Freestanding Risers In The Gulf Of Mexico - A Unique Solution For Challenging Field Development Configurations

D. Maclure, D. Walters

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FREESTANDING RISERS IN THE GULF OF MEXICO – A UNIQUE SOLUTION FOR CHALLENGING FIELD DEVELOPMENT CONFIGURATIONS

By
Duncan Maclure (2H Offshore Engineering Ltd.)

&
David Walters (2H Offshore Inc.)

ABSTRACT
Freestanding risers have become an increasing familiar riser solution for deepwater field developments in West Africa and more recently Brazil. A total of 4 field developments in West Africa will utilize the freestanding riser concept by the end of 2007, with a total of 14 risers installed that includes a combination of bundled risers and single pipe or pipe in pipe arrangements. To date, the Gulf of Mexico market has focused on the use of deepwater dry tree units with direct access vertical risers, or with flowlines and steel catenary risers to tieback subsea developments to the host facility. With the industry striding into ultra deepwater, evaluating the use of FPSOs with shuttle tankers, and the increased value in tying back smaller fields to existing platforms, the riser design is a critical component that must be thoroughly evaluated to accommodate ever changing design parameters such as the consideration of extreme vessel motions, temporary riser abandonment and host facility payload limitations. This paper will describe the basic design arrangement of single line freestanding risers and address the following key considerations for challenging deepwater field developments in the GOM:

- Installation methods and contract strategies;
- Accommodation of extreme vessel motions;
- Ability to accommodate temporary abandonment (transfer from Early Production System to Full Field Development);
- Field layout considerations and positive impact on flowline design issues;
- HP/HT issues;
- Suitability for tieback to existing facilities.

In addition, a case study is presented for a HPHT single line freestanding riser tied back to a payload sensitive facility, to demonstrate the riser performance in potentially harsh Gulf of Mexico environment.

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INTRODUCTION
As oil and gas exploration continues to move into ever increasing water depths there is a need to develop technically viable and cost effective riser systems for both new field developments and tiebacks to existing facilities. The riser system becomes increasingly significant in terms of cost and complexity as water depth increases.

A number of different riser systems are implemented on deepwater fields worldwide. The main types include top tensioned risers (TTRs), steel catenary risers (SCRs), flexible risers and free standing hybrid risers. The tendency in the Gulf of Mexico is to use dry tree units with direct access vertical risers or flowlines tied back to the host facility with steel catenary risers for subsea developments. However, with increasing water depths, higher reservoir pressures and temperatures, the complexity of existing solutions is increasing.

The nature of deepwater field developments requires riser systems that are robust, cost effective and flexible during design, construction and installation phases. For certain applications, riser systems such as SCRs do not meet the demands of deepwater, resulting in an increased consideration and implementation of alternative riser solutions.

Free standing hybrid risers, such as the 2H developed Single Line Offset Risers (SLORs) are becoming more frequently considered and installed in deepwater developments around the world. They are considered to be an enabling technology for deepwater and ultra deepwater field developments due to the robustness and flexibility inherent with the design.

The objectives of this paper are to provide an overview of existing riser technology, describe the main components of the SLOR, highlight the main advantages of the riser design in terms of installation and response and to demonstrate the feasibility of using such riser solutions in the Gulf of Mexico.
OVERVIEW OF CURRENT DEEPWATER RISER SOLUTIONS

Flexible Risers
Flexible risers consist of a number of spiral laid steel and thermoplastic layers and are extensively used for shallow and some deepwater riser applications worldwide. The beneficial feature of flexible pipe is its ability to accommodate high curvature, allowing ease of installation and accommodation of dynamic motions. The compliancy of the flexible riser eliminates the need for heave compensation or tensioning devices and results in a riser suitable for a wide range of environments and host facilities. However, careful design and qualification of the pipe is required to ensure that the large movements and potential for compression at the seabed do not result in failure. Flexible risers are used in a simple or wave catenary arrangement, as shown in Figure 1.

Development of flexible risers is progressing rapidly due to the demand to accommodate higher reservoir pressure and temperatures, larger diameters, deeper water and the potential for sour service. The improved specification of flexibles results in higher overall costs due to more exotic materials and complex manufacturing processes. However, the flexibility of these pipes allows them to be spooled continuously on a reel, or in a carousel, for efficient and quick transportation and installation. Installation speeds can average 500 metres per hour, but care must be taken as high curvatures and bending moments can be experienced at the TDP, which can result in pipe failure. Flexible risers are installed from a large number of reel lay vessels, however for larger pipe diameters and deeper water the number of capable vessels is reduced.

![Simple Catenary and Lazy Wave Catenary Arrangements](image)

**Figure 1 – Simple and Wave Catenary Arrangements**

Steel Catenary Risers
Steel catenary risers (SCRs) are emerging as a major alternative to flexible risers for mild to moderate deepwater environments, such as the Gulf of Mexico, West Africa, Brazil and Indonesia. It is considered that SCRs are the “base case” riser system for subsea wells tied back to deepwater floating platforms in the Gulf of Mexico. The main advantage of the SCR is that steel pipe costs significantly less than flexible pipe and can be constructed for a wider range of diameters, pressure ratings and water depths.

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The SCR is perceived as a relatively simple design as it consists of a steel pipe free hanging from a vessel to form a simple catenary shape. The pipe interfaces with the vessel via a flex-joint, taper joint or pull tube in the case of the spar, to accommodate dynamic motion. SCRs are used with all types of vessel but are particularly suited for use on motion optimised vessels such as tension leg platforms and spars.

Despite the perception that SCRs are a simple concept, the structural response observed is highly complex and there remains a degree of uncertainty in the ability to accurately predict the long term fatigue life. This is primarily due to the complexities associated with the touchdown point at the seabed and uncertainties regarding Vortex Induced Vibration (VIV). These problems are compounded by the uncertainty in achieving adequate weld quality.

The SCR is made of a series of welded pipe joints and the fatigue performance of the welds is highly dependent on several interrelated factors including pipe and weld material properties, joint dimensional tolerances, welding processes, welding procedure and inspection criteria. Good quality offshore welds are required in order to achieve sufficient fatigue lives for SCRs. As such, high specification vessels are required to perform these critical offshore welds, however it is noted that these vessels command high day rates and mobilisation costs.

SCR design remains complex with a level of uncertainty that requires suitable safety margins/factors. The ability to improve the design processes and reduce error in assumptions ultimately allows wider application of these systems.

**Top Tensioned Risers**

Top tensioned risers (TTRs) are commonly used with tension leg platforms and spars that facilitate direct well access. The TTR runs directly from the subsea wellhead to the vessel deck where the surface trees are located. Tension is applied to the riser by either buoyancy cans or deck mounted hydro-pneumatic tensioners.

The conventional construction method for top tensioned riser joints is based on ‘weld-on’ threaded connectors on the end of each riser joint. However, recent TTRs are based on riser joints made up using integrally machined threaded and coupled connections. Threaded and coupled connections are made up using similar running procedures to weld-on threaded connectors. However, as the riser joints do not include welds, higher strength material grades may be utilised. Extensive experience is available in the design and procurement of TTRs. Materials are readily sourced, with large diameter steel pipe, pipe upsetting and machining capabilities available from many different suppliers.

**Hybrid Risers**

Although a relatively new technology, the free standing hybrid riser (FSHR) design is field proven on a number of projects including Placid, Girassol, Kizomba A & B. The concept is also planned for large diameter export purposes on the Petrobras P52 field. The free standing riser consists of a vertical steel pipe connected to a foundation pile at the seabed. The system is tensioned by means of a buoyancy can that is mechanically connected to the line pipe. The buoyancy can is located at the required depth below the surface, typically 50 to 150m below MWL, depending on the current profiles. At the top of the buoyancy can is a gooseneck.
assembly that the flexible jumper is attached to. The key advantage of this hybrid arrangement is that the vertical riser response is largely decoupled from the vessel motions and hence becomes less susceptible to fatigue damage.

There are numerous designs for free standing risers, the three main types, shown in Figure 2 are as follows:

- Single Line Offset Riser (SLOR).
- Concentric Offset Riser (COR) – Pipe in pipe variation.
- Bundled Hybrid Riser – a number of small diameter flow paths configured into a vertical bundle and supported by buoyancy.

![Figure 2 – SLOR, COR and Bundled Riser Cross Sections](image)
SINGLE LINE OFFSET RISER DESIGN
A SLOR design considered for the Gulf of Mexico is described below. A sketch of the SLOR arrangement is shown in Figure 3. The following sections describe the main SLOR components.

Figure 3 – SLOR Arrangement
Foundation
A typical SLOR foundation consists of either a suction pile or a drilled and grouted pile to which the riser is connected via a high integrity connector. The connector mates with the profile on the connector mandrel located at the top of the foundation pile. The connector has a stinger to align the connector over the mandrel, and to provide orientation of the riser. The riser may incorporate a rigid base connector or a low stiffness elastomeric material to reduce bending moments at the base.

Large diameter suction piles are generally not good at resisting bending loads and so elastomeric flex elements are used to reduce the load transferred to the foundation. This can lead to large motions at the base of the riser, which creates difficulties for the rigid base jumper design. The preferred solution is to use small diameter drilled and grouted piles typically of 30-40inch diameter. These piles are more structurally suited to accommodate large bending loads and can therefore utilise taper joints. This reduces the loading on the base jumper and results in a less critical base jumper design.

Lower Assembly
The lower riser assembly consists of a lower offtake spool connected to a lower stress joint. The offtake spool has an internal flow path from the side of the spool to which an induction bend is attached. A rigid base jumper is attached to the end of the induction bend using either a horizontal or vertical subsea connection system. The base jumper is designed to accommodate extreme riser motions and flowline expansion / contraction due to start up and shut down operations and therefore typically contains a number of loops. The lower stress joint is a high specification component that is designed to control the large bending moments at the base of the riser. The taper joint profile is optimised to withstand both extreme loads and long term fatigue loading. The lower end of the taper joint is connected to the upper end of the offtake spool via an integral compact flange connection.

Figure 4 – Lower Assembly Details
**Standard Riser Joints**

The standard riser joint are assembled using non-welded threaded and coupled connections and high strength steel pipe as shown in Figure 5. These types of connections have been used for many years offshore, particularly for drilling applications. The advantages of threaded and coupled connectors are discussed later.

![Figure 5 – Threaded and Coupled Connectors](image)

**Buoyancy Can**

The riser is tensioned by means of an air or nitrogen filled buoyancy can. The can contains a number of individual compartments, separated by bulkheads. The bulkheads contain stiffeners arranged on the underside of each bulkhead plate to provide additional reinforcement. The buoyancy can is designed to be pressure balanced with the external pressure of the water, this allows the thickness of the buoyancy can skin to be limited to minimal wall thicknesses. The buoyancy can is designed such that at least one compartment is maintained permanently water filled as a contingency. In the event of a failure of another buoyancy can compartment, a contingency compartment can be de-watered to maintain the tension in the riser string.

A central pipe runs through the buoyancy can that acts as the main structural component. The riser pipe is attached to the top of the buoyancy can by a load shoulder, which transmits the tension directly to the riser string.

**Keel Joint**

At the base of the buoyancy can a keel joint arrangement is used to control the bending moment transferred to the riser string due to riser motions. The keel joint arrangement is similar to that used on production risers on with dry tree units, however the design is simplified as there is no requirement to design for axial motion (stroke).
The keel joint consists of back to back tapered stress joints. The riser is centralised against the buoyancy can at the thickest section. The diameter of the keel centraliser is slightly smaller than the bore of the buoyancy can. Additional centralisers are included along the length of riser string within the buoyancy can to control the curvature of the riser string within the buoyancy can stem.

Gooseneck Assembly
The gooseneck assembly provides fluid offtake from the riser to the flexible jumper. It comprises of an induction bend that is structurally supported to a spool piece at the base of the assembly in order to react the loads from the flexible jumper.

The bends in the offtake spool and rigid base jumper are configured as 3D and 5D radius bends. This is a requirement to allow pigging through the risers. For production riser, depending on the type of fluid it may be required to consider an erosion allowance.

Flexible Jumper
A flexible jumper is used to transport the fluid from the riser to the vessel. Bend stiffener are used at the gooseneck and vessel termination points in order to restrict the bend radius of the jumper. The jumper properties are very much dependent on riser service, pigging requirements and insulation requirement.
INSTALLATION HISTORY
To date a total of 14 hybrid risers have been installed worldwide as shown in Table 1. The first installation was Placid’s bundled riser in Green Canyon, Gulf of Mexico in a water depth of 470m. This was a hybrid riser located directly beneath the production facility that required only a short length of flexible to connect with the vessel. The bundled Girassol risers were installed in water depths of 1350m and are the first use of an offset arrangement, i.e. at some distance away from the production facility. The first single line offset risers were installed for the Kizomba A development offshore West of Africa.

<table>
<thead>
<tr>
<th>Field</th>
<th>Riser Type</th>
<th>Location</th>
<th>Water Depth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Placid Green Canyon</td>
<td>Bundle</td>
<td>Gulf of Mexico</td>
<td>470</td>
</tr>
<tr>
<td>Enserch Garden Bank</td>
<td>Bundle</td>
<td>Gulf of Mexico</td>
<td>670</td>
</tr>
<tr>
<td>Total Girassol</td>
<td>Bundle</td>
<td>West Africa</td>
<td>1350</td>
</tr>
<tr>
<td>Kizomba A</td>
<td>SLOR</td>
<td>West Africa</td>
<td>1200</td>
</tr>
<tr>
<td>Kizomba B</td>
<td>SLOR/COR*</td>
<td>West Africa</td>
<td>1200</td>
</tr>
<tr>
<td>Petrobras P-52</td>
<td>SLOR</td>
<td>Brazil</td>
<td>1800</td>
</tr>
</tbody>
</table>

*The Concen tri c Offset Riser (COR) is a pipe in pipe version of the SLOR presented in detail in this paper.

Table 1 – Free Standing Riser Installations

CASE STUDY – SINGLE LINE OFFSET RISER IN THE GULF OF MEXICO
A case study of a single line offset riser is presented in the following sections. The SLOR is identified as a suitable riser system for subsea tiebacks to existing platforms in the potentially harsh Gulf of Mexico environment in a water depth of 4,500ft. The SLOR is feasible with all vessel types but has particular benefit for production facilities that are restricted on payload capacity as the jumper loads are significantly less than the equivalent steel catenary riser (SCR).

Configuration Development
The initial configuration of the SLOR is developed using hand calculations and static riser analysis. To demonstrate feasibility a number of other design considerations are addressed, as follows;

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- Interference between existing risers, umbilicals and mooring lines (or tendons).
- Response to extreme vessel motions and current loading.
- Response to vortex induced vibration (VIV) fatigue.
- Vessel hang-off loads.

The SLOR is constructed using threaded connections to allow installation via a number of installation vessels including mobile offshore drilling units (MODUs). The final SLOR configuration is given in Table 2.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steel Pipe OD</td>
<td>0.2445, 9-5/8”</td>
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<tr>
<td>Material Grade</td>
<td>X80</td>
</tr>
<tr>
<td>API Wall Thickness</td>
<td>27mm, 1.06”</td>
</tr>
<tr>
<td>Base Tension</td>
<td>175Te, 400kips</td>
</tr>
<tr>
<td>Separation Distance</td>
<td>~ 275m, 900ft</td>
</tr>
<tr>
<td>Buoyancy Can Length</td>
<td>30m, 98ft</td>
</tr>
<tr>
<td>Buoyancy Can Outer Diameter</td>
<td>5.5m, 18ft</td>
</tr>
<tr>
<td>Required Upthrust</td>
<td>~325 Te, 720kips</td>
</tr>
<tr>
<td>Potential Upthrust</td>
<td>~375 Te, 830kips</td>
</tr>
<tr>
<td>Jumper Length</td>
<td>375m, 1230ft</td>
</tr>
<tr>
<td>Foundation Pile Length</td>
<td>~80m, 260ft</td>
</tr>
<tr>
<td>Foundation Pile Outer Diameter</td>
<td>0.762m, 30”</td>
</tr>
<tr>
<td>Maximum Vessel Hang-Off Load</td>
<td>~30Te, 65kips</td>
</tr>
</tbody>
</table>

**Table 2– SLOR Configuration Details and Design Parameters**

**Interference Analysis**

Interference analysis is found to be a key issue in the configuration of the system due to the proximity of other risers, umbilicals and vessel structures. The possibility of clashing is also made more likely by the occurrence of loop currents and submerged eddy currents that are common in the Gulf of Mexico.

Interference problems tend to arise between riser systems, mooring lines and umbilicals that move differently under extreme vessel and environmental loading. For example, a light weight umbilical moves differently to the vertical section of a SLOR and may result in a clashing issue due to the difference in response. Interference issues may also arise between the SLOR flexible jumper and the host vessel due to the low stiffness of the flexible jumper when hung in a catenary shape.

The configuration of the SLOR is optimised based on the results of the interference analysis. The SLOR response is modified to mitigate interference with other structures by adjusting the following key parameters:

- Volume and location of distributed buoyancy.
- Upper aircan upthrust.

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- Offset distance of riser base from vessel.
- Flexible jumper length and weight.
- Depth of upper aircan to avoid high currents.
- Flexible jumper hang-off point.

In general a solution can be found, however this is hugely dependent on the host vessel type and existing field layout.

**Response to Extreme Vessel Motions**

The extreme storm response of a SLOR is largely quasi-static. As the riser and buoyancy can are located away from the wave zone and surface current regions, the direct environmental loading on the system is low. The flexible jumper connecting the riser to the vessel dissipates any vessel motions, such that at the attachment point of the flexible jumper to the gooseneck the dynamic component of the loading is small.

The riser response tends to be driven largely by vessel offset, which may deflect the riser in the direction of the vessel offset as shown in Figure 9, resulting in an increase in loading at the gooseneck and also at the riser base. This can be accommodated by local strengthening of the gooseneck and lower riser assembly in the form of taper stress joint and thickened pipe sections, as discussed in earlier sections. High loading may also be experienced where the riser exits at the base of the buoyancy can, and hence careful design of the tapered keel joint is required.

Where the flexible jumper is attached to the vessel and the gooseneck, bend stiffeners are used to control the rotation between the jumper and the vessel / riser connection.

A typical plot of the von Mises stress along the riser length under storm loading is presented in Figure 8. From the plot, it is seen that along the majority of the riser string, the stress shows a gradual linear increase towards the top of the riser, which is mainly due to axial tension and hoop stress in the riser. At both ends of the riser however local bending loads are seen in the system, but are accommodated using locally thickened or tapered components to control the curvature.
Figure 8 – Typical SLOR Stress Response to Extreme Vessel Motion

Figure 9 – Typical Response to Extreme Vessel Motion

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Response to Vortex Induced Vibration (VIV) Fatigue

The example VIV fatigue response of the SLOR is shown in Figure 10. Low fatigue damage is obtained along the majority of the riser length and damage peaks occur at the riser base and at the interfaces of the riser and the buoyancy can. The critical region for VIV damage tends to occur just below the interface of the riser with the buoyancy can.

It is necessary to design the components at the locations of the peak fatigue damage such that they are capable of withstanding the predicted stress cycling, using tapered or thickened riser joints and high quality welding. Generally components can be designed with adequate fatigue performance, and the use of strakes is not necessary. However, the addition of VIV suppression strakes would provide the riser with fatigue lives with large margins of safety.

For this particular application threaded and coupled connections are used. The assumed fatigue detail of a threaded and coupled connection is a DNV B-curve with an SCF of 3.0. The target design fatigue life of 200 years is met at all locations along the riser.

If required, VIV fatigue response can be improved by tuning the mode shapes of the riser to avoid a particularly damaging VIV response for critical current profiles. This can be achieved through a moderate adjustment of the riser tension, however the extent to which the base tension can be adjusted is limited by practical considerations with respect to clashing and installation.

![VIV Fatigue Life Along Length of SLOR](image)
**INSTALLATION METHODS**

The SLOR pipes can be either welded or mechanically connected, allowing installation from a range of vessels including drilling and pipeline construction vessels. The riser is purposefully designed using proven components and installation procedures.

A large proportion of existing deepwater risers are currently based on a welded pipe construction. One of the main reasons welded construction remains the ‘default’ method of is that historically, shallow water flowlines (less than 100m) were installed using low strength, readily weldable steel using the S-lay technique. This is a cost effective method for shallow water, which established a high level of confidence and track record in offshore welded connections.

This practice has continued as the industry moves into deeper water, with installation contractors developing more sophisticated welding techniques and building higher specification vessels to meet the demands of deep water. This provides the Operator with little choice on installation method. However this approach in deepwater may result in a high cost and often a complex riser solution.

It is inherent that riser steel weight increases proportionally with water depth, which has a significant effect on the tension requirements of the installation vessel. As field developments approach water depths in excess of 6,000ft with thick wall HPHT production risers and large diameter export risers, the number of installations vessels capable of installing such risers diminishes, creating limited availability. The freestanding SLOR can be installed from a variety of vessel and with the use of high strength steels in excess of 100ksi, the riser weight is reducing such that an increased number of installation vessels are capable of installing the risers, even in water depths beyond 8,000ft.

The design of the SLOR allows the riser and jumper to be pre-installed during suitable environmental conditions. The jumper is hung vertically from the gooseneck in the standby mode, and when the host vessel arrives, the lower end is picked up for connection to the vessel. This has the benefit of simplifying project schedule by eliminating complex logistics with installation vessels, and reduces riser hook up time.

The ability to free stand without tension applied from a vessel offers a significant advantage over other types of riser. As well as pre-installation, the possibility for temporary abandonment exists, which is attractive when updating field developments from temporary early production systems.

**Welded SLOR**

Installation of a welded SLOR can be performed using a J-Lay derrick barge. For this technique riser stalks of up to 6 joints (hex-joint) are prefabricated onshore, reducing the number of welds that need to be made offshore. J-lay collars used to support the pipe during installation are welded around the pipe and can be designed to act as buckle arrestors. The number of vessels capable of deeper water J-lay installation decreases with water depth due to tensioning capacity, as previously discussed. The current maximum tension limit is around 1,000Te for high-end installation vessels, with several more vessels with capacities of over 500Te. High vessel day rates and mobilisation costs are applicable to this type of vessel.

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Threaded and Coupled Connections

An alternative construction method to welded risers utilises premium mechanical connections in the form of non-welded threaded and coupled (T&C) connections, as have been used on recent TTRs.

T&C connections are a cost effective method of joining pipes together. There are a large number of threaded connector designs available on the market, many of which are proprietary. The use of threaded couplings for riser and flowline solutions can provide significant benefits:

- Faster make-up speed compared to welding - threaded connections (9 5/8-inch diameter) can be made up in 2-5 minutes compared to 30-50 minutes for a typical offshore welding and inspection procedure for a fatigue sensitive application. Non-welded construction allows the use of high strength steel (P110), this reduces riser weight, reducing the buoyancy requirements or payload on the vessel.
- Improved fatigue performance – Qualification testing of threaded couplings shows that the fatigue performance is comparable to or even better than what can be achieved with a good quality single sided weld.
- Cost – the cost of pipe machined threaded and coupled connections are greater than that of plain ended pipe. However it is noted that the steel cost is a small proportion of the total system cost, cost savings are achieved through alternative installation as discussed below.

One of the key benefits of using T&C connections is the ability to improve the installation procedure, particularly for SLORs. Threaded and coupled connections are used for applications, which inherently require installation from a drilling derrick, specifically designed to efficiently handle and install pipe joints with threaded connectors, such as down hole casing. Along with their extensive use down hole, recent successful applications of T&C connections for TTRs qualify them to be considered a field proven solution for deepwater risers.

Although mobile offshore drilling units (MODUs) are not generally used for installation of flowlines, SCRs or SLORs, the facilities available on these vessels are well suited for J-lay mode. The available handling equipment such as spiders and torque tongs are tailored for the use of threaded connections. The derrick capacity is variable, but is usually greater than the majority of J-lay installation barges. MODU is often already mobilised in the field to drill development wells, and probably on a long-term charter, which can facilitate flexible scheduling, typically MODU costs are less than that of a J-lay barge. In addition, the motion characteristics of a MODU are more superior to those of a pipelay barge. The peak roll and heave response periods of MODUs are further from the wave periods that occur in installation conditions, leading to decreased periods of installation downtime. Furthermore, barges tend to be more sensitive to vessel heading and must be orientated during installation towards the waves. This can lead to difficulties during lay operations.

As with AUT inspection of welded joints, threaded and coupled connections require integrity confirmation upon completion of the make up. Poor make up of T&C connections is eliminated by the introduction of computer controlled torque tongs with feed back logic control. This has allowed the precise control of threaded connection make up, producing torque turn charts, allowing the Operator to efficiently confirm whether a good connection has been made.

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Threaded connections can be made up in 2-5 minutes and it conservatively estimated that completion of each 80ft double joint can be done in a total of 15 minutes. This includes the joint make up, integrity confirmation, installation of field joint half shells and application of a heat shrink sleeve. Unlike welded construction, the lay rate of threaded pipe is not sensitive to variations in pipe diameter or wall thickness.

CONCLUSIONS
It is concluded that the SLOR is a field proven riser system that is well suited for deepwater riser application worldwide. The key conclusions are as follows:

- SLOR’s have good structural response under extreme environmental and vessel loading.
- Fatigue performance is good and large margins are obtained despite the strong loop currents, submerged eddies and hurricanes in the Gulf of Mexico.
- The use of threaded and coupled connections is an enabling technology for ultra deepwater SLOR’s due to improved fatigue performance, faster make-up speed and weight saving over conventional welded joints.
- Installation method is flexible and can be conducted from a variety of low cost vessels including MODUs and even reel lay, S-Lay and J-Lay if required. This provides the Operator with extensive contract strategy choices, enabling costs to be competitive.
- The installation schedule is improved due to the ability to install SLOR’s at any stage during the field development. The SLOR can be installed and left in a free standing configuration prior to the arrival of the host vessel. In the case of an early production system the riser can be disconnected and reconnected to the permanent facility.
- Low host vessel payload and low vessel / riser interface complexity.

The flexibility of the design and installation methods and the additional features that are inherent with the SLOR design indicate that this will be an enabling technology as the industry moves into even deeper waters.

REFERENCES


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