

Near-Surface BOP Drilling System

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ABSTRACT

The idea of using a surface BOP located on the deck has received much attention in recent years. Despite the numerous benefits provided by a surface BOP drilling system in comparison with the conventional subsea BOP system, its safety remains a concern. This paper presents a hybrid, freestanding “near-surface” BOP drilling system that combines the better features of the surface and subsea BOP configurations.

The near-surface BOP drilling system is described together with the structural analysis and operational assessments that have been performed to demonstrate its feasibility.

KEY WORDS: Deepwater; BOP; Drilling; Riser; Freestanding

INTRODUCTION

Offshore drilling in water depths beyond the reach of a mobile jack-up drilling unit is conventionally carried out from a ship-shaped or semi-submersible floating units using a subsea BOP system isolating the well at the seabed. The drilling riser is almost always of 21 in. outer diameter, offering a 19 ½ in. minimum bore and a low pressure design tensioned from the drilling unit. In increasing water depth, however, the drilling riser becomes longer and heavier, eventually requiring an upgrade to the derrick facility and riser tensioning system to install and operate it. The main advantage of a subsea BOP system is the ability to shut-in the well at the seabed and disconnect the drilling riser in an emergency. However, in a deep water depth, a long length of riser needs to be retrieved before the vessel can move off location.

Some operators and drilling contractors then revert to a surface BOP approach in deepwater locations with a benign environment and when they can drill the larger holes in open water leaving only the deeper high pressure holes to be drilled through a smaller bore drilling riser. The smaller bore riser is lighter in water, and less the weight of a subsea BOP during deployment, extensive upgrade of the derrick

facilities can thus be avoided. The main problem with a surface BOP on a floating drilling unit is that well shut-in is at the surface and the high pressure riser, usually made up of threaded casing joints suitable only for short term dynamic usage, can not be disconnected for the vessel to move off location in an emergency. To overcome this problem, an acoustically controlled emergency subsea disconnection package complete with a shear ram is normally added to a point just above the seabed wellhead.

Various solutions have been proposed in the past to address the aforementioned deepwater drilling issues associated with subsea and surface BOP systems. Many of them favour a freestanding riser configuration whereby only a short length of the drilling riser is disconnected and retrieved, leaving much of the riser freestanding below the wave and high current zone.

Majority of these systems retain the use of a subsea BOP located at the seabed (e.g. Nguyen et al, 2006). Two systems, to the authors’ knowledge, propose the use of a subsea BOP located at an elevation substantially above the seabed (Moutrey and Lim, 2006, and Horton, 1985), both likening their systems to a “raised seabed” so that a shallow water drilling rig can drill using its shorter riser and lower capacity derrick facility. However, both systems suffer from significant installation issues. The more recent Atlantis system described in the Moutrey paper involves towing of an artificial buoyant seabed to site, holding it in mid-water while the “tieback” riser is threaded through it, and completing the artificial seabed before the conventional drilling riser can be run. The earlier 1985 Horton system involves the installation of a substantial buoyant structural tower freestanding above the seabed before any “shallow” water drilling operations can be carried out.

This paper presents a near-surface BOP drilling system that negates the installation pitfalls associated with the Atlantis and Horton systems, and advocates the philosophy of putting a surface BOP in shallow water rather than raising the seabed to support a shallow water subsea BOP.

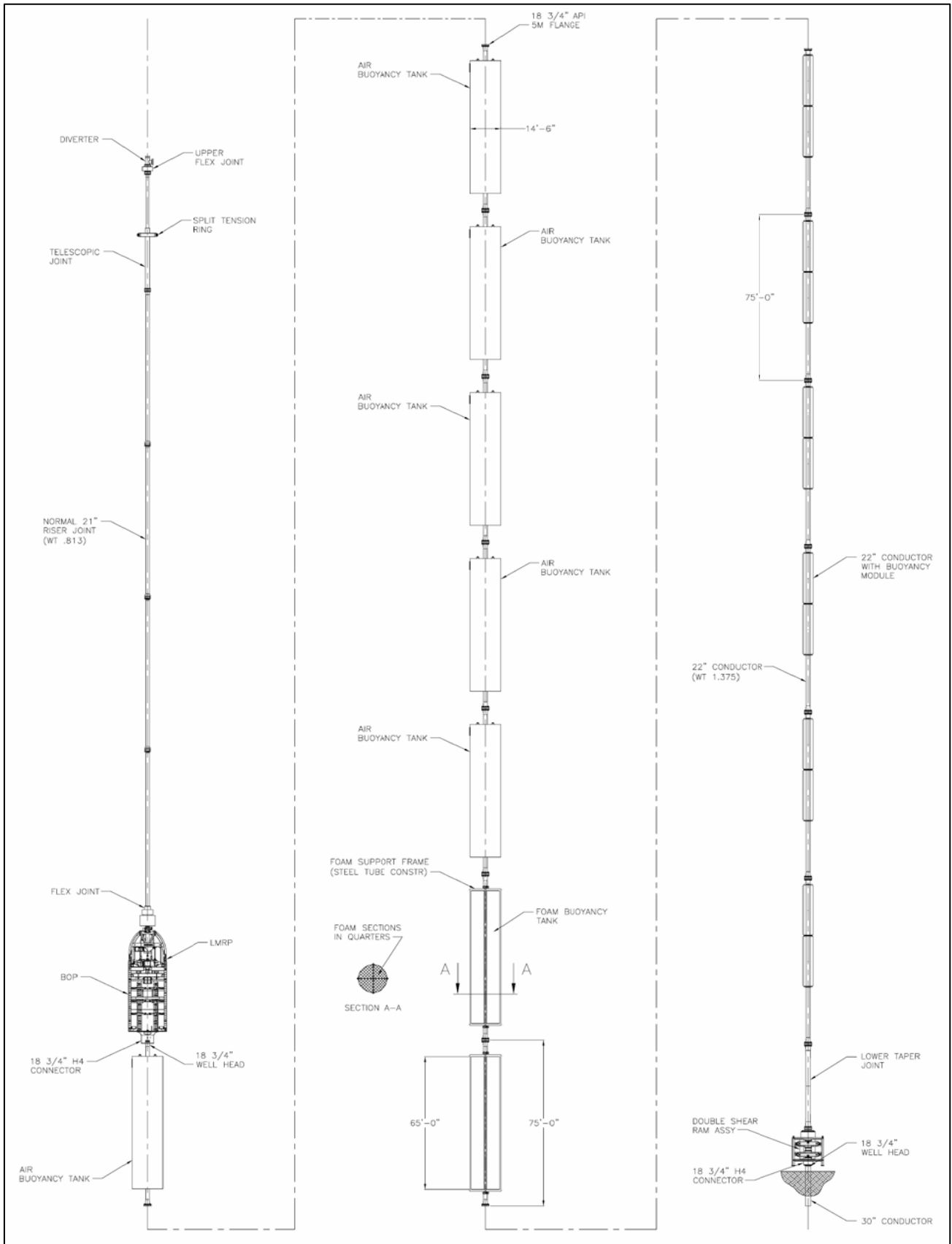


Fig. 1 - Near-Surface BOP Drilling Riser System Configuration

RISER CONFIGURATION

The proposed near-surface BOP drilling riser system is schematically shown in Fig. 1.

A conventional low pressure drilling riser with a subsea BOP is deployed to connect to a freestanding high pressure riser section equipped with an upper wellhead.

The high pressure riser section is kept freestanding mainly by a combination of large-diameter upper adjustable air buoyancy tanks and passive foam buoyancy tanks. The number of each type required is dependent on the installation weight of the riser system and the ultimate tension required to be applied to the freestanding riser.

The riser string underneath the buoyancy tanks is made up of riser joints partially covered in foam buoyancy modules to reduce the submerged riser weight. The buoyancy modules are staggered in a manner to mitigate lock-on of vortices that can cause fatigue damaging vibrations.

Located at the lower end of the freestanding riser is an acoustically activated emergency disconnection package, complete with shear rams, which is capable of capping the well below in the unfortunate event of a failure in the high pressure riser.

In the event of severe weather or vessel drift/drive off, the low pressure drilling riser can be disconnected, leaving the subsea BOP behind in a conventional manner on top of the freestanding high pressure riser section.

All components in the near-surface BOP drilling system are sized and designed for handling and installing from the drilling rig. The large diameter buoyancy tanks are handled and installed from the moonpool deck using the BOP handling facility, whilst the high pressure riser joints are installed from the drill floor through the rotary table.

During riser installation, the air buoyancy tanks will initially be flooded on entering the sea to ensure that the riser string is heavy in water for lowering towards the seabed wellhead. Once the high pressure riser section is connected to the seabed wellhead, air will be injected into the buoyancy tanks to provide sufficient buoyancy to keep the riser in tension and freestanding.

Each steel air buoyancy tank is divided into compartments such that accidental flooding of 2 adjacent compartments will not jeopardise the riser's ability to free stand.

Amongst the many advantages presented by the system just described, the following are highlighted:

- A conventional drilling riser with its subsea BOP system can be used directly with no modification
- Shorter time to retrieve the section of riser above the BOP, in the event of severe surface weather, leaving the well safely contained in the freestanding section below
- Reduced riser tensioning requirement hence the ability to use a mobile drilling unit of a lower specification to drill deepwater wells
- Minimum additional offshore marine operations

CASE STUDY

A Case study is performed for such a riser configuration in the Gulf of Mexico environment to demonstrate its feasibility in terms of structural response and operating windows.

The water depth considered is 2000m. The upper wellhead on the freestanding riser is located at 250m below mean sea level, but this location can be varied to optimise the system performance for different environmental conditions.

For an arbitrarily well design pressure, the wall thickness is assumed to be 1.375 in., hence a 22 in. outer diameter high pressure riser section is used in order to give sufficient bore for passage of drilling tools.

In this study, 5 air buoyancy tanks and 3 foam buoyancy tanks are found to be required; and for the riser joints below, approximately 2/3 of each joint is covered by conventional drilling riser buoyancy modules.

ANALYSIS METHODOLOGY

Simplified global riser analysis is carried out using a non-linear time domain analysis program. A suite of post processors is then used for the assessment of riser response.

Static analysis is conducted for both a connected and disconnected riser system under various current profiles. For the connected riser system, the riser is supported at the top by an optimised top tension in order to reduce flex joint rotations without significant increase in riser stresses. While for the disconnected mode, the convention drilling riser is disconnected with its LMRP thus leaving the freestanding BOP and casing in the water column subjected to environmental actions. Additional bottom current profiles are also used in the disconnected riser analysis as the bottom current is expected to produce the worst case based on our extensive riser analysis experience.

The analysis is performed in accordance with API-RP-2RD (API, 1998). The allowable stresses and flex joint angles should not exceed the design criteria given in Table 1 below.

Table 1 – Riser Allowable Stresses and Flex Joint Angles

Condition	Allowable Riser von Mises Stress	Flex Joint Angles
Normal Operating	$0.67 \times \sigma_{yield}$	± 2 degrees mean ± 4 degrees maximum
Extreme Storm	$0.80 \times \sigma_{yield}$	90% of maximum rotation
Survival	$1.00 \times \sigma_{yield}$	90% of maximum rotation

RISER RESPONSE

Connected Riser Mode

Figs. 2 and 3 show the riser upper and lower flex joint angles at different vessel offsets under various current loadings. API recommends that in these static conditions, drilling should not take place when the flexjoint angle exceeds 2 degrees to prevent excessive wearing of the flexjoint. The results show that the allowable vessel offsets under drilling condition are largely constrained by the upper flex joint angles. In the case studied, the acceptable range is ~3% water depth (~60m).

By lowering the elevation of the upper wellhead, and optimizing the buoyancy supporting the freestanding riser section, the acceptable vessel offset range from the constraint of flexjoint angles can be widened. In an optimized configuration, the acceptable offset ranges for the upper and lower flexjoints should be roughly the same

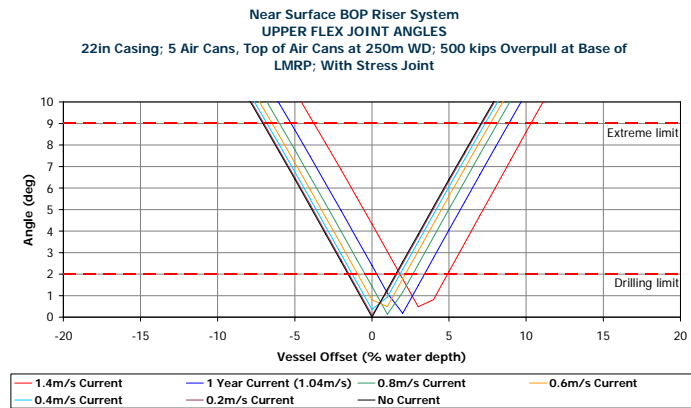


Fig. 2 – Upper Flex Joint Angles

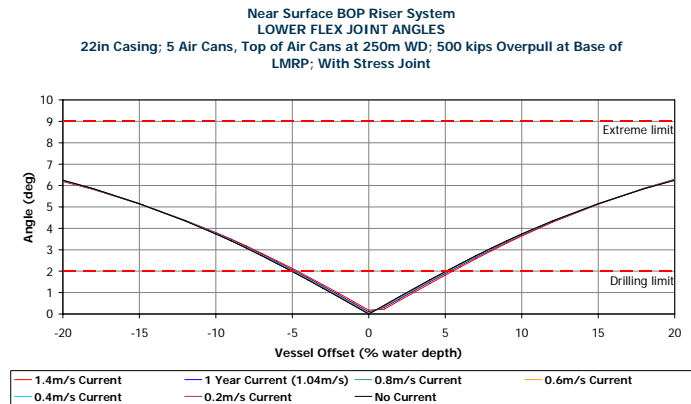


Fig. 3 – Lower Flex Joint Angles

Fig. 4 indicates the maximum stress utilisation in the riser system. It can be seen that the acceptable offset range decreases with increasing current. In the worst case, the system can survive up to a vessel offset range of ~9% of water depth (~180m).

Fig. 5 summarises the outcome of the previous 3 figures, with no wave applied, in the form of operating envelopes. At most current conditions, drilling is possible within a vessel offset range of ~3% water depth

(~60m) and it is still possible in surface currents up to 1.4m/s with diminishing acceptable offset range.

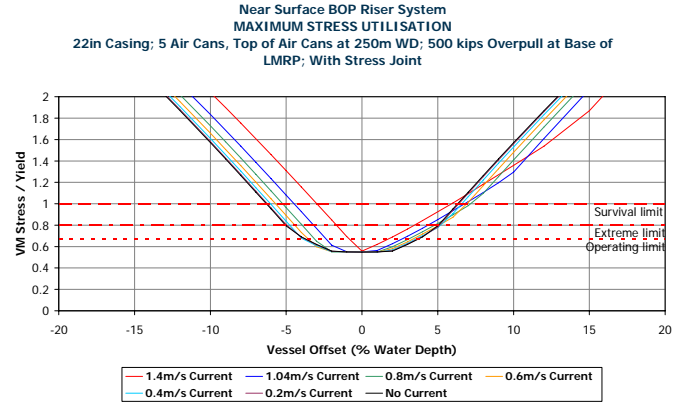


Fig. 1 – Maximum Stress Utilisation

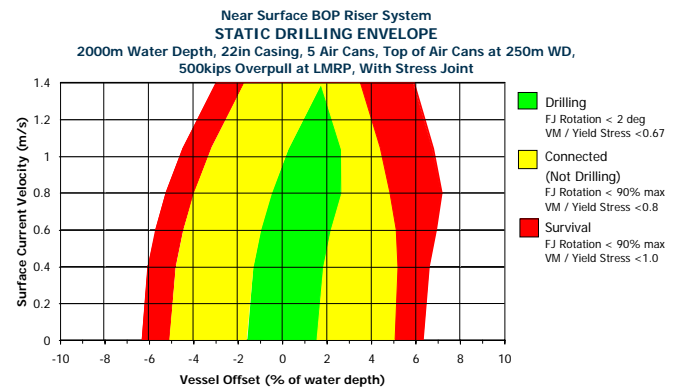


Figure 2 – Static Operating Envelopes

Disconnected Riser Mode

Table 2 lists the maximum von Mises stress utilisation at critical locations along the riser system under disconnected mode. The maximum von Mises stress utilisation along the riser is found to be within the allowable limit of 1.0 recommended by API codes for all cases including the worst case bottom current profile.

Table 2 – Maximum von Mises Stress by Riser Component

Current Profile	Maximum von Mises Stress Utilisation		
	Conductor	Wellhead	22in Casing
Opposing 1Yr Surface & 1.5x 1Yr Bottom Current	0.925	0.514	0.629
Opposing 1Yr Surface & 1Yr Bottom Current	0.475	0.305	0.473
Collinear 1Yr Surface & 1Yr Bottom Current	0.726	0.426	0.526
1.04m/s Surface Current	0.455	0.297	0.473
0.6m/s Surface Current	0.363	0.250	0.473
0.2m/s Surface Current	0.344	0.238	0.473
No Current	0.344	0.237	0.473

Table 3 – Maximum Bending Moment by Riser Component

Current Profile	Maximum Bending Moment (kNm)	
	Conductor	Wellhead
Opposing 1Yr Surface & 1.5x 1Yr Bottom Current	7109.0	5201.0
Opposing 1Yr Surface & 1Yr Bottom Current	2440.0	1908.0
Collinear 1Yr Surface & 1Yr Bottom Current	5158.0	3914.0
1.04m/s Surface Current	2176.0	1734.0
0.6m/s Surface Current	718.0	591.1
0.2m/s Surface Current	79.6	65.5
No Current	0.0	0.0

Table 3 shows that the maximum bending moments of the conductor and wellhead under disconnected mode are below the allowable limit of 7Mft-lbs (9500 kNm).

FURTHER WORK

There is obviously further work to be done. These include dynamic analysis, fatigue analysis and further optimization of the buoyancy setting and upper wellhead elevation to achieve better operating envelopes than they are now.

One of the main concerns will be safety for something new like this.

The offshore industry had spent many years debating the use of surface BOP in deepwater exploration and production. It is now widely used on production platforms like spars and TLPs all over the world, but its use is still limited and treated with great caution when coming to exploration drilling from a mobile offshore drilling unit despite its many benefits.

No near-surface BOP drilling system has been used to-date, but a trial is planned for the Atlantis system in a water depth of about 500m in the South China Sea this year. When the trial proves successful, there remain questions about the idea of treating it as, and the significant effort involved in installing, an artificial “seabed”.

The concept of a near-surface BOP is a very plausible one, it is the execution and the safety measures which have to put in place that set the industry pondering.

CONCLUSIONS

A new near-surface BOP drilling system is presented. It negates a lot of the installation issues associated with the two similar systems, Atlantis and Horton, known to the authors.

A brief preliminary assessment is made of the system for an arbitrary Gulf of Mexico application in 2000m water depth.

Static analysis is performed to establish drilling windows which are found to be less than satisfactory in the particular configuration studied. Further optimisation of the near-surface wellhead elevation and buoyancy setting of the freestanding riser will improve the operating envelopes.

This paper points the direction a near-surface BOP drilling system has to take in order to gain acceptance in a community that is generally very skeptical and reluctant to adopt a new method of working.

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