THIRD GENERATION DEEPWATER HYBRID RISERS

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Introduction

As oil exploration and production move into deeper water there is a need to develop technically viable and cost effective risers. A candidate riser arrangement is the hybrid riser system, which is the basis for a number of developments offshore West Africa.

Hybrid risers consist of a vertical bundle of steel pipes supported by external buoyancy. Flexible jumpers connecting between the top of the riser and the vessel are used to accommodate relative motion between the vessel and riser bundle.

The first generation hybrid risers, which were installed in the Gulf of Mexico, were designed for a large number of flow paths and were installed through the moonpool of a drilling vessel. However, due to the large size, design complexity and weight of these systems installation was very costly.

The second-generation hybrid riser design, proposed for Girassol, is fabricated at an onshore site with installation by tow out and upending. This approach provides significant cost reductions as a result of weight savings, design simplification and reduction of installation schedule.

The disadvantages of both first and second-generation hybrids are:

- design complexity of the bundle
- installation risk
- low field development flexibility

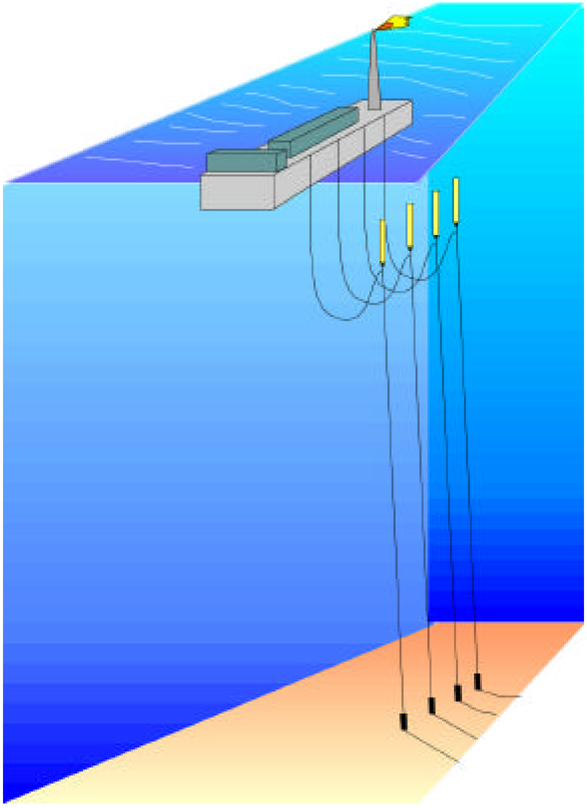


Figure 1 – COR General Arrangement

The Concentric Offset Riser (COR), developed by 2H Offshore, may be considered to be a 3rd generation Hybrid riser. It offers many of the benefits of the earlier concepts but, having a simple bundle design, can be quickly and economically installed from a drilling vessel. This greatly reduces risk and the smaller bundle arrangement increases development flexibility. The following paper describes the system arrangement, preliminary analysis results and costing data.

Concentric Offset Riser Description

The 2H COR is a free standing riser configuration for deep water environments. The main features of the system compared to earlier hybrid arrangements are:

- Simple design and construction
- Installation from a drilling rig
- High development flexibility
- High level of thermal insulation
- Highly cost effective

The arrangement of the COR allows it to be installed quickly from any deepwater drilling vessel using standard rig equipment and procedures. The riser uses a thermally efficient concentric, pipe in pipe arrangement as shown in Figure 2.

Typically a central production flow path, 10-3/4 inches diameter located inside a 16 inch outer casing. The annular space may be filled with air or hydrocarbon gas for gas lift or injection purposes.

The outer casing provides efficient buoyancy reducing top tension, thermal insulation by virtue of the annulus and a second pressure barrier allowing monitoring of leaks from the central production line.

A small diameter service line or heating line may also be included within the annulus as shown or included externally within a buoyancy recess.

The riser joints are manufactured from high strength steel. This is selected to minimise steel weight and buoyancy requirements. The riser joints are assembled offshore using casing connections.

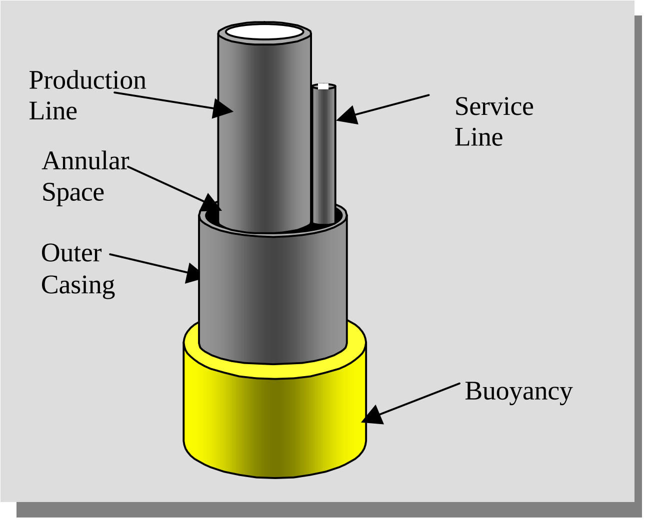


Figure 2 – COR Bundle Arrangement

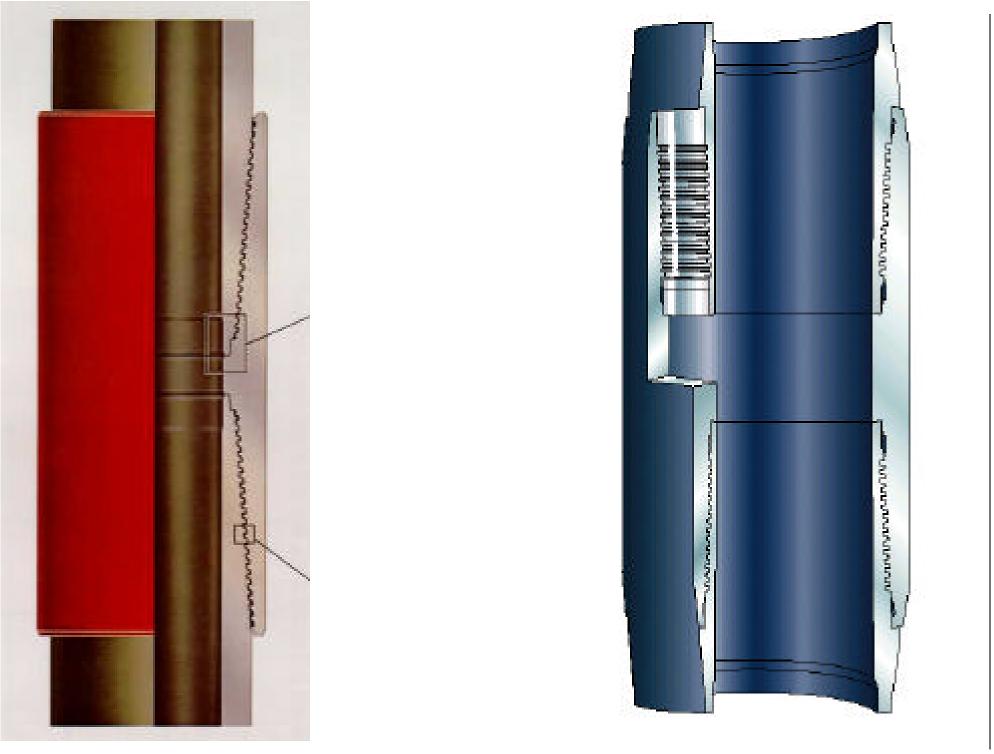


Figure 3 - Standard Casing Connector and Modified Casing Connection

Two types of connection may be used. The standard casing connection has the lowest cost but suffers from potential thread corrosion due to seawater ingress unless modified and has a relatively high Stress Concentration Factor (SCF=4.0). However, as welding is avoided, the fatigue performance is based on the parent pipe material, which has a better fatigue performance than a single side weld. Consequently, good fatigue lives can be obtained even in harsh and high current environments.

The alternative connection is the modified casing connection developed by V&M. This has small external load shoulders that reduce the SCF and provides a quality metal to metal environmental seal. The connector requires a minimal upset on the pipe ends however, the impact of this on the manufacturing cost is small. Consequently, such couplings offer a low cost solution with excellent performance and can be assembled rapidly and reliably using standard equipment.

At the seabed the riser is connected to a drilled and grouted 30 inch pile using a ‘wellhead’ connector. The Bottom Riser Assembly (BRA) is located immediately above the wellhead connector. The BRA includes facilities for fluid take-off, location and sealing of the inner pipe string and provides riser base gas lift facilities. A taper joint is used above the BRA to control riser curvature at the interface with the conductor. Fluid offtake is achieved using steel spools, which connect between the BRA and flowline head or manifold. The decision to use a taper joint in preference to a flex joint is taken to simplify the connection to the flowline, which is then largely static.

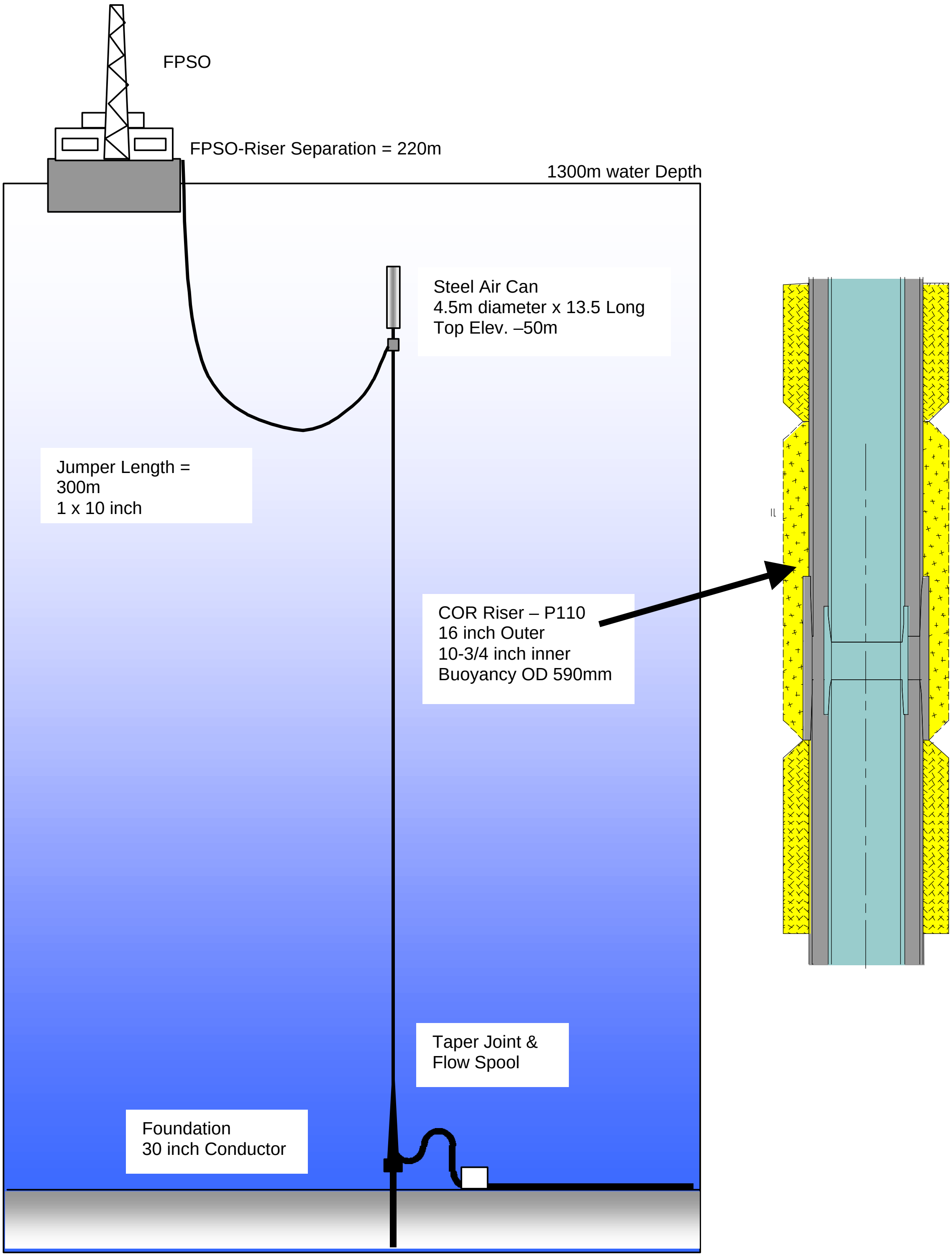


Figure 4 – West African COR Schematic with Bundle Arrangement

An air can buoyancy module is connected to the upper end of the riser. This supplements the syntactic buoyancy used along the riser length and ensures that the riser can accommodate the wave and current motions and also move sympathetically with the vessel. The air can is connected to the riser using a simple articulation/swivel, which is **not** fluid or pressure containing.

Flexible pipe jumpers are used to connect between goosenecks, located immediately below the air can, and the vessel. A procedure has been developed to allow the jumpers to be quickly installed from the drilling vessel eliminating the need to mobilise a second installation vessel. The critical subsea gooseneck connection can be made in the dry simplifying the procedure.

The COR described has a single 10 inch main flow path however, multiple flow paths are feasible such as 6 x 6 x 2 inches. Additionally, the concept can be further simplified for export and injection lines and for production service where insulation is not important. In these cases the outer 16 inch casing can be eliminated greatly reducing the riser weight, complexity and cost. For a large field development multiple CORs are required to meet production and process requirements. The CORs are located along the side of the FPSO in the case of a spread-moored vessel or radially around the turret in the case of a turret moored vessel. The positioning and spacing of the risers is selected to ensure that interference between risers is prevented.

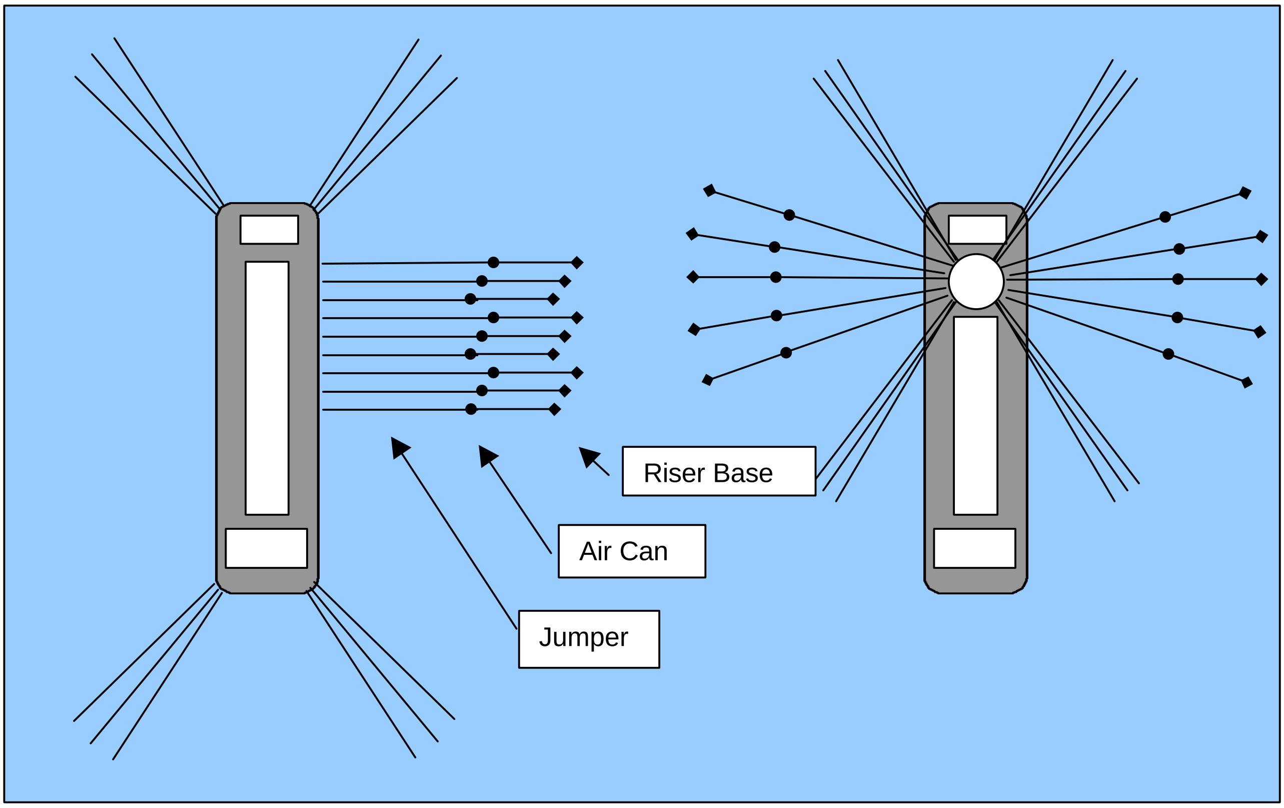


Figure 5 – Typical COR and Vessel Field Layouts

Preliminary Sizing and Storm Analysis

Preliminary sizing and analysis has been developed for an example application located offshore West Africa. The field development requires 6 off 10 inch production and 6 off 2 inch diameter services lines in 1300m water depth. The vessel is a spread moored FPSO, with the riser porch located on the side of the vessel, see Figure 5. Each COR consists of a 16inch x 10inch pipe in pipe riser bundle with the annulus used for gas lift service line.

The lines are sized according to internal pressure and external pressure, Table 1. Sizing is carried out for a range of scenarios including installation, pressure test and in-place operation. This is based on the nominal diameter of each peripheral line and takes into account internal and external pressure gradients.

	Outer Casing	Inner Product Line
OD (mm)	406.4 (16 “)	273.1 (10 ¾”)
Wall Thickness (mm)	11.5	12.5
Design Fluid	Gas (Air)	Oil
Fluid Density (kg/m³)	250	800
Operating Pressure (psi)	3000	5000
Pipe Material	P110	P110

Table 1 – Line Sizing Summary

Buoyancy requirements are calculated by determining the required in-water weight of the riser during installation and in-place conditions and thermal insulation requirements. A balance must be achieved between the aircan and syntactic buoyancy to achieve the correct technical and commercial solution. The upper air can is 4.5m diameter and 13.5m long and cylindrical in section providing approximately 150Te upthrust and giving a base tension in the production mode of 100Te.

Storm analysis using typical West Africa environmental criteria is performed allowing optimisation of the jumper lengths and vessel separation, air can submerged depth and riser tensions. Figure 4 shows the system arrangement, with a vessel separation of 220m and 300m long flexible jumpers. Maximum stress occurs in the lower stress joint. Figure 6 shows the displaced riser system under extreme current loading and maximum near and far vessel offsets. The maximum and minimum predicted separations between the vessel and air can are 240m and 40m respectively for far and near offset conditions. Maximum jumper tensions at the tower end for the 10 inch and 3 inch jumpers are 250kN and 110 kN respectively.

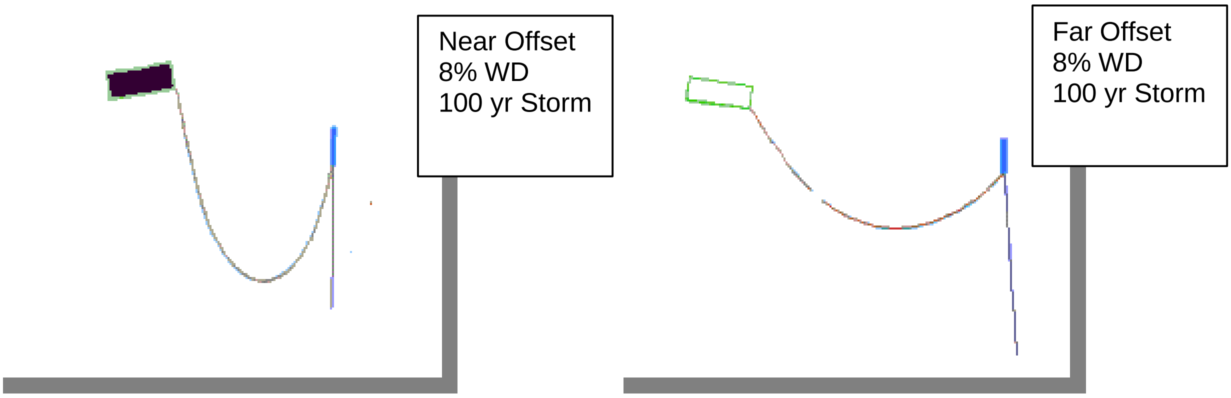


Figure 6 – Near and Far Offsets 100yr Storm Condition

Preliminary Costing

Preliminary costing for a field development requiring 6 off CORs as described above in a 1300m water depth West Africa. The results are compared with a conventional beach fabricated hybrid riser. The main conclusions of the study are summarised in Table 2, which concludes that the COR system is over 30% cheaper than the conventional hybrid. The main areas of cost saving are syntactic buoyancy, fabrication/assembly, installation and site set-up.

	COR	Second Generation Hybrid
Total Steel Weight	1439Te	1200Te
Syntactic Buoyancy	441m3	1320m3
Air Can Upthrust	656Te	331Te
Installation Cost	£1.8m*	£5.3m
Total Installed Cost	£16.2m	£25.3m

*based on 48hrs per riser at $250,000/day

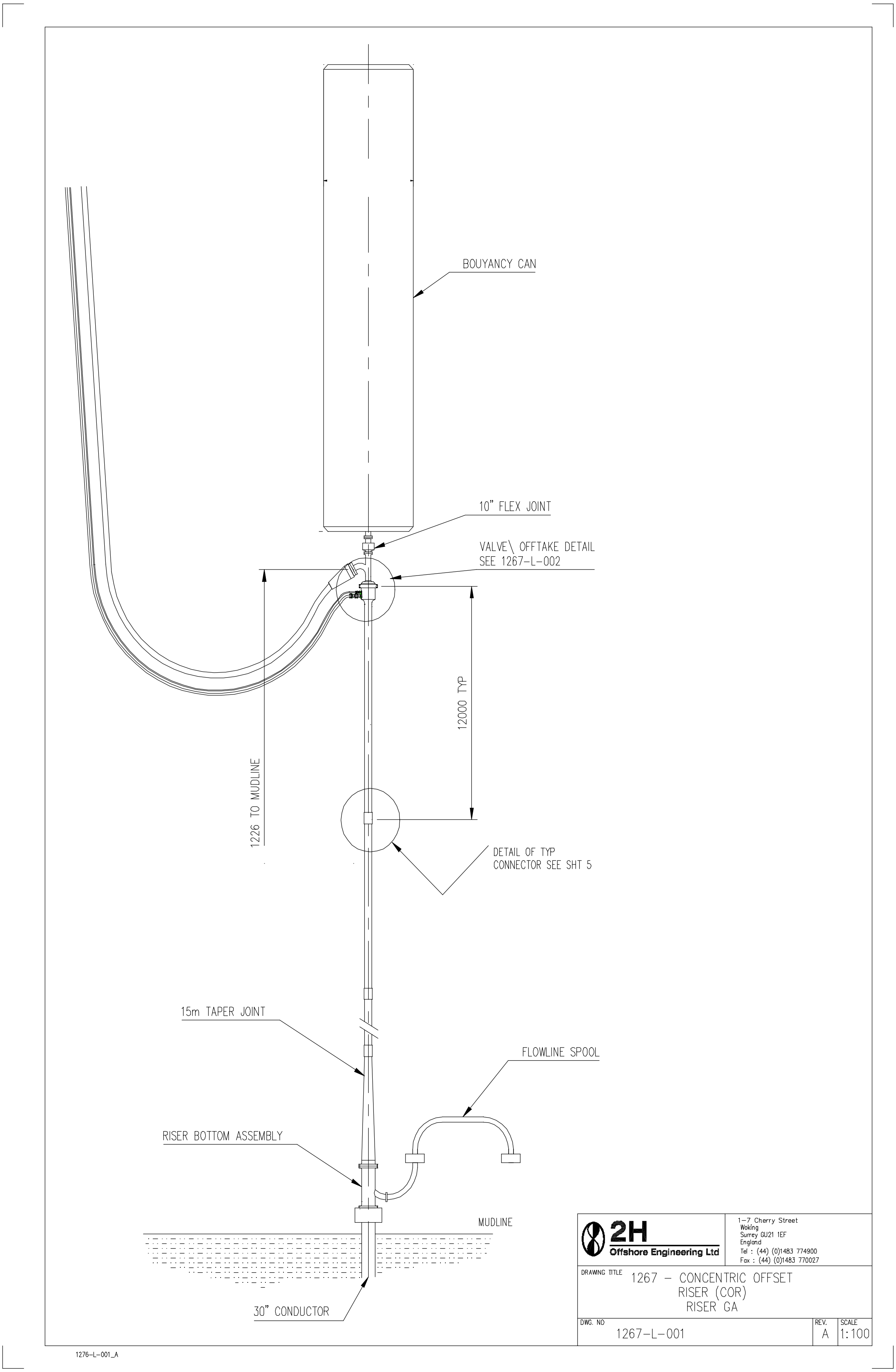
Table 2 – Preliminary Cost Comparison

Conclusion

The COR is a hybrid riser arrangement for medium and deepwater applications. The concept is suited to both mild and harsh environments and its key feature is the ability to be installed from a mobile drilling unit. The COR is cost effective and in addition has the following features:

- No onshore fabrication requirement
- Low risk installation from MODU (compared to tow out)
- Standard rig procedures and tooling
- Individual risers provide distributed and reduced development risk
- Ability to add or replace risers through field life
- Proven and readily available hardware
- High thermal efficiency
- Active heating and riser base gas lift
- Dual barrier isolation for production flow path
- Ability to accommodate a range of line sizes and pressures
- Chemical injection or dedicated heating lines readily incorporated
- Cost effective with low CAPEX

In conclusion the COR provides an alternative riser solution to be considered against steel catenary, flexible and conventional hybrid riser systems when configuring the arrangement of deep water field developments. The COR is particularly attractive for developments requiring a high level of thermal insulation such that simple catenary risers are often not feasible.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