the production tree hazardous area. Inside the wellbay, a guiding structure is used to accommodate all relative motions between the barge and the risers. The fluids are transferred from the production risers via jumper hoses between surface wellhead trees and the barge (see figure 3).

The production risers are tensioned by steel buoyancy cans.This tensioning system has the advantage of a totally passive system, with minimum maintenance and can accommodate larger stroke requirements than typical hydro-pneumatic tensioning systems. The main challenge of the riser design and analysis was to prove acceptable response within the moonpool of a Wellhead Barge. This required optimisation of riser support, structural arrangement and buoyancy distribution.

The riser architecture adopted for the Wellhead Barge (WHB) is extrapolated from that successfully used on Tension Leg Platforms (TLP). However, some characteristics of the WHB are more favourable than a TLP. One is the moonpool which protects the risers in the most exposed area from wave and current action, and a second is the platform offset (as a proportion of water depth) which is less than for existing TLPs. This arrangement is particularly favourable for mild environments as found in Indonesia (see table 1).

Production riser design is based on the following key issues:

- Extreme stress and fatigue of the taper stress joint and riser joints below the upper buoyancy assembly.
- Deck clearance in relation to relative riser vertical and angular movements to the vessel.
- Clearance circle required for arranging the subsea wellheads on the seabed to facilitate installation of the production and drilling risers.

Figure 4 gives the von Mises stresses envelope along the production riser in the 100-year wave sea state with its associated current and barge offset.

This production riser arrangement is similar to that of a SPAR except that the upper section is guided at a single point above the buoyancy cans, rather than being constrained at multiple elevation along the air cans. Therefore, the risers are largely free to deflect, stresses are lower and fatigue life is well improved.

Riser Stroke:

The height of the skid base of the drilling structure and the length of the flexible jumpers are governed by the total relative vertical motions between the surface trees and the WHB.

The clearance distances imposed by the design rules include the high frequency wave induced component calculated for extreme conditions (see figure 5)

The day to day riser stroke is lower than 3 meters (97% of the time).

6.3. Drilling Facility

Drilling is performed from a single position in the wellbay, using a surface BOP and a H.P. riser (see figure 6).

The configuration allows any well sequence for drilling, completion or work-over operation.

The WHB can be adapted to perform simultaneous drilling and completion operations.

The large deck area and the low sensitivity of the barge to weight increase allows flexibility in rig design, possibility to drill top hole section, improvement of safety by using mechanised pipe handling, and reduction in well construction cost.

A modular solution has been selected for fast pre-commissioning and better asset utilisation i.e. possibility to re-use the package on other platforms (easy demobilisation, possible conversion to workover rig).

6.4. Hull Structure

The hull of the WHB is a rectangular barge 180 m long, 60 m wide and 16 m deep. It is equipped with a central moonpool 80 m long and 20 m wide allowing drilling operations and housing the high-pressure production risers (see table 3).

The hull dimensions have been selected in order to reach a good hydrodynamic behaviour allowing a high drilling operability. The large deck area provides ample room to support all topsides equipment.

The moderate size of the hull allows construction in several shipyards world-wide using conventional shipyard procedures.

Water ballast is used to maintain the operational 6 m draft, during drilling operations and after drilling rig removal, compensate for heel and trim angles and reduce still water bending moment.

The hull also provides large storage capacities for Diesel oil and drilling fluids.

The hull preliminary structural design is based on the American Bureau of shipping and the Bureau Veritas classification Rules, deep-sea notation (reference 2 and 3).

6.5. Seaworthiness and Drilling Operability

The seaworthiness limits of a barge combining surface trees and drilling are given by both motion criteria for drilling operations and relative displacement between the barge and the surface trees (see table 4).

Indeed, The main component of the relative motions between the WHB and the risers is the wave induced motion of the barge itself.

The RAOs of the Wellhead has been compared to those of two drilling units: a latest generation drill ship and a semi-submersible for head and beam seas and for heave, roll and pitch (see figure 7).

This comparison shows that the Wellhead has a very good global behaviour relative to vessels designed to drill in more severe sea environments (Gulf of Mexico and North Sea).

The drill-ship taken for this comparison is one of the latest generation drill-ships fitted with active motion reduction systems.

The RAOs show that the Wellhead behaviour is in between the two drilling vessels: not as good as the semi-submersible but better than the latest generation drill-ship.

The operability approach requires to take into account the time percentage associated to the different drilling operations. The calculation is based on the probability of having a critical sea state, which occurs while the associated operation is carried out.

Barge operability is mainly dependent on the drilling actions, which are associated with important well time. There are less than 0.2 % of the sea states which would induce motions above working limits for operations which represent 90% of the well time. The most restrictive operations, as regards to motion responses, are associated with the shortest well time percentage.

If the whole drilling sequence is considered; taking into account each respective operation well time, the barge probability for operability is estimated to be more than 99.5%.

6.6. Mooring System

It is composed of 12 conventional catenary lines, 3 located at each corner of the Wellhead Barge, and arranged in a sector from 40° to 50° respectively to the barge longitudinal axis. Mooring lines are fixed to the seabed by suction anchors, and pass through the fairleads to the tensioners. The fairleads are positioned low on the hull to reduce the risk of impairment due vessel impact.

Mooring analysis has been performed according to criteria recommended by the API RP 2SK (reference 4).

The lines themselves are a combination of chain and steel cable.

6.7. Topsides construction and integration

The WHB solution allows a large degree of flexibility in the choice of construction site, integration site and integration method.

Indeed, topsides elements can be build on several construction sites or directly on the integration site.

Possibilities for integration method include: load-out and transfer using multi-wheel trailers, skidding of the modules onto the hull using a pulling system, several small lifts of pre-assembled units or PAUs, or transfer of larger modules using a high capacity floating crane.

6.8. Liaisons to Host Platform

The WHB is connected to an host platform to which oil and gas are exported in separate lines after a first stage separation.

Other connecting lines may include gas and water injection as well as service umbilicals for energy supply and remote well control.

These lines may be steel catenary risers.

7. MODEL TESTS

Model tests of the WHB are scheduled before the end of 1999.

The model test program that has been established is an entire part of the solution development scheme and will be used to confirm the motion performances obtained by computer analyses.

The tests will address barge motions, wellbay hydrodynamics, relative motions between risers and barge as well as forces acting on risers.

8. ADVANTAGES OF THE SOLUTION

The WHB is an attractive alternate to other wellhead floaters such as mini-TLP and SPAR platform for mild environments for the following reasons:

- The surface trees allow easy and economical intervention on the wells.
- Riser tensioning system by buoyancy cans and riser guiding system at a single level above water level provide a robust reliable and easily inspected solution.
- The large deck area leads to a clear segregation of production and drilling areas and hence to an improved safety level;
- The large deck space allows the installation of a high performance rig i.e. reduced well construction / completion time, lower risk level due to concurrent operations leading to substantial cuts of the total "non productive time", noise reduction, controlled discharge system and re-drill possibilities.
- The barge is a conventional and simple structure, which can be built in many shipyards or dry docks;
- The solution allows hull construction, topsides integration, and hook-up to be performed in an industrial area.
- Therefore, if some of the wells have been entirely pre-drilled, the WHB will be able to start production early after its arrival on site i.e. after very limited offshore work.

9. CONCLUSION

The development work performed by the partners in the project (Bouygues Offshore, Sedco-Forex and 2H Engineering) has proved the technical and economical soundness of the WHB solution for the development of offshore oil and gas fields in deep waters and mild environments.

Typical environmental conditions of the Indonesian waters featuring lower wave height associated to small periods and lower current speeds than in the Gulf of Guinea, the WHB should be a cost effective solution for the offshore developments in this area.

10. ACKNOWLEDGMENTS

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LIST OF FIGURES

LIST OF TABLES

BIOGRAPHIES

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Stéphane Anrès is R&D Project Manager at Bouygues Offshore where he has been working on the development of new concepts for nine years.

He has been involved in the development of barges with surface trees since 1995 and was in charge of the latest development studies on the WHB.

He has extensive experience, as Project Engineer, in concrete offshore structures including floating and fixed platforms (Gravity Base Structures, barges and FPSO's).

He received his engineering degree from the "Ecole Supérieure des Ingénieurs de Marseille", France and a MS from Carnegie Mellon University in Pittsburgh, USA.

Pierre Béligné

Pierre Béligné is area coordinator of BOUYGUES OFFSHORE activity for Asia, Australia and Latin America. Job function includes definition of objectives as well as coordination of commercial and technical activities.

Previously, he was in charge of the proposal for a large floating break-water structure for Monaco Harbour and of the coordination of the Contractors Alliance.
Budget approx. 200 Million US$.

He has extensive experience as Proposal Manager and Project Manager for offshore constructions, Maritime & River works, industrial projects.

He received a degree in « Technical Sciences » from University of Nancy

Claude Gabillard

Claude Gabillard is a senior Project Engineer working for Schlumberger Drilling Division Sedco Forex. He is involved in many engineering development and construction projects . Prior to this , from 1993 to 1995 , he was Computer Aided Design manager charged with providing drawings related to both current drilling rigs and new project design. Since joining the Company in 1975 , he has been working on construction , upgrading and conversion of many types of land and offshore rigs as Project Engineer and recently Project Manager.

Stephen A Hatton

A graduate of Newcastle Upon Tyne University, Stephen Hatton has 15 years experience in subsea equipment and riser systems design. He worked for Cameron Offshore Engineering for 7 years where he was Engineering Manager and was involved in the design of subsea trees, manifolds, flowline connection systems TLP, drilling and workover riser systems.

In January 1993 he was jointly responsible for establishing 2H Offshore Engineering where he has continued his involvement with riser and subsea systems design and analysis.

2H Offshore Engineering is an independent Engineering consultancy that specialises in riser system design and particularly the development of riser systems for deep and ultra deep water floating production.