Heavy Oil Gas Lift Using the Concentric Offset Riser

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Abstract
The production of heavy oil presents a number of problems to deep water operators. A combination of high fluid density, hence hydrostatic head, and viscosity in the risers tied back to the floating production vessel limits the oil production rate. The Concentric Offset Riser (COR) offers a solution for convenient provision of riser base gas lift all in a single arrangement. The injection of gas at the riser base mixes with and lightens the oil, and hence enhances the production rate from heavy oil reservoirs.

The COR is a free standing and thermally efficient pipe-in-pipe riser system suitable for subsea developments tied back to a floating host vessel. The annular space has many potential uses, one of which is gas lift. The vertical riser is tensioned at the top with a buoyancy tank, and tied back to the production vessel with a flexible jumper. Such systems are being implemented in West Africa.

This paper describes the benefits of implementing the COR design for deepwater heavy oil developments.

Introduction
The COR is suitable for heavy oil developments in both mild and harsh environments and for a range of production facilities. In addition, the COR arrangement has been developed with full consideration to dynamic response, thermal and process capability, hardware selection, installation, and field development flexibility. A key feature of the COR is the ability to install them quickly from any deep water drilling vessel using standard rig equipment and procedures.

Conventionally one riser for import production and one riser for gas lift are employed. The COR reduces the number of riser strings by allowing gas lift using the annulus.

Configuration
There are a number of variations to the COR design, one of them is described below and shown in Figure 1.

The COR consists of two concentric vertical steel pipes connected to a foundation pile at the seabed. A buoyancy can assembly near the surface, but located below the wave and high current zone, is used to tension the pipe system. The riser pipes run through the bore of the buoyancy can where centralizers maintain concentricity of the outer riser pipe within the buoyancy can stem. The COR is tied back to the vessel with two flexible jumpers for access to both the riser annulus and bore. The flexible jumpers are attached to the gooseneck assembly at the top of the buoyancy tank, and the flexible jumpers decouple the vessel motions from the riser.

Depending on water depth, vessel excursions, and number of risers to be accommodated, the riser foundation is typically 200m or more from the vessel. The flexible jumper lengths are chosen to provide comfortable hang-off angles and accommodate vessel excursions. The gas lift flexible jumper has different length from production jumper in order to avoid interference. Typical base tension for the COR is 100 to 150 tonnes, and is chosen to optimize the riser response.

Foundation. The foundation consists of a drilled and grouted pile to which the riser is connected with a high integrity connector. The foundation diameter and penetration depth is dependent on the riser base tension and the soil conditions at the site. The riser has a rigid base connection.

Lower Riser Assembly. The lower riser assembly consists primarily of the lower off-take spool, gas lift injection system, and the lower taper joint. The off-take spool is a component with an internal flow path which is open at the side of the spool. Attached to the side of the spool is an induction bend, and a base jumper is joined to the end of the induction bend by either a horizontal or vertical connection system. The opposite end of the jumper is connected to the flowline via a Flowline End Termination (FLET).
The gas lift injection system is attached to the off-take spool top. This component completes the gas injection flow path from the annulus to the riser bore.

The lower taper joint is connected to the top of the gas lift injection system. This component is designed to control the bending at the base of the riser where it is connected to the stiff lower riser assembly.

**Riser String.** The majority of the riser string consists of two concentric riser pipes manufactured from high strength steel and constructed from threaded and coupled steel joints. Centralizers maintain pipe-in-pipe concentricity at required locations along the riser. Alternatively, a welded construction is possible which is discussed later in the text.

**Buoyancy Can.** The COR is tensioned by a single nitrogen filled buoyancy can or an assembly of smaller cans. Internal bulkheads are used to divide the can into compartments to limit buoyancy tank flooding in the event of localized damage.

The riser pipe is attached to a load shoulder at the top of the buoyancy can, and thus the upthrust generated by the buoyancy can is transmitted directly to provide tension in the riser string.

**Keel Joint.** At the base of the buoyancy can, where the riser exits from the central structural pipe, a keel joint arrangement is used on the riser to control the bending moment transferred in to the riser string due to vessel excursion and riser motion. The keel joint arrangement is similar to that used for dry tree production risers, except that there is no relative stroke between the buoyancy can and riser string.

**Gooseneck Assembly.** The gooseneck assembly provides fluid off-take from the free standing riser to the flexible jumpers. It consists of two induction bends to accommodate access to the riser bore and annulus, which are structurally braced back to a gooseneck support spool at the base of the assembly to react the loads generated on the assembly by the flexible jumpers.

The bends in the gooseneck, off-take spool and base jumper are typically configured as 3D or 5D radius bends. These can allow the passage of pigs and prevent flow restrictions.

**Flexible Jumper.** Flexible jumpers are used to transfer fluid between the riser and the vessel. Bend stiffeners are used to control the bend radius of the jumper at the vessel and gooseneck termination points.

**Alternative Configuration**

COR configurations may depend upon the specific project parameters and contract strategy. The COR described below has been implemented for riser base gas lift offshore West Africa. An illustration of this configuration is provided in Figure 2.

There are two main differences in the West African COR configurations.

- Gooseneck location
- Foundation

The gooseneck for the West African COR is located below the buoyancy can. This configuration simplifies the interface between riser and buoyancy can as the riser pipe does not pass through the buoyancy can. However, there are advantages to placing the gooseneck at the top of the buoyancy can as the flexible jumper can be installed after the riser is free standing by a separate and smaller installation vessel. Also, the gooseneck is diver accessible when located at the top of the buoyancy tank. This allows for easier repair and replacement of the flexible jumper in the event that it is damaged.

The West African COR has a gravity assisted suction pile foundation, which can be easily installed from many different vessel types and fabricated locally. In addition, a flexible joint at the riser base mitigates bending moment in this region. This differs from the other configuration, which uses a tapered joint to distribute the high bending at the riser base.

**Gas Lift Arrangement**

The lower riser assembly, complete with gas lift injection system is shown in Figure 3.

The inner production pipe has multiple holes equally spaced around the circumference for the distribution of gas to the production bore. As gas flows through these holes, which vary in diameter depending upon the specific fluid requirements, the flow streams will impinge on each other and mix with the heavy oil. This reduces the effective density of the oil and increases the production rate.

There is a small annulus at the base of the COR, which may collect water during some modes of operation. Whilst the locations of the gas lift injection holes are selected to minimize this volume, the area may be overlaid with corrosion resistant material to prevent corrosion if this is considered an issue. However, during non gas lifting operation, a back pressure will be maintained in the annulus and small influxes of oil with small volumes of water are expected to constantly flush this area as opposed to having just stagnant water. During gas lift, the warm gas will maintain a positive back pressure preventing influx of production fluids and also evaporating any moisture that collects in this area. On this basis, corrosion is not considered a problem. In addition, the riser pipes are designed with thick sections at these locations.

**Design Response**

The riser is tied back to the FPSO via a flexible jumper. The design of the riser is such that it experiences predominantly quasi-static loading due to the flexible jumpers, which decouple the vessel motions form the vertical riser. In addition, the top of the riser tower is typically 50m to 100m below mean water level, which is below the wave and high
current zone. The COR is designed in accordance with API-RP-2RD [1].

**Strength Response.** Because the flexible jumpers mitigate the transfer of vessel motion to the free standing riser, the COR has excellent stress response. In addition, the regions of potential high load are addressed by implementation of a joint with tapered wall thickness to distribute bending moment over its length. The potential high stress regions of the riser are located at the riser base and at the base of the aircan where the riser exits the buoyancy can stem.

The stress response is driven by vessel excursion, and is relatively insensitive to other parameters. Hence, the COR is a robust design.

**Fatigue Response.** Because the flexible jumpers mitigate direct wave actions and the transfer of vessel motion to the free standing riser, the COR has excellent fatigue performance. In addition, the top of the COR tower is located below the high current zone in the top 50 to 100m of the water column thus reducing VIV fatigue damage.

**Installation**
The original design of the freestanding COR utilizes high strength steel and non-welded threaded and coupled connections. The high strength steel assists in reducing wall thickness, making the riser lighter and therefore requiring smaller air cans to provide the required top tension. Threaded and coupled connections, or casing connections as they are often referred to, is a proven and cost effective method of joining pipes together. There are a large number of threaded connector designs available on the market, many of which have designed for fatigue applications in top tensioned risers.

The use of threaded and coupled connectors facilitates installation of the riser system from a mobile offshore drilling unit (MODU), diving support vessel (DSV) with a derrick, or other construction vessel with a suitable derrick structure capable of running casing joints. The ability to install the riser system from a MODU offers the following advantages:

- The MODU is usually already chartered by the Operator and is in the field drilling production wells for the field development, hence there are no mobilization costs.
- There is widespread availability of suitable vessels capable of installing a freestanding riser, in the event that the Operator does not wish to divert the field MODU from drilling production wells.
- The MODU’s are specifically designed to efficiently handle and install threaded connections. Experienced rig personnel are readily available and procedures and tooling are established.
- Typically a 3rd generation MODU has a lower day rate than that of a pipe-lay construction vessel.
- Threaded connections can be made up much faster than welding and inspection, and is independent of wall thickness.

To date, all freestanding CORs installed are welded primarily due to the preference of the installation contractors who are also responsible for the welded flowlines. However, although this highlights the installation flexibility of the freestanding riser arrangement the real benefits of threaded installation have not yet been realised. The benefit of having an alternative to welding should not be overlooked in contract negotiations with installation contractors.

The COR design allows the complete riser and jumper to be pre-installed prior to the arrival of the host vessel. The jumper hangs vertically from the gooseneck and is strapped to the air can and riser at regular intervals to secure the flexible jumper while it is in the temporary ‘freehanging’ condition. Upon arrival of the vessel the straps can be removed by ROV and the jumper pulled in and connected to the vessel. This has the benefit of simplifying project schedule by eliminating complex logistics with installation vessels, and reduces riser hook up duration.

**Conclusion**
Implementation of the COR is an ideal tieback solution for heavy oil developments as the riser base gas lift can be employed using the annulus as the gas injection flow path. Furthermore, the capability of the of the COR to perform riser base gas lift reduces the number of required riser strings as conventional gas lift utilizes one riser for import production and one riser for gas lift.

- Moderate dynamic response
- Thermal and process capability
- Common hardware
- Cheap and flexible installation
- Field development and schedule flexibility
- Low maintenance

**References**
Figure 1 – Typical COR General Arrangement

Figure 2 – West Africa COR General Arrangement [2]

Learn more at www.2hoffshore.com
Figure 3 – Lower Riser Assembly