A Major Offshore Trial of a Free-Standing Mid-Depth BOP Drilling Riser System

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Abstract

A major offshore trial of a mid-depth BOP drilling riser system was conducted in 2009 by COSL in 470m water depth of the South China Sea. The objective of the trial was to demonstrate the feasibility of using a shallow water drilling platform to drill in depths which would otherwise be beyond its reach. A free-standing tieback string supported by a buoyancy unit presented an “artificial seabed” and wellhead at an elevation which the platform’s existing drilling riser with its subsea BOP could connect to and drill through.

The trial mobilised a 3rd generation semi-submersible drilling platform Nanhai 5, its drilling riser and subsea BOP, a test tieback string, and a fully commissioned buoyancy unit. The full offshore transportation and installation sequences were executed for Nanhai 5 to successfully connect to a mock-up ‘real seabed’ wellhead via the afore-mentioned set-up.

The novel components in the system, particularly the tieback string and buoyancy unit, were instrumented and monitored to study their motion behaviour for correlation against analytical predictions.

In the present day ultra-deepwater drilling world, the interests for such a depth-extending system have revived, in the context of the fleet of modern 3000m-rated drilling platforms wanting to go beyond 3000m water depth. The lessons learnt from the COSL trial bear significant relevance for designing future systems.

This paper describes the trial, its design and planning, certain problems encountered and some recorded system behaviour.

Introduction

Hurricanes and typhoons that often battered the offshore facilities in the Gulf of Mexico and South China Sea have prompted many operators and drilling contractors to rethink the way their drilling risers are designed for disconnection and retrieval before the cyclone arrives.

When drilling in very deep water depths, retrieval of the drilling riser is time consuming and tedious; and in emergency situations like the imminent arrival of a severe storm, the drilling rigs risk not being able to recover the drilling risers in time before the evacuation of personnel or sailing for shelters, with potentially devastating consequences.

A solution to overcome this concern is to modify the existing drilling riser to make it disconnectable closer to the surface and leave the long riser string and subsea BOP below in a safe and freestanding mode to survive the storm. Nguyen, et al (2006) designed a mid-depth buoy with a disconnection package, breaking a conventional low-pressure drilling riser string into two portions.
Similar, but different in objective, is an issue facing the operators and drillers that the drilling rigs affordable or available to them have a water depth operating limit. Then they have a business or operating requirement to drill in water depths beyond their normal capabilities. Instead of stalling on the opportunity or paying a premium for a superior facility, they look for the adaptation and extension of existing technologies to achieve that objective.

Some looked at using their existing drilling rig and its ‘short’ drilling riser with a subsea BOP to connect to a raised ‘artificial seabed’ consisting of a buoyancy can and a secondary wellhead, brought by a tieback string from the seabed to a reachable water depth elevation. This idea was suggested by Horton E (1985), Moutrey D & Lim F (2006) and Lim F, et al (2009).

This paper follows this latter ‘artificial seabed’ concept and describes a major full scale offshore trial conducted by COSL China Oilfield Services Limited (COSL) in the spring of 2009 to demonstrate the feasibility of such a system in the South China Sea. Atlantis Deepwater Technology Holding (ADTH) provided the buoyancy unit; 2H offshore designed the tieback string system, performed system analysis and provided monitoring instrumentation; and DrilQuip supplied the tieback equipment. COSL, in a joint venture with ADTH, executed the trial with their own drilling and support vessels.

**Free-Standing Mid-Depth BOP Drilling Riser System**

The mid-depth BOP drilling riser system consists of a buoyancy unit which is installed at a shallow depth, typically 200-300m below the water surface, and replaces the functions of the real seabed. A tieback string provides the anchorage of the buoyancy to the subsea wellhead at the mudline, as well as presenting a mid-depth wellhead at the top of the buoyancy unit.

The level of upthrust provided by the buoyancy unit can be varied in order to maintain tension throughout the tieback string and to support the buoyancy unit’s self-weight, BOP weight and other operational loads. A conventional drilling riser and LMRP then connect the BOP to the surface drilling vessel.

An artist impression of the system is shown in Figure 1.
The main steps to install the system are outlined below:

- Drilling vessel is positioned over the well location and moored
- Well conductors and seabed wellhead are installed from the rig
- Buoyancy unit is towed to site, handed over to the drilling vessel and positioned under the moonpool
- Unit is ballasted to slightly below its designed depth, with additional help of weighted catenary chains from the rig
- Tieback string and seabed connector are deployed from the rig and threaded through the buoyancy unit
- String is lowered and connected to the seabed wellhead
- Buoyancy unit is de-ballasted and raised to act against a load shoulder at the top of the tieback string to tension the string
- Artificial seabed and mid-depth wellhead are ready to receive the rig’s drilling riser and BOP

**Design and Planning**

The purpose of the offshore trial is to demonstrate that the COSL owned 3rd generation moored drilling rig Nanhai 5, an enhanced Pacesetter design semisubmersible with a maximum operating water depth of 500m, can drill in deeper water depths with the mid-depth BOP drilling riser system.

The first task in planning the trial was to find a suitable location within reasonable transit distance from the Zhanjiang supply base in the Guangdong province of China with a water depth close to the rig’s water depth limit. A location with 470m water depth was found with environments and seabed soil properties close to the regions in the South China Sea where water depths are beyond 1000m.

ADTH had a ready-made buoyancy unit already commissioned in a previous sea trial in Norway which could be utilised. The main parameters of the buoyancy unit are given below:

- Dimensions: Height 10m x Diameter 20m
- Number of ballast compartments: 10
- Net upthrust when all compartments flooded: 35 te
- Maximum net upthrust: 450 te

2H Offshore was engaged to design the tieback string and its critical structural load interface with the buoyancy unit. The resulting schematic arrangement of the trial system stack up is shown in Figure 2.
The tieback string was a high pressure design comprising 40 ft. flanged joints of 22 in. OD and 1 in. wall thickness supplied by DrilQuip, who also supplied the mid-depth wellhead and the load shoulder interfacing with the buoyancy unit, and the seabed tieback connector.

Comprehensive analysis was performed to assess the strength and fatigue of the tieback string and Nanhai 5’s drilling riser during installation, normal operation and potential accidental events, using environmental data taken from a nearby site and buoyancy unit configuration provided by COSL and ADTH. The results of the analysis were then assessed to determine operational limitations based on the buoyancy unit setting, environmental conditions and the mooring capabilities of Nanhai 5.
Figure 3 shows a typical stress plot from the analysis.

Figure 3 – Typical Stress Distribution in Tieback String and Drilling Riser

The trial was to physically run through the entire installation and retrieval process of the artificial seabed system, and to verify the following major operations and functions:

- Logistics
- Equipment layout
- Rigging requirements
- Handover of buoyancy unit from tugs to vessel
- Positioning of the buoyancy unit
- Buoyancy unit’s ballast control system
- ROV interventions
- Equipment interfaces
- Personnel training

Monitoring Instrumentation

In order to capture the behaviour of the drilling system for future correlation with theoretical predictions, and to aid operational decisions, during the trial, the buoyancy unit and tieback string were comprehensively instrumented to provide a mixture of real-time display and passive recording of the system performing parameters and dynamic motions.

Monitoring packages were deployed during the trial to record at least the following:

- Buoyancy unit dynamic motions
- Tieback string twist and dynamic motions
- Buoyancy unit tension applied to the tieback string

The array of instruments deployed is shown in Figure 4.
The Trial

Pre-trial
Before the main trial, a pre-trial was conducted on the buoyancy unit alone, Figure 5, to test its functionality and response. It was found that:

- Buoyancy unit could sink and float as per operating procedure
- Two tugs were adequate to tow and manoeuvre the unit
- When submerged in a 0.5m/s current, the unit tilted about 3.5 degree
- There was no redundancy in certain elements of the control system

The findings above allowed counter measures and procedures to be put in place before the main trial.

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Main Trial
The main trial began in mid-April 2009 and lasted a total of 11 days, from the arrival of the buoyancy unit on test site to its re-floating to the surface after test.

The trial completed the following major activities:

- Seabed conductors and wellhead were installed by Nanhai 5
- Buoyancy unit towed to site and handed over to the rig
- Unit was lowered under the rig to 250m below water surface
- Tieback string was deployed (Figures 6 and 7)
- Seabed connector was threaded through buoyancy unit (Figure 8)
- Tieback string connected to seabed wellhead
- Buoyancy unit de-ballasted to apply tension to tieback string
- Nanhai 5’s drilling riser and BOP were deployed to connect to the mid-depth wellhead
- Drilling riser was disconnected leaving the BOP on the buoyancy unit
- Drilling riser was re-connected to retrieve the BOP
- Process was reversed to recover the tieback string
- Buoyancy unit was re-floated to the surface
Figure 6 – Seabed Connector of Tieback String

Figure 7 – Mid-Depth Wellhead at Top of Tieback String Going through Drill Floor

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Issues Encountered
All the above activities were successfully and safely carried out, mostly to plan, but several issues encountered are highlighted below:

- Bad weather - Delayed the start of the trial and prolonged the trial itself
- ROV failure - ROV cable damaged after entangling with the buoyancy unit weighted chain resulting in ROV power loss
- Instrument failure - Water proofing of the strain gauges failed resulting in loss of tieback string tension reading. Tension had to be implied from upthrust calculation from the buoyancy unit instead
- Air hose damage - The air fill hose from the rig to the buoyancy unit broke in bad weather
- Loss of buoyancy modules - A large number of foam buoyancy modules attached externally to the buoyancy unit broke loose during the tow back to base in bad weather

These and other technical issues related to the buoyancy unit were processed as lessons learnt so the system hardware and procedures can be improved upon in further development of the system.

System Response

No unexpected global behaviour of the buoyancy unit and tieback string was observed during the trial.
All data recorded by the motions loggers were downloaded for post-processing. Of particular interest is the behaviour of the tieback string before it reaches its full design tension during installation.

Figure 9 is a plot of acceleration against time in the middle of the tieback string where vortex induced vibrations (VIVs) are observed to have occurred. VIVs are inevitable in a long unsupported string like this, however it is noted that the actual vibration amplitudes are somewhat smaller than the predictions under different current conditions.

It is important to attempt to quantify the phenomenon during the design stage. Although it may be conservative, it will serve to provide assurance of the integrity of the tieback string.

Concluding Remarks

It was a truly remarkable effort by COSL and ADTH, with the support of other specialist companies, to engineer and execute such a full-scale sea trial of a novel drilling riser system, to extend the water depth capabilities of the existing fleet of rigs. Unfortunately, market situation would have it that around the time of the trial many drilling companies were also investing in building new 6th generation 3000m-rated rigs, overshadowing the desire to use old rigs like Nanhai 5 and avoiding the risk of adopting new technology. Although the trial was declared a success, the program was suspended in favour of the new builds.

Fast forward to 2015, when drilling activities around the world are reaching new frontiers and depths that are starting to exceed 3000m. A few operators are already looking for rigs that can drill in >3000m water depths.

The traditional interests of making drilling risers lighter by exploring new materials, such as carbon composite choke and kill lines, to stay within the rig handling and tensioning limits in deeper depths have re-kindled.

However, the authors believe that the free-standing mid-depth BOP drilling riser concept will soon enjoy a comeback, because dividing the drilling riser system into a free-standing lower section and a ‘quick’ recoverable upper section solve the cyclone evacuation issue, and it enables the current rigs to drill in >3000m waters. It is a familiar story!

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References


