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Storm-Safe Deepwater Drilling

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Abstract

The recent hurricanes that battered the offshore facilities in the Gulf of Mexico have prompted many operators and drilling contractors to rethink the way their drilling risers are designed for disconnection and retrieval before the hurricane 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 hurricane, 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 below (and subsea BOP) in a safe and freestanding mode to survive the storm.

This paper presents the feasibility of such a modification, and describes the simple buoyancy system and additional components required. The study also outlines hydrodynamic and structural analyses required to demonstrate integrity of the freestanding drilling riser.

Introduction

Drilling and completing activities have been significantly impacted by severe weather condition as the oil and gas development moving into deeper water. In areas with frequent hurricanes and extreme loop currents, such as in the Gulf of Mexico (GoM), the cost of drilling and completing well increases significantly due to rig downtime in these conditions. Drilling activity is suspended and the riser is pulled. As the water depth gets deeper, the riser needs to be pulled several days ahead of the approaching severe weather. Pulling lengthy riser in deepwater is a time consuming task and expensive.

Different riser technologies have been studied to evaluate the benefit of drilling and completing wells for deepwater development in the Gulf of Mexico. Among those is the freestanding drilling riser technology. This technology avoids the need to pull the entire riser string. Only a short riser section below the water surface needs to be pulled; and the remaining riser string is supported by a cluster of buoyancy can. This allows the rig to stay connected and continue drilling or completing activities longer as it only take a few hours to disconnect and drift away. A recent study by British Petroleum (BP) for the Atlantis field in ultra deepwater Gulf of Mexico shows a significant cost saving and mitigation of risk with the use of the freestanding drilling riser as compared to a conventional riser [2].

The freestanding drilling riser is referred to as FSDR throughout this paper.

FSDR Functional Requirements

The FSDR is designed to provide all functions of a conventional marine drilling riser and an additional function that is the ability to disengage the riser at an interface component located at a short distance below the water surface. The lower riser section is left freestanding and held up by a buoyancy can system. This feature is unique to the FSDR and a key advantage over a conventional system. The FSDR brings significant benefits in deep water drilling operations where the weather windows regularly suspend the drilling activities.

The interface component above is referred to as a Near Surface Disconnection Package (NSDP) through out this paper.

Planned Disconnect. Equipped with the FSDR, the rig can avoid the need to recover the entire riser system in advance of an approaching bad weather or loop current that may not allow the drilling activity to be continued. Only a short section of the riser needs to be retrieved, thus reducing time spent pulling the riser. This significantly reduces the preparation time for evacuation, from normally a few days to just a few hours, hence allowing the drilling operation to continue longer. In addition, with a short riser section being recovered, the risk of being caught in unexpected environmental conditions that suspend the riser recovery operations is significantly reduced. Subsequently upon returning to the well site, this definitely shortens the re-deployment and allows the drilling operation to be continued quickly.

This feature also allows suspending the drilling activity to perform other non-drilling activities that require the use of

equipments or space on the rig well center. For offshore drilling operations, downtime due to retrieving and redeploying riser, especially in deep water is substantial and costly. In this situation, only part of the riser needs to be recovered and the freestanding riser may be left on the well head or parked at a nearby wellhead or pre-installed dummy stump.

Emergency Disconnect. The FSDR also retains a conventional disconnect point at the LMRP/BOP interface to allow planned disconnect and emergency disconnect modes. Some FSDR concepts have suggested an emergency disconnection system (EDS) at the NSDP to maximize the advantage of the FSDR. However, in this paper the EDS is suggested to be located at the conventional LMRP/BOP interface. The justification to this choice is primarily due to a safety issue and is elaborated in the subsequence section.

FSDR Configuration Overview

Selection of EDS Location. One important feature to the FSDR design is the location of the EDS. The ability to quickly seal off the well bore and then disconnect the riser, plays an extremely important role in offshore drilling operations, both for safety and environmental reasons. The emergency disconnect system is designed to allow the rig to be disengaged from the well quickly in the event of an inability to maintain rig position within a prescribed watch circle. This could be due to loss of rig power, failure of dynamic positioning control system, mooring failure, or environmental conditions that exceed the rigs station keeping capability.

Some FSDR concepts prefer the EDS to be remain at the BOP/LMRP interface above the seabed similar to the conventional system, while others prefer the emergency disconnect function to be combined into a single near surface disconnection package, or have both.

Of the issues needed to be addressed if the EDS is located at the NSDP, the presence of high pressure inside the riser during well control is among them. Most low-pressure drilling risers are not designed for high-pressure containment. The introduction of well control at NSDP as opposed to normal practice could require riser qualification for high-pressure containment and could have regulatory implications.

To resolve this issue, a FSDR with two disconnect points, one at the conventional BOP/LMRP interface and another at the NSDP, is suggested. Prior to an emergency disconnection, the BOP rams will quickly isolate the well bore preventing unexpected bore pressure entering the riser. The shear ram on the NSDP will then shear off the drill pipe or casing, close the annular and release the connector allowing the rig to drive off with the riser and the upper half of the NSDP [1].

Both these configurations require the FSDR buoyancy can system to be fully charged through out the riser deployment in order to hold up the freestanding riser immediately after an emergency disconnection. A massive charged buoyancy can system positioned directly underneath the vessel is an enormous risk to the rig safety as it accelerates toward the surface in an event of unexpected parting or failure at any location along the riser length below the buoyancy can system.

A significant number of accidental disconnect of the lower marine riser packages (LMRP) from deepwater floating drilling rigs due to human factors have been recorded during the last six years [3]. An incident of riser separation at mid-depth due to failure of a riser joint flange connector was also recorded in 2003 [5]. It would be detrimental to the rig safety if these risers were equipped with charged buoyancy cans. For that reason, the rig safety issue is a primary concern that governs the location of the EDS and the philosophy of charging up the buoyancy can during the deployment of the drilling riser.

Other secondary issues include the increase of the riser drag loading which is a consequence of enlarging the buoyancy can system. Moving the riser EDS up to the NSDP would require additional amount of buoyancy to support not only the weight of the EDS, but also the column of mud inside the freestanding riser after emergency disconnection. This would result in a significant increase in the number or size of the buoyancy can modules. This would extend the deployment and recovery time for the FSDR system, and may require the presence of workboats for additional riser storage space.

Given these considerations, the buoyancy can modules should be charged with just enough air to be neutrally buoyant during the deployment of the riser. As it would take several hours to charge the buoyancy cans, there would be no means to support the riser if the riser is quickly disconnected at the NSDP. Therefore, the location of the EDS is considered best located at the conventional BOP/LMRP interface. The NSDP is only used for planned disconnect event, where the riser is circulated with seawater and the buoyancy can de-ballasted before disconnection at the NSDP. This configuration is adopted through out this paper.

It appears that the FSDR is only beneficial for planned disconnect events, and not the emergency disconnect ones. However, considering the rarity of the emergency disconnect event, the clear benefit of the FSDR is unquestionable.

System Description. With the EDS location remaining unchanged, a conventional drilling riser can be converted to an FSDR by adding two components: an NSDP and a cluster of buoyancy cans, as illustrated in Fig. 1. The configuration of an FSDR is described as follows from the seabed up to the vessel.

- The riser section below the buoyancy can cluster, including auxiliary lines and subsea cables, is exactly identical to the conventional drilling riser;
- The buoyancy can cluster consists of normal riser joints with steel buoyancy cans. The buoyancy can modules can be pre-installed on the riser or assembled onto the riser over the moonpool during riser running. The function of the buoyancy can is to support the weight of the freestanding riser and to provide adequate amount of tension overpull required to meet the design criteria when the riser is in freestanding mode. The location of the buoyancy can cluster is evaluated through analysis. It generally should be located below the wave zone and below the high surface currents.
- The NSDP is an interface component between the upper riser and lower riser sections. It is located

immediately above the top buoyancy can joint. It consists of two sections - a lower and upper section. They act as the interface for the riser strings above and below the NSDP. The NSDP provides these important features:

- Interface to connect and disconnect the riser;
- Continuation of auxiliary lines and subsea cables from the BOP to the surface through wet-mateable connectors;
- Interface to control buoyancy can charging.
- The riser section above the NSDP is identical to a conventional riser with the addition of several air supply pipes and a subsea cable to control the NSDP.

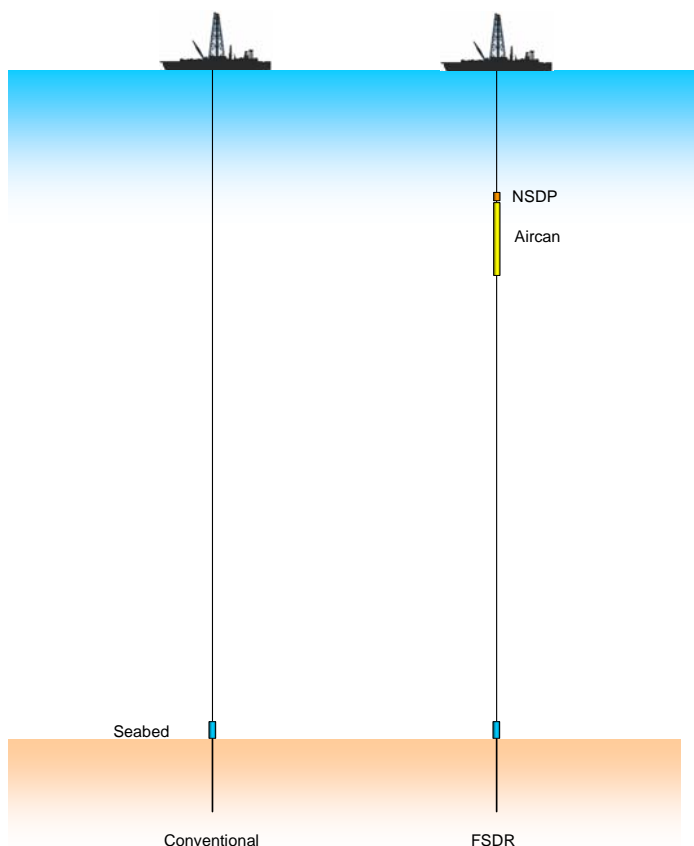


Fig. 1 – Conventional and Freestanding Drilling Riser

The conversion of a conventional drilling riser to a FSDR presents some challenges that need to be addressed during the course of the development phase. These challenges exist in all areas such as normal rig operation practices, hardware reliability, riser installation and storage, requirement of addition equipments, rig modifications, and so on. Some of the identified issues and concerns are as follows.

- Reliability of BOP stack need to be improved to avoid pulling the entire riser for servicing the BOP
- To allow connecting and disconnecting at the NSDP, the existing BOP control MUX cables requires integration of wet-mateable connectors at the NSDP.

Reliability of wet-mateable connector is crucial to the riser system;

- Riser deflection in freestanding mode due to current loading may cause high bending loads on the LMRP/BOP/wellhead connectors and wellhead conductor;
- Excessive riser deflection and inclination angle at top of riser may be a problem to the riser reconnect operation;
- Change of riser behavior (vortex induced vibration, dynamic response, recoil) due to the presence of large diameter buoyancy cans and NSDP;
- Modification to rig to provide storage space and transporting of the buoyancy can from the storage area to the moonpool;
- Possible addition of handling equipment to enable the installation of buoyancy cans and NSDP;
- Addition of NSDP control system, buoyancy can charging equipments, air pressure vessel (APV), reels on the rig, air lines along the upper riser section;
- Change in rig operation practices to adapt with FSDR system.

Of the issues identified, the reliability of the BOP system is considered a potential major challenge. As the FSDR deployment and retrieval is complicated by the presence of several large buoyancy cans, the riser running and pulling process needs to be minimized. Unfortunately, failure of BOP control system has been a main cause of pulling the riser to provide access to the BOP system components [4]. With most current BOP stack configuration, if the failure point is on the BOP, the FSDR can be parked on a temporary wellhead and the BOP can be retrieved by drill string. If the failure point is on the LMRP, the entire riser must be retrieved. Therefore, in order to maximize benefit from the FSDR, the reliability of the BOP stack is paramount.

Global Analysis

Similar to the conventional riser system, analysis of the FSDR system is required to ensure integrity of the riser and to define and optimize the riser configuration, operational envelopes and operating procedures. The main difference between the conventional drilling riser and FSDR is the freestanding mode, which is considered a most onerous mode as the riser is not constrained at the top and vulnerable to strong currents.

FSDR consists of three operating mode: freestanding (disconnected) mode, connected mode, and hung-off mode, as illustrated in Fig. 2. Riser global analysis should be conducted for all these modes. A typical global analysis process for a FSDR includes the following.

- Determine the location of the NSDP below water surface;
- Determine amount of upthrust required for the freestanding riser to maintain riser stress, conductor stress, wellhead/BOP/LMRP connector loading and lower flexjoint rotation within allowable limits;

- Define limiting current speed to allow deployment and retrieval;
- Establish drilling and non-drilling operating envelopes to define vessel excursion limit during connected mode;
- Perform hang-off analysis to evaluate riser response in a dynamic environment;
- Conduct extreme storm analysis;
- Conduct first order and fatigue analysis and VIV analysis;
- Optimize the riser stack-up, if necessary;
- Conduct analysis to identify the watch circle and limiting environmental condition for emergency disconnect sequence.

Considerations to some of the above activities are discussed below.

NSDP Depth Assessment. The location of the NSDP is identified through a series of parametric studies, in which riser stresses, wellhead connector loads, lower flexjoint rotation angles and riser top inclinations are checked against the freestanding riser length, tension and various extreme currents profiles. Typically, the NSDP should be located far below the wave zone to minimize wave action on the buoyancy cans, and below the strong surface current region to reduce drag loading which can significantly affect the FSDR behavior in freestanding mode.

Buoyancy Can Upthrust Requirement. The buoyancy can is discharged and kept in a neutrally buoyant state during connected mode. It is only charged when the riser is in freestanding mode. The buoyancy can upthrust has to provide sufficient amount of upthrust to support the weight of the freestanding riser and to maintain suitable riser response under strong current loading.

Strong current loading deflects the riser and may cause several concerns in the lower riser region such as high bending stresses in the conductor and large flexjoint rotations above the allowable limit. Increasing the buoyancy can upthrust helps to reduce the lateral deflection and, consequently, improve the riser response. The effect of high effective tension along the riser length also improves the riser response to vortex-induced vibration, which has been a major issue for deepwater drilling development where risers normally experience high current loading.

Freestanding Mode. The freestanding (disconnected) mode is considered the most onerous design condition as the riser is unconstrained at the top. A bottom or submerged current loading is the only external loading that the FSDR may experience. It can be the driving factor to the design of FSDR in the freestanding mode. Strong bottom currents generate high drag force along bottom region of the riser causing excessive flexjoint rotation, high bending moment in the riser connectors and high stress in the conductor. Improvement of the riser response to a large bottom current can be achieved with additional buoyancy can modules to increase the riser tension.

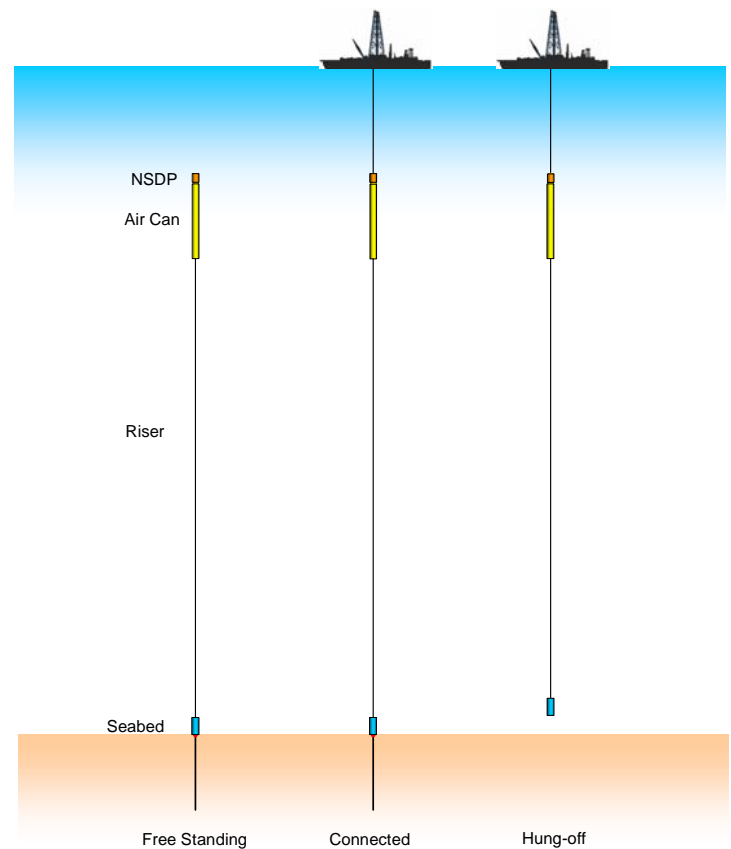


Fig. 2 – FSDR Operation Modes

As opposed to the bottom current, strong surface currents generally do not pose any concerns to the riser response. It may cause large inclination at the top of the freestanding riser. A suitable elevation of the NSDP should be evaluated to achieve appropriate inclination to allow mating of the upper and lower riser in surface currents.

Installation and Retrieval Window. The limiting current and wave criterion need to be identified to allow the deployment and retrieval of the riser. There are two different cases of deployment and retrieval: upper riser only and entire riser. The criterion for deployment/retrieval of the upper riser is quite similar to the conventional riser because the upper riser above the NSDP remains the same from the conventional riser. The criterion is significantly different for the deployment/retrieval of the entire riser. The window is expected to reduce significantly due to the impact of the environmental loading on the buoyancy can cluster as it is passing through the waves zone and the high surface current zone.

Waves loading may cause high stress in the riser section between the adjacent buoyancy cans, where the sudden change in bending stiffness exists. Current loading on the buoyancy can may cause clashing between the riser and the diverter housing or between the buoyancy can and the moonpool structure during deployment. These issues should be analyzed and addressed.

Operating Envelope. The purpose of this analysis is to define the vessel excursion limit for the drilling and non-drilling condition as the riser is connected to the wellhead. Typical operating envelope of a conventional riser, as shown in Fig. 3, is driven by the limiting criteria of the lower flexjoint angle, upper flexjoint angle and the wellhead bending moment. These are mainly controlled by the combination of vessel offset and current drag force. If the buoyancy can cluster is not located in the high current region, the operating envelope of the FSDR is expected to be quite similar to the conventional riser.

Hang-off Mode. The presence of buoyancy cans and NSDP should not show significant variation of riser response compared with a conventional drilling riser in hang-off mode.

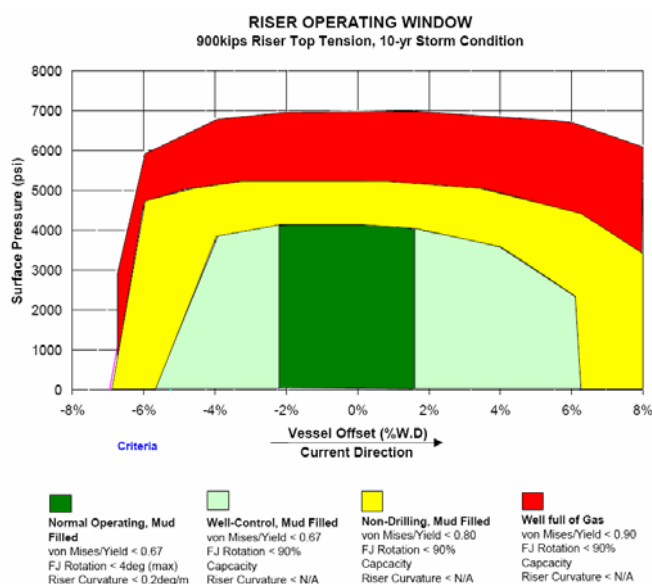


Fig. 3 – Typical Operating Envelop

Hardware Modification Requirements

The conversion of the conventional riser to a FSDR requires the addition of two major components - the buoyancy cans and the NSDP - along with other components less novel but crucial to the functionality of the major items. This section describes these components and the required modifications.

Near Surface Disconnect Package. The NSDP is an interface component bridging the upper and lower riser. It provides a disconnect point for a planned disconnect situation. The NSDP is divided into two halves – upper and lower NSDP. When disconnected, the upper NSDP is retrieved with the upper riser and the lower NSDP remains with the lower freestanding riser.

The upper NSDP is best described as a simplified version of a lower marine riser package (LMRP). It consists of a control system and equipments being controlled and monitored remotely to perform the intended functions provided by the NSDP. These equipments include the control pods, accumulator bottles, hydraulically operated riser connector and interfaces for mating of the choke and kill lines, booster line, hydraulic line, and subsea BOP control cables. In

addition, it also contains interface for the air supply lines to the buoyancy cans and an acoustic location/orientation sensor providing the position of the upper NSDP during riser reconnection.

The lower NSDP is simpler than the upper NSDP. It mainly consists of interfaces to accept mating of the riser connector and all the lines from the upper NSDP. The lower NSDP also need to have a set of hydraulic control valves to allow the buoyancy can to be charged before riser disconnect and to contain the high-pressure air inside the buoyancy cans before and while the riser is in freestanding mode. The acoustic location and orientation sensor is also required on the lower NSDP to assist the reconnect operation.

The orientation and alignment guiding components are required on both upper and lower NSDP to assist the reconnect process. Analysis should be conducted to identify the limiting current profiles that cause excessive inclination at top of the freestanding riser and hinder the riser reconnecting operation. Riser reconnecting should be achievable with an angle difference less than 2 degrees between the inclination of the upper and lower NSDP and with the assist of guiding structures on the NSDP. The relative movement of the upper and lower NSDP may not allow them to mate easily. Use of guide wires with ROV assistance may be required during riser reconnection.

The major technical challenge of the NSDP interface components is the qualification of the wet make/break multi-pin electrical connectors that provide electrical continuity for the subsea BOP control cables running from the vessel to the BOP and being split at the NSDP to allow riser disconnection. Even though wet make/break connector has been widely used for subsea applications and proven with good record of accomplishment, extensive testing is required to provide high level of confidence of its use on the FSDR system.

The NSDP would also need to have capability to unlock NSDP connector by means of ROV intervention.

Buoyancy Cans. The purpose of the buoyancy cans is to provide the upward vertical force to support the freestanding riser string after the riser being disconnected at the NSDP. During the connected mode, the buoyancy cans are maintained in neutrally buoyant for a safety reason addressed in the previous section.

The buoyancy can is normally fabricated from steel. To be beneficial from the effective density (dry weight to volume ratio), steel buoyancy can is normally designed with large outer diameter. The buoyancy can outer diameter (OD) is limited by the moonpool dimension. Twelve to 14 foot OD buoyancy cans have been installed on several production risers. The buoyancy can is normally divided into several longitudinal or horizontal chambers that are separated by a pressure tight diaphragm, called a bulkhead. This arrangement is simply for redundancy purpose, so a single point failure along the buoyancy can does not cause a complete loss of the buoyancy can. Each chamber has one air pipe and one vent pipe. The air pipe provides flow path for air to be pumped into the chamber during charging the buoyancy can, and air to exit during de-charging. Similarly, the vent pipe provides a flow path for seawater to exit during charging and to enter during de-charging. The air pipes are routed from the top of the air

can to the pressure supply unit on the vessel in a similar way as the choke and kill and auxiliary lines. The vent pipes are routed within the buoyancy can. Its arrangement is different for each design philosophy. An example of a typical structural arrangement inside a chamber of a buoyancy can is illustrated in Fig. 4.

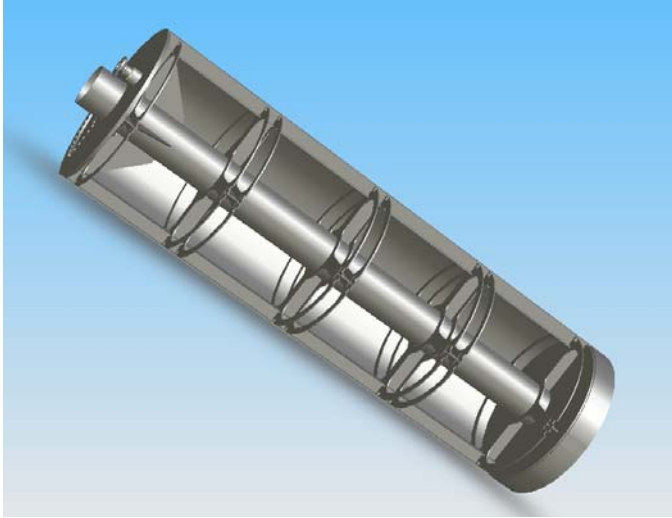


Fig. 4 – Example of Buoyancy Can Structural Arrangement

The handling of several large diameter buoyancy cans during riser installation can be a challenge, as vessels have not been designed with FSDR in mind. It would be ideal for the deployment of an FSDR system if the drill floor is designed with a large opening and retractable spider to allow the riser joints with pre-installed buoyancy can to be run and supported in the same manner that the conventional riser is run. Unfortunately, most existing rigs do not have this capability. To avoid extensive modification of the drill floor, the buoyancy cans need to be designed with the rig limitations of handling capabilities in mind. In addition, the rig needs to be tailored to provide handling capability to install the buoyancy cans and NSDP during riser running and retrieval.

Two types of buoyancy cans can be considered for the FSDR, integral and non-integral. Integral type refers to the buoyancy can being pre-installed on the riser joint before the riser joint is run. Non-integral types are buoyancy cans installed on the riser joint as the riser is being run. As the non-integral buoyancy can is installed while the riser is hanging from the rotary table, a C-shaped or split buoyancy, as shown in Fig. 5, can arrangement is preferred. The buoyancy can is transported to the moonpool well center and skidded onto the riser. The integral buoyancy can system can take several configurations, as it is not installed on the critical path.

The following sections elaborate on the advantage and disadvantage of each type, assuming the rigs do not have the capability to install the buoyancy can through the drill floor and must install the buoyancy can in the moonpool.

The choice of buoyancy can type is mainly driven by the handling capability of the rig. Installation of integral buoyancy can requires a second riser table at the moonpool to support the hang-off riser string to make up the buoyancy can joint. The moonpool beam structure may need to be strengthened to

support the weight of the riser as it is supported by the secondary riser table. A work platform at the top of the buoyancy can joint is also required to make up the riser-handling tool to lift the riser string once the buoyancy can joint is made up. Modification of the riser joint is likely required, as the moonpool headroom is normally shorter than the length of the standard riser joint. This results in a requirement of several short riser joints dedicated to the buoyancy can joints.

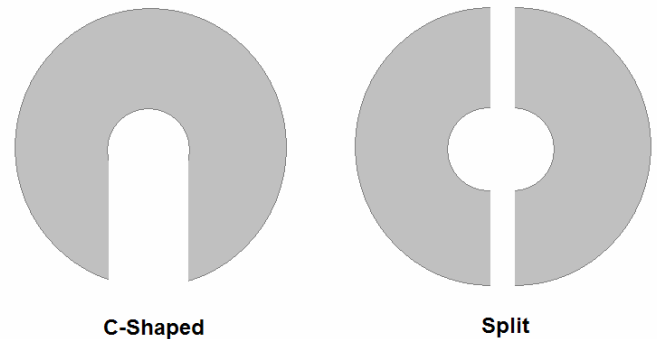


Fig. 5 – C-Shaped and Split Aircan

For most existing rigs, the non-integral buoyancy can seems to offer more advantages compared to the integral. As the buoyancy can is installed on the riser when the riser is supported from the drill floor, the moonpool structure is only required to support the weight of the buoyancy can before mounted on the riser. The riser string is only supported on the moonpool beams when the NSDP is being installed. At this time, most buoyancy cans are below the MSL and can be partially charged with air to provide some amount of upthrust required to support the weight of the hanging riser string. Another advantage of the non-integral buoyancy can is the flexibility of its height to accommodate the moonpool headroom. It can be fabricated in short modules, if required. In view of the installation requirements for non-integral buoyancy cans, most rigs seem would have few problems handling buoyancy cans with similar dimension as the BOP stack. A buoyancy can of this size can provide significant amount of upthrust. For example, an buoyancy can of 14 ft OD x 4 ft ID x 30 ft long can provide approximately 200 kip net upthrust (280 kip buoyancy force and 80 kips dry weight).

Allocating buoyancy can storage space on rigs for several buoyancy cans can be an issue on rigs. To provide adequate tension to a 3000 ft water filled FSDR, it may require 400-kip tension to support the riser weight and an additional 400 to 600 kip to maintain acceptable riser response. This is equivalent to four or five buoyancy cans of 14 ft OD x 30 ft long, which occupy a considerable amount of deck space. If storage space is not available, an overboard storage structure may need to be constructed or workboat can be used for storage. The use of workboat for buoyancy can storage should not be considered as a primary option, as this would require the workboat to be on site whenever the riser is recovered. However, given the rarity of emergency disconnect situation, this option can be implemented with careful consideration.

Auxiliary Equipments. Other equipments required to operate the NSDP and buoyancy can include:

- Reel for NSDP control lines
- Air supply hose reel. This can be bundle with the NSDP control lines.
- Driller control panel for NSDP and buoyancy can.
- Addition air pressure vessel (APV) dedicated to buoyancy can charging (de-ballasting)
- Moonpool riser hang-off platform capable of supporting the suspended riser string. The size and arrangement of this structure is largely dependent on the type of buoyancy can to be used.
- Buoyancy can handling equipment to provide mean to transport the buoyancy can to the moonpool center
- Testing station for buoyancy can and NSDP

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Conclusions

A solution to address the concern of having to retrieve a drilling riser in deep water in time for the drilling rig to evacuate its personnel, or sailing for shelter, before the arrival of a severe storm is presented. It involves modifying the existing drilling riser to make it disconnectable closer to the surface and leave the long riser string below (and subsea BOP) in a safe and freestanding mode to survive the storm. Subsequently, it significantly reduces redeployment time upon the returning to the well site to continue the drilling operations

The configuration of such a FSDR is proposed, and its design and hardware requirements are discussed.

The FSDR is designed to provide all functions of a conventional marine drilling riser but with an additional function of disengaging the riser at the NSDP located at a short distance below the water surface. Once disengaged, the lower riser section is held upstanding by buoyancy can modules attached to the top of the riser joints. This feature is unique to the FSDR and a key advantage over the conventional system

The conversion of a conventional riser to a FSDR requires the introduction of the NSDP components and buoyancy can modules, both of which are off-the-shelf or fabricated items of equipment readily available from the market.

The FSDR will bring significant benefits to deep water drilling operations where the weather windows regularly suspend drilling activities.

Nomenclature

<i>FSDR</i>	<i>Freestanding Drilling Riser</i>
<i>NSDP</i>	<i>Near surface disconnect package</i>
<i>EDS</i>	<i>Emergency disconnect system</i>
<i>ROV</i>	<i>Remotely Operated Vehicle</i>
<i>BO</i>	<i>Blowout Preventor</i>

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