Bottom Weighted Riser – A Novel Design for Re-location and Disconnection

Frank Lim and John McGrail
2H Offshore Engineering Ltd.
Woking, Surrey, United Kingdom

ABSTRACT

Flexible pipe risers have limitations in deep water depths and pressure/collapse ratings compared to rigid steel pipe risers. Use of steel pipe systems has therefore attracted the interest of deepwater riser designers, not least to dissociate from the monopoly of the limited few flexible pipe suppliers in the world. Examples are the steel catenary riser and freestanding hybrid riser systems.

An all-steel pipe Bottom Weighted Riser (BWR) system and its components are described in this paper. It is a novel approach ideally suited for short to medium term usage for production, injection and export of hydrocarbons in a large range of riser diameters. Its key advantage is the ability to relocate in a re-usable form, and disconnect from the production vessel in severe weather conditions.

The feasibility of the BWR is shown in terms of the operating envelopes when connected to a floating production vessel.

KEY WORDS: Deepwater; Steel Riser; Disconnection; Relocation

INTRODUCTION

The use of a generic re-locatable production riser system for use with a disconnectable Floating Production Storage and Offloading (FPSO) vessel or Floating Production Unit (FPU) in a range of shallow to medium water depths has been the topic of a number of offshore projects in the South China Sea.

Such a system is attractive when early production is desirable whilst the reservoir condition remains uncertain, in an area where typhoon is almost a predictable event.

A flexible riser system conventionally adopted for this range of water depths is deemed to be less than ideal from an economic standpoint. It is also disadvantaged by typically long delivery schedule, susceptibility to damage during retrieval and re-installation, and inadaptability to different water depths.

The Bottom Weighted Riser (BWR) concept was first mooted more than a decade ago (Huang and Hatton, 1995). It was originally intended for large diameter risers operating in deep and harsh environments. Its design and configuration are now recognised to possess features that lend itself to be a re-locatable riser system, for use with a mobile production vessel operating in a seasonally harsh environment.

The system is engineered to use proven oilfield technology, and utilise components that are readily available from a number of equipment suppliers to ensure that procurement and manufacturing schedules are kept to a minimum. The system is also designed to be readily retrievable and easily adaptable to allow it to be moved with the production vessel to a new location following the completion of a short to medium term production program and consequently be re-used on a number of fields with different water depths.

RISER SYSTEM DESCRIPTION

The generic re-locatable production system consists of a BWR used in combination with an integrated tree assembly. The system is designed as a production system suitable for a single well tie-back from a subsea well to a disconnectable floating production system (FPSO or FPU), dynamically positioned or otherwise moored such that the riser does not restrain the vessel movement. The primary application of this technology is for use with an Early Production System (EPS) which may require a single relatively small diameter production riser system for use on a short term basis without the requirement for a dedicated subsea tree.

A description of the system is given in the sub-sections below.

Connected Riser Configuration

The basic configuration of the system when in a connected configuration is shown in Fig. 1.

The system consists of two sections of rigid pipe, connected between the wellhead or production manifold and riser porch on the FPSO. At the connection points between the tree and the two pipe sections are swivel assemblies which allow the riser to articulate without overstressing the rigid pipe. These articulations allow the riser system to accommodate the vessel motions and offsets, environmental loading, and 360 degree weather vaning of the vessel.

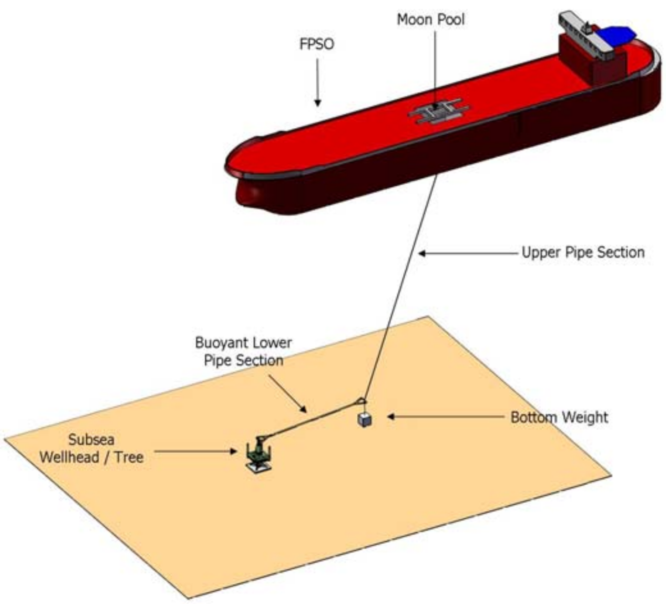

Fig. 1 – Generic Re-locatable Production Riser System

At the connection between the two rigid pipe sections, a weighted structure is located. The mass of this structure provides tension in the upper section of riser pipe, which is necessary to ensure stability of the riser system. The mass used can be tailored to suit the specific parameters for a particular field development (i.e. water depth and environmental loading).

The relative lengths of the two pipe sections can be adjusted to suit the water depth and expected vessel and environmental loading at the specific field location.

The rigid pipe sections are made up of short (typically 12m) steel pipe joints made up by threads, flanges or other mechanical means. This allows for easy length adjustments for different operating conditions, and the joints can be re-used after routine refurbishment. Procedures have been developed to install the riser system from a drill rig or well intervention vessel equipped with a pipe handling derrick before handing over to the host vessel.

At the vessel connection a short section of flexible hose is used, with the system supported using chains connected to a winch system on the vessel deck. The flexible hose contains a breakaway coupling with a valve to allow the riser to be disconnected from the vessel and contain the well fluids. A view of a proposed arrangement of the riser interface at the FPSO is shown in Fig. 2.

Although Fig. 2 shows a FPSO with a moonpool, the riser can also be attached to a vessel without a moonpool but a dedicated porch will have to be built to support it.

The compliance of the system allows for offsets and rotations of the FPSO to be accommodated and allowable vessel offset limits can be defined based on the selected pipe section lengths and expected local environmental loading cases.

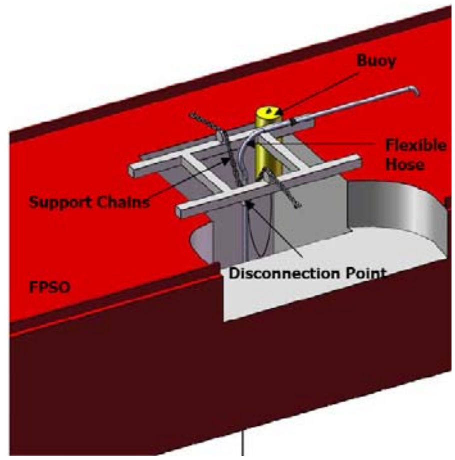

Fig. 3 – Riser Interface Arrangement at Vessel

Disconnected Configuration

In the event of a severe storm (i.e. typhoon), the production system can be disconnected from the FPSO to prevent damage to the equipment, and enable the vessel to leave the field location before the storm occurs. This capability also enables a dynamically positioned (D.P.) vessel to be used as the system can be easily disconnected in the event of a loss of station-keeping control.

During the disconnection process, the flexible hose at the vessel is released via the breakaway coupling, and the riser lowered by paying out the support chains/wire until the bottom weighted structure comes into contact with the seabed. This structure is designed with a mud-mat and interface skirt to allow it to be safely landed on the seabed, and to ensure that it is firmly located. As the riser is lowered, the buoy located near to the top of the riser enters the water and supports the weight of the upper section of the riser. Once successfully landed on the seabed, the winch line can be removed from the riser and the vessel can depart. A drone buoy is also be deployed to assist with locating and recovering the riser system during retrieval. A view of the disconnected riser arrangement is shown in Fig. 3.

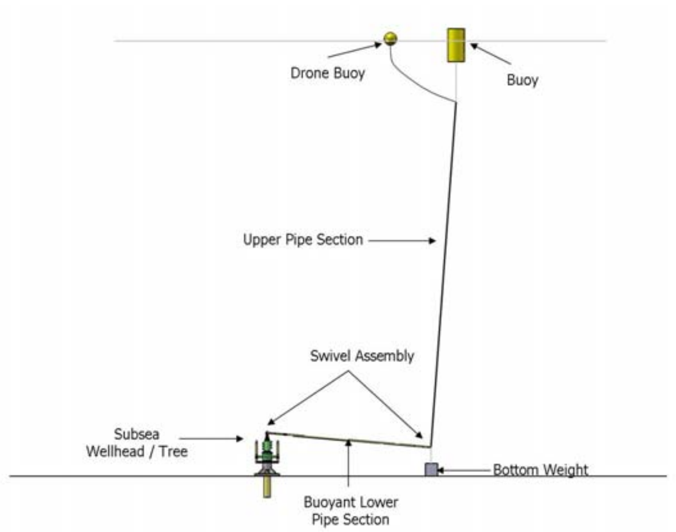

Fig. 3 – Disconnected Configuration

While in the disconnected configuration, the buoy at the top of the riser supports the weight of the upper section of the riser pipe, and prevents this section from falling onto the seabed. This method ensures that the only point of contact of the riser with the seabed is through the bottom weight structure, thus providing stability to the disconnected riser system and minimising the risk of damage to potentially sensitive parts of riser system if control can not be maintained during the disconnect process.

TREE AND WELLHEAD SYSTEM

The riser can be combined with a simplified tree/wellhead arrangement to provide a complete well to vessel tie-back production system; it can also be connected to a manifold in the case of a multi-well development.

The tree shall be able to interface with a subsea wellhead, equipped with a control/shutdown valve, and can facilitate well workover in a manner similar to a conventional tree.

Once the well is completed, the production riser system can be connected to the top of the tree. A controls umbilical can be integrated with the riser system to provide direct well control from the production vessel.

Following completion of the production program, the riser is removed and plugs reinserted into the well as part of a conventional well intervention procedure. The well can then be abandoned, thus allowing the tree system to be removed and re-used on future production wells.

SYSTEM BENEFITS

The generic re-locatable production system is designed for use with a minimal facility floating production system with a primary application for use with an EPS. When used in this application the system can offer the following benefits:

Adaptable 'Modular' Design
- Allows simple adjustment of equipment for use with range of vessels, water depths and environments
- Can accommodate a wide range of design parameter variations
- Potential to re-locate and re-use system as part of a mobile EPS

Simplified/Re-useable Tree System
- Connected to subsea wellhead
- Similar functionality to conventional tree
- Facilitates simple connection of riser system
- Possible to retrieve and re-use on future wells

Controlled disconnection
- Allows use with wide range of D.P. vessels
- Enables system to be abandoned in extreme storm events (i.e. Typhoon)
- Simple disconnection process minimises risk of damage due to contact with seabed and enables straightforward re-connection

Simple installation
- Small, lightweight equipment enables low cost installation/construction vessels to be used
- Potential to install equipment using MODU or intervention vessel
- Retrieved as reverse of deployment process

Cost/schedule effective, proven equipment
- System designed using proven field equipment
- Long lead time equipment avoided

ANALYSIS CASE STUDY

A case study is carried out to determine the system performance characteristics. The BWR model is shown in Fig. 4 for an assumed water depth of 1,700m.

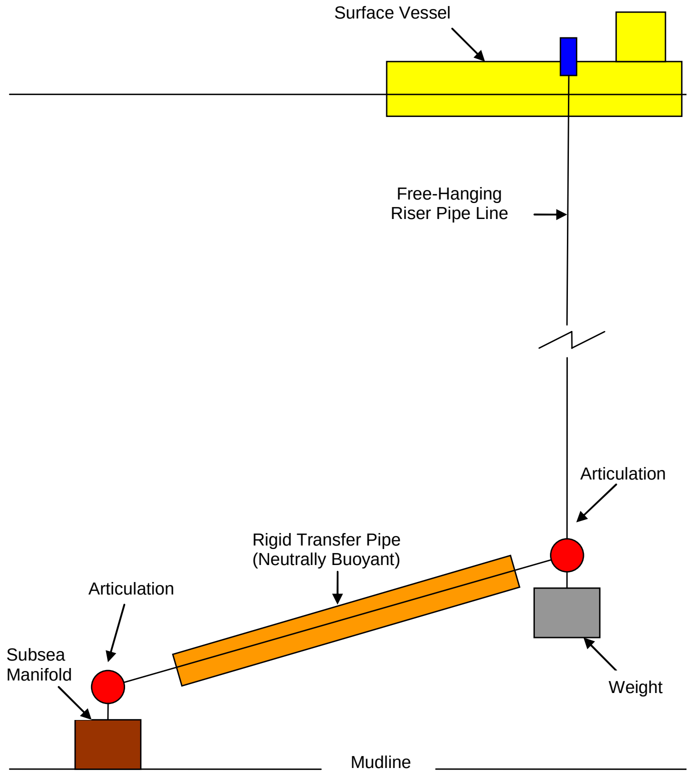

Fig. 4 – BWR Analytical Model

The riser pipe design data considered in the analysis are summarised in Table 1.

Table 1 – Pipe Design Data

Parameter	Value
Pipe OD (inch)	13-3/8
Pipe ID (inch)	11-7/8
Wall Thickness (mm)	19.05
Operating Design Pressure (psi at seabed)	4,000

The lower pipe section, or the rigid transfer pipe (RTP), is assumed to be 100m long and neutrally buoyant which will be achieved in practice through the use of syntactic buoyancy modules. No buoyancy is applied to the main vertical riser length. The material yield strength is 95ksi for the riser pipe.

The bottom weight is assumed to be 150 tonnes, and the riser system is filled with sea water.

The maximum stress levels defined in Table 2 must be satisfied to confirm acceptance of the riser design and configuration (API, 1998).

Table 2 – Allowable Stresses

Design Case	Allowable Ratio to Yield Stress
Operating (Connected)	0.67
Extreme (Stand by)	0.80
Survival (Disconnected)	1.00

The minimum tension allowed along the RTP is 0 tonne to prevent buckling from compression; whilst the maximum allowable tension is assumed to be 50 tonnes to avoid excess loading on the subsea facility.

Reference positions of the surface vessel and subsea manifold from which the analysis is conducted is shown in Fig. 5.

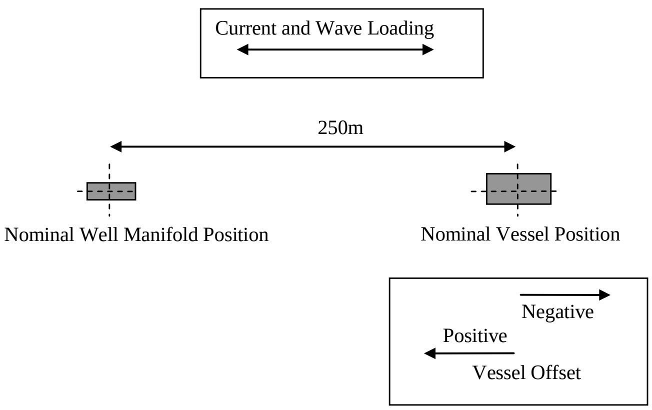

Fig. 5 – Vessel Offset Reference

For this case study, a typically severe environment for which the BWR will remain connected is assumed, as the production vessel can be disconnected to avoid the storm. The wave and current considered are given in Table 3.

Table 3 – Environmental Conditions

Design Case	Value
Regular wave height	5.5m
Wave periods	7-16 s
Surface Current Velocity	1 m/s
Current Profile	Linear to zero at seabed

Static Operating Envelope

Static analysis of the connected riser system is conducted at increasing vessel offsets to determine the operating limits in terms of minimum and maximum tension along the RTP and the maximum von Mises stress in the main vertical pipe string. Different nominal inclinations of the RTP, with 20m vertical height difference between the articulations, are also considered.

Current loading is applied in both directions in addition to vessel offset.

Fig. 6 shows the results of the static analysis for the main vertical riser pipe string (stresses at top and bottom) and the RTP (load at subsea well).

Fig. 7 shows the actual tension loads in the RTP.

The maximum survival vessel offset envelope extends from -60m to 150m, governed entirely by the RTP loading. The stresses in the main riser section are well within the acceptable limit.

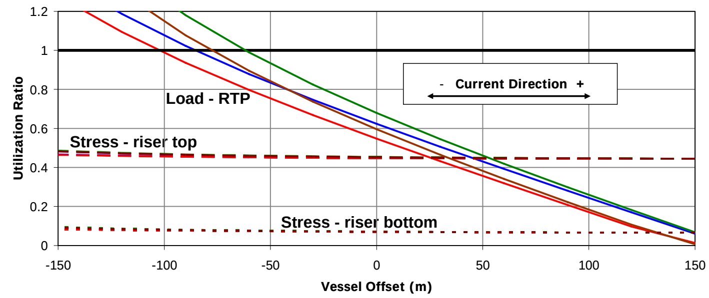

Fig. 6 – Riser Stresses and RTP Load Utilisations

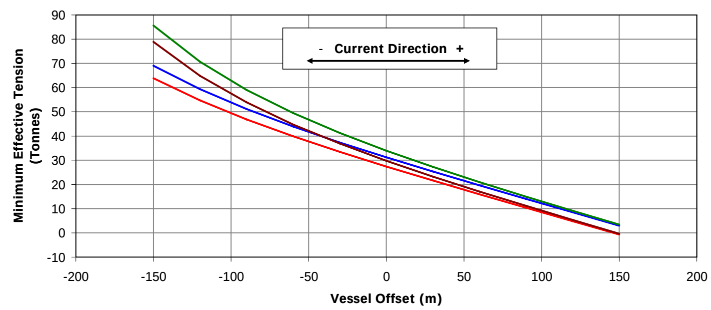

Fig. 7 – Tension Loads in RTP

Dynamic Analysis

Head sea regular wave analysis is carried out for the maximum wave height considering a range of wave periods as given in Table 3 to determine the dynamic amplification of the BWR response.

The analysis is conducted for the following conservative conditions:

- Negative vessel offset of 55m
- Positive vessel offset of 140m
- Current in negative direction
- High RTP inclination

Fig. 8 shows the dynamic stress amplitude in the main vertical riser section under the different wave loading condition. It can be seen that the maximum stresses are still well within the allowable limit.

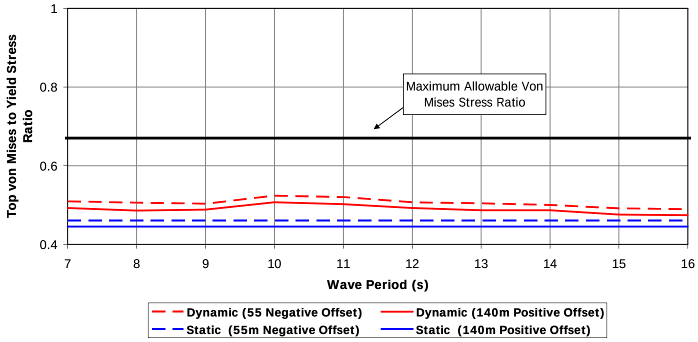

Fig. 8 - Dynamic Stresses at Top of Main Riser

Fig. 9 shows the dynamic loads in the RTP under the same wave loading conditions. It can be seen that the maximum load now exceeds the maximum allowable of 50 tonnes. This effectively means that the load capacity of the subsea facility to which the riser is attached has to be strengthened to more than 50 tonnes (e.g. 60 tonnes), or the vessel negative offset has to be kept to less than 55m (e.g. 25 m); however both measures are considered to be achievable without compromising significantly the feasibility of the concept.

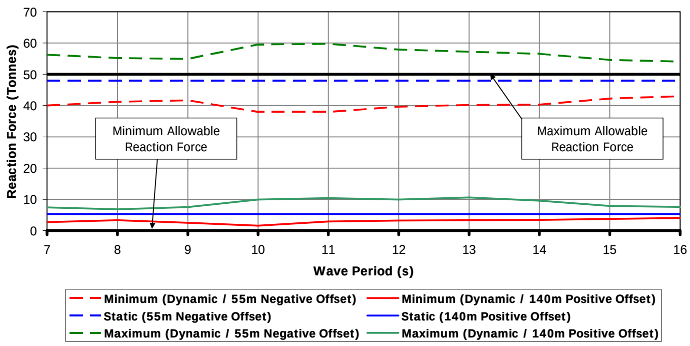

Fig. 9 - Dynamic Loads in RTP

DISCUSSIONS AND CONCLUSIONS

A novel riser design is presented in this paper. It has many operational advantages particularly when used in conjunction with deepwater early production systems where reservoir potential is difficult to establish before hand. A re-locatable and re-usable system thus mitigates the capital investment risks inherit in many other less adaptable riser systems.

The BWR system is described in outline in this paper and some preliminary analysis is conducted in a 1700m water depth case study to assess its response in a typical operating environment. Both static and dynamic analyses help to determine a vessel offset operating window which is considered reasonably achievable for this water depth and environment. This exercise also identifies areas where technical improvements can be made.

The work is by no means conclusive. As with all new design, further optimisation and work will be required to qualify all the processes needed to engineer, manufacture and install it when a potential application is found.

REFERENCES

Huang S and Hatton S (1996) – "Rigid Bottom Weighted Large Diameter Risers – Concept, Analysis and Design", *Technologies for Deep Hostile Seas*, Aberdeen, June 1996.

API (1998) – "Recommended Practice for Design of Risers for Floating Production Systems and TLPs", *API-RP-2RD*, 1st Edition, June 1998.