Proceedings of OMAE04
23rd International Conference on Offshore Mechanics and Arctic Engineering
June 20-25, 2004, Vancouver, British Columbia, Canada

OMAE2004-51107

FREE STANDING RISERS FOR EXTENDED ULTRA DEEPWATER TESTS

Roberto Rodrigues
Petrobras,
Rio de Janeiro, Brazil
rrodrigues@petrobras.com.br

Renato Brandão Mansano
Petrobras,
Vitoria,
Brazil
mansano@petrobras.com.br

Cesar Del Lucchese Junior
Petrobras,
Rio de Janeiro, Brazil
lucchese@petrobras.com.br

Francisco Edward Roveri
Petrobras,
Rio de Janeiro, Brazil
roveri@cenpes.petrobras.com.br

Mauricio Barbosa
FMC,
Rio de Janeiro, Brazil
mauricio.barbosa@FMCTI.com

keywords: Free Standing Riser, Extended Well Test, Heavy Oil, Drill Pipe Riser.

ABSTRACT

Petrobras presently has a significant part of its reserves located in deep and ultra deep waters. To produce this oil economically Petrobras created the well-known research program PROCAP 3000. This paper presents one project being developed under such program, the Extended Test for Deep and Ultra Deepwater.

Petrobras has been using early production system and extended test for some years. Since 1998 Petrobras has been testing wells (extended test) with the Seillean FPSO (Floating Production Storage and Offloading). One challenge in this concept is the use of a dynamically positioned (DP) tanker with a rig and a threaded pipe (drill pipe riser) to produce and test wells in deep and ultra deep water. Another challenge is the frequency of changes of location of the FPSO, since the objective of an extended test is to produce for periods of three to twelve months. Therefore the system must have enough flexibility to make the installation and recovery easier. The proposed Itinerant Production and Evaluation Pilot System concept is easy to deploy and demobilize for extended trials. Under certain circumstances, it may even work as an Early Production System. It consists of a free-standing drill pipe riser system connected directly to the Christmas tree at the sea bed and to an air can at the top, which is located around 100 metes below sea surface. A flexible jumper links the air can to an FPSO. To improve production flow rate, an electric submersible pump (ESP) is installed at either downhole or at the top of Christmas tree.

The main purpose of the extended test is to collect data, enhancing knowledge of the reservoir through more reliable information. Although attempting to minimize implementation costs, it may present a negative Net Present Value for shorter periods, especially if the value of the information obtained is not included in the calculation. Most of these ideas and concepts are still under study, and some of them will certainly be reassessed, reviewed and possibly improved. Petrobras has been working with some partner companies to develop the conceptual study and assess the system feasibility. This paper presents the main issues involved in this project. The objective of this paper is to summarize a preliminary conceptual design to conduct a feasibility analysis for Petrobras' Free Standing Drill Pipe Riser (FSDPR).

INTRODUCTION

An original completion riser, the so-called Drill Pipe Riser (DPR) was developed by Petrobras in 1999, which sharply decreases both subsea tree and tubing hanger running time. In addition, the cost of this system, including maintenance costs, is very low compared with conventional completion riser systems. The system is basically composed of drill pipes, control pod and control umbilical, which provides annulus access and pod Electro hydraulic multiplexed control. An existing type of drill pipe has been selected in order to minimize costs while improving reliability.

This system has been modified to run a specially designed subsea tree from a dynamically positioned FPSO (SEILLEAN) to allow production of two piggy-back wells in water depths up to 2000 m (6,500’). Although the design was done to work with two piggy-back wells, this configuration has not been used so far due to a limitation of the SEILLEAN processing capacity.

Petrobras has been successfully operating with the Drill Pipe Riser (DPR) since the system was developed to reduce the time to first oil production in Roncador field. On that occasion a subsea oil well was produced at 1,853 meters water depth breaking the world record.

DPR is a production and completion system basically consisting of a special subsea production adapter base and a conventional (not horizontal tree), riser string and a dynamically positioned FPSO (Seillean). Despite the success of the Petrobras system, the high rates of this dedicated and special vessel have always been concern.

DRILL PIPE RISER HISTORY

The original scope of work of the Drill Pipe Riser (DPR) project was only the design and development of an ultra deepwater completion/workover riser aiming mainly at reducing running time while decreasing acquisition costs. This project was developed through an EPC contract awarded, in July 1997, to KOS, responsible for the design and manufacture of two sets of DPRs.

In March 1998, when almost all DPR components were under manufacturing, a decision was made: to hire the SEILLEAN in order to reduce the time to first oil in Roncador field to only 9 months. This would affect favorably on the project economics by enabling income to be generated at a much earlier stage of the development. In addition, valuable reservoir information could be attained in advance.

The SEILLEAN is a dynamically positioned floating production, storage and offloading vessel (FPSO) which operated in the North Sea, at 150m (492’) for BP from 1991 to 1996. It is a completely self contained vessel, capable of handling up to 20,000 barrels per day and storing 310,000 barrels of oil. Oil production was through a heave compensated rigid riser deployed from the ship’s moon pool. The rigid riser consisted of 6 5/8”drill pipes with control umbilical attached, similarly to the Drill Pipe Riser. The riser was mated with the previously installed subsea tree by means of the Emergency Disconnection Package (EDP). During production, the ship vaned around the riser which was equipped with flexible joints to allow the vessel positional latitude. When the oil tanks were full, the ship unlatched from the well and transported the oil to its destination, no shuttle tank being required.

At the time this project was known as SWOPS (Single Well Oil Production System) in spite of producing from two subsea wells in piggy-back. The SWOPS was designed for operation in shallow water depths up to 200m.

Upgrading the SWOPS to work in Brazil at water depths up to 2,000 m (6,500’), ten times greater than before, in 9 months time, was a challenge whose critical path was soon identified as the riser design and fabrication.

In order to overcome this problem, one of the two Drill Pipe Riser sets has been adapted and made compatible with the SEILLEAN. This project was then renamed Early Production Riser (EPR).

Unlike the SWOPS where the subsea tree had to be previously installed by a completion unit, the EPR should be designed to run the subsea tree from the ship’s moon pool as well. An ultra deepwater subsea tree and a special production adapter base were then designed to meet the ship’s characteristics.

EARLY PRODUCTION RISER SYSTEM

The Drill Pipe Riser has been converted into the Early Production Riser (figure 1), which comprises a riser and a control system. The complete system shall be installed and operated from the FPSO SEILLEAN and shall interface with the subsea equipment, which is mounted on a pre-installed wellhead.

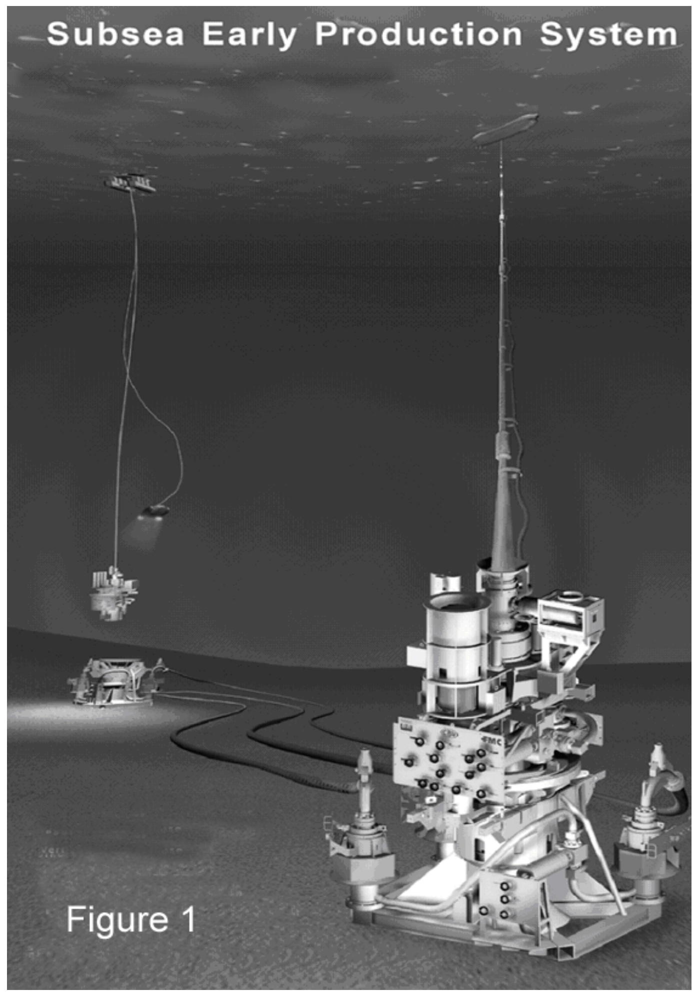

Figure 1

The EPR allows the initial gathering of reservoir fluids from the connected well, the remote well shall be connected at a later date. The wells will space at approximately 3 km distance and fluids from the remote well will be transported to the connected well by means of a flexible flowline. Thereafter, the two streams flow to the FPSO via the riser system.

The specially designed subsea tree, which is described in detail below, consists of a main valve block which performs the functions of a manifold, subsea tree and workover BOP. This assembly is secured to a universal guide base. An emergency disconnect package, EDP, is landed on the top of the subsea tree, which in turn interfaces with the lower uniflex joint.

The riser system extends from the top of the EDP, where a flex joint is positioned, to the tensioning arrangement on the FPSO. Support of the riser string is effected from the tensioning system on the vessel.

The interface is performed via the slew ring adapter plate on the tensioning system. On the top of the adapter plate is mounted a swivel which supports the surface flow tree and accommodates the relative rotational movements between the vessel and the flow tree.

A hydraulic quick connector shall be supplied to interface to the top of the surface flow tree and assist with the installation of the riser string and wireline operations. Flow of the reservoir fluids is controlled by the surface flow tree, from where they are discharged to the processing equipment via a flexible hose. Below the slew ring adapter plate are mounted the flex joint and strengthened top joint.

These units accommodate the loads induced between the riser string and the vessel. Relative rotational motion between the riser string and the vessel are accommodated by a slew ring assembly in the adapter plate

The EDP houses the Subsea Control Module. Signals from the control system are transmitted through the control umbilical, which is clamped to the riser string, to the SCM and further to the subsea equipment.

The control system is designed to control both the connected and remote wells and interface to the necessary control systems of the FPSO. An acoustic riser angle monitoring system is also mounted on the EDP.

The EPR has been designed for both production and workover mode of operation. Therefore, several additional equipment and characteristics had to be incorporated into the DPR to make it compatible with the SEILLEAN.

The use of a dedicated subsea tree, specially designed for this application, made possible the optimization of the control system design. As a result, the control pod could be mounted on the EDP, thus dispensing with the use of the transition joint.

The EDP was equipped with a safety system that automatically initiates the emergency shutdown sequence in case of loss of both electrical and hydraulic power. This simulates umbilical loss.

Also, mimics for production and workover mode have been developed and the HPU was permanently connected to the Ships Bridge where a second remote panel was installed.

Specifically, the upper riser assembly was specially designed to fit in the ship’s moon pool and withstand the loads from the riser. In order to maximize the fatigue life, an upper and a lower flexjoint were incorporated in the riser.

Drill pipes external spray aluminum coating has been deemed necessary to avoid corrosion.

The SEILLEAN derrick has been upgraded to allow pipe stands to be racked back, thus minimizing running time and damage to external coating.

THE SUBSEA EQUIPMENT

The early production system utilizes subsea equipment comprised by the following parts resident on the seabed: two subsea Trees, six Vertical Connection Modules and an Emergency Disconnect Package with Multiplex Controls.

Considering the Seillean process plant capacity (20.000 bbl/day) and the potential production expected for each vertical well in Roncador field, the piggyback fashion was chosen.

The subsea equipment includes the satellite Tree and a master tree, which will commingle the production of the satellite tree in a piggyback fashion. Both trees have a Production Adapter Base (PAB or Tubing Head). The flowlines and control umbilical from the piggyback PAB are connected to the master tree’s PAB via Vertical Connection Modules (VCM). There are modules for both ends of the production flowline, annulus flowline and interconnection satellite umbilical. The flowlines are laid independently due to the loads on the pipelay vessel related to flowline weight.

The master tree is supplied with a subsea choke for control of the produced fluids from satellite tree. The production from the piggyback tree and the master tree are commingled in the master tree before flowing up through the Emergency Disconnect Package (EDP) to the Early Production Riser (EPR) and to the FPSO. There is a chemical injection port in between the master valve and the shear swab of the master tree. Hydrates can be prevented or broken by injecting glycol or ethanol through the 1” line of the umbilical.

The EDP consists of a high angle release hydraulic connector and the 40 function subsea multiplex control module (SCM) incorporating an emergency shut down system enabling a quick release in case of a drive off of the FPSO Seillean. Foot valves installed at the end of the annular and production bores in EDP, associated with a crossover valve, provide environment protection, drill pipe and HCR hose testing and circulation capabilities.

In order to achieve this emergency shut down sequence, the master tree had its swab valve modified to incorporate wireshear capabilities. The gate is capable to shear 1 ½” coiled tubing, 0,23” electric cable and slick line.

The SCM provides hydraulic power to the valve and choke actuators on both trees as well as the electric power for the downhole and tree sensors. The SCM is connected to the FPSO by an umbilical that incorporates the 9 hydraulic lines, 4 electric cables and a 1” annulus line.

EXTENDED WELL TESTS IN OFFSHORE HEAVY OIL RESERVOIRS IN PETROBRAS

Extended well tests (EWTs) in offshore fields are the best way to reduce the uncertainties and mitigate the risks before approving the huge investments associated to the definitive production system. Petrobras has a long tradition in operating Early Production Systems (EPS) or perform EWTs in its deepwater fields – Marlim, Marlim Sul, Marlim Leste, Roncador, Barracuda, Caratinga, among others.

From the reservoir engineering standpoint, the early production allows not only to prove reserves through material balance, but mainly to gain knowledge about the reservoir internal characterization, which is critical for the success of waterflooding projects.

For offshore heavy oil fields, however, the main objective of an EWT is to figure out the whole production process. The use of the Value of Information (VOI) methodology (refs. 2) is fundamental to allow the approval of an EWT or an EPS in offshore heavy oil fields, since they may not pay out considering just the EWT cash flow. The VOI can justify the EWT, considering the optimization it would provide for the definitive system.

A good example of an EWT in offshore heavy oil was the one performed in the Captain Field in 1993 (ref. 2), which set the basis for the economic development of the field, discovered sixteen years before. Many issues related to the production process were investigated, such as: vertical permeability, oil-water relative permeabilities, water coning behavior, performance of the long horizontal length well, artificial lift system and processing plant.

The next two topics describe Extended Well Tests performed by Petrobras in offshore heavy oil areas.

EWT IN THE MARLIM SUL FIELD.

The Marlim Sul Field is located directly south of Marlim Field, comprising an area of more than 600 km2, under water depths ranging from 1,000 to 2,600 m. The field was discovered in 1987 by an exploratory well which found 40 meters of the Oligocene / Miocene age reservoir saturated with 25^{o} API oil. The oil quality reaches 28^{o} API at the northern part of the field and decreases as water depth increases. As for the neighboring Marlim Field, the reservoir rock properties are excellent. However, the stratigraphy is more complex, which makes the prediction and identification of the reservoir compartments important but difficult tasks. To investigate the reservoir performance and anticipate production problems, three Extended Well Tests were implemented in the field. In this topic we will discuss the one that dealt with heavy and viscous oil.

In August, 1997, the subsea completion world-record at the time, well MLS-3B, drilled at water depth of 1,709 m, was connected to a Floating Production Storage and Offloading (FPSO, figure 2), moored at water depth of 1,300m, through 3 km of subsea flowline .

Figure 2

The vertical well perforation was 40 meters in length and the well was gravel-packed. The well resulted damaged, but, as it was not essential for the EWT, no attempts were made to remove it. MLS-3B produced a 16.5^{o} API oil, with 3,000 cP at 20^{o} C, during one year, being shut in August 1998. In the beginning, the well produced through natural flow, having reached almost 1,000 m3/d (6,300 bpd). After one month, the gas lift was started and the well rate jumped to 1,500 m3/d (9,500 bpd). Later, it was necessary to restrict the well rate due to the increase in the well GOR. During the production process, the oil temperature at the FPSO varied from 15^{o} C to 10^{o} C. The wax appearance temperature was around 17 ^{o} C, but no paraffin deposition or other flow assurance problems were reported, even after shutdowns. Important information regarding the low temperature flow in the subsea pipeline and riser, as well as the gas-lift performance, were gathered and allowed the calibration of the multiphase flow correlations.

At last, it is worth to mention that new subsea technology developed by the Petrobras PROCAP was successfully tested during the EWT of MLS-3B, particularly the FPSO mooring system and the 6” riser performance, allowing the optimization of the production installations for fields located in deeper waters.

The results of the EWT were extremely useful for the review of the development concept of deep water portions of the Marlim Sul field.

EWT IN JUBARTE FIELD.

Jubarte is the most recent oil field discovered by Petrobras in the Campos Basin, which took place in January 2001. The field is located about 70 km offshore the Espírito Santo State, under a water depth of 1,300 m. The main reservoir is a non-consolidated Cretaceous turbidite, containing a 17^{o} API oil, with reserves, only in the Jubarte field, estimated in 600 million barrels.

The discovery well, ESS-100, was tested without sand contention mechanism and presented a productivity index insufficient to guarantee commercial rates in the deepwater environment.

A study based on the Value of Information supported the decision of drilling a horizontal appraisal well. In February 2002, the ESS-110HP well was drilled, preceded by a pilot well. The horizontal length was 1,070 m, completed with an openhole gravel pack. The final result was amazing, with a well productivity index 13 times higher than the vertical well PI. An EWT was proposed and approved, with the VOI approach, with the objectives of:

- Investigate the aquifer strength and its connection with the oil zone.
- Allow material balance calculations.
- Calibrate the Kv / Kh ratio, fundamental to optimize the development plan.
- Calibrate the oil-water relative permeability with production data.
- Impose a drawdown in the reservoir to allow the identification of compartments, if they exist, reducing the risks of the development plan.
- Identify damage mechanisms in the long horizontal well during the production process.
- Investigate the natural flow and artificial lift performances.
- Anticipate problems related to the production facilities, regarding to gas-oil and oil-water separation.
- Evaluate the performance and reliability of the storage and offloading procedures currently used.
- Improve the processing and marketing strategies for the heavy oil.

The Seillean FPSO, a dynamic positioning vessel with the capability of performing light workover operations, which was operating in the neighboring Roncador Field, was mobilized to allow the heavy oil production in a water depth of 1,300 m. Some improvements in the processing plant were necessary in order to process the heavy and viscous oil of Jubarte.

Using an innovative solution, a 900 HP, 25,000 bpd capacity ESP was installed above the X-Mas Tree (figure 3). The well was connected to the FPSO through a 6” riser.

The production started in October 2002 and the well produced by natural flow during two months, with a stabilized rate of 16,500 bpd, with constant bottomhole pressure. In December 2002 the ESP was turned on and the flow rate was increased to 18,300 bpd, being limited due to the constraints in the processing plant at the FPSO. The well potential with the ESP is 23,000 bpd but some changes are necessary in the processing plant and surface pumping system to allow increasing the flow rate. The major problem detected in the separation process is related to the severe foam formation, which is being mitigated with the use of chemicals.

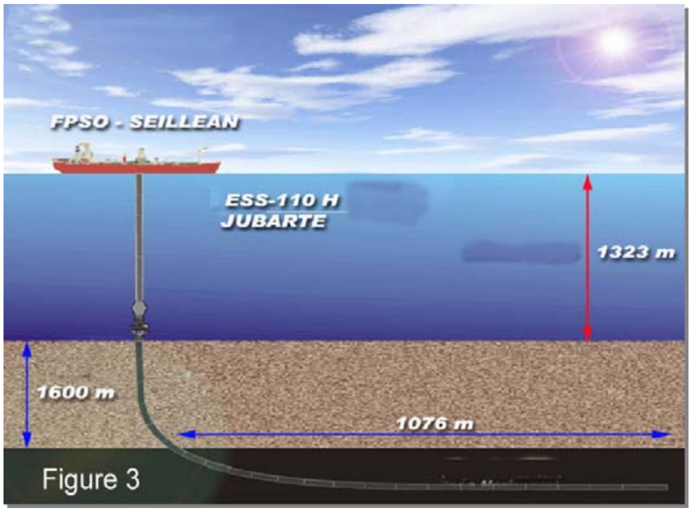

Figure 3

The Jubarte oil is similar to the MLS-3B oil at surface conditions, that is: the dead oil viscosity is 5 times the Marlim dead oil viscosity. It is one of the most viscous oils, at surface conditions, being produced offshore through a subsea completion well. During the EWT two extension wells were drilled and the field was declared commercial. The excellent results of the EWT are currently being used to optimize the development plan for the Jubarte field.

EARLY PRODUCTION SYSTEMS X EXTENDED WELL TESTS

At times it is very difficult to distinguish an early production system from an extended well test. Sometimes a system began like extended and later became early, because your profitable production postponed the decision of stopping it. Well technology development have been increasing production no matter which of these two concept is applied. Today is common to see a simple well producing more than 20,000 bod.

Extended Well Tests (EWT) are necessary to reduce the risks of the definitive system in offshore heavy oil fields, this can be quantified by the Value of Information methodology. Some EWTs have been successfully performed by Petrobras in heavy oil fields in the Campos and Santos Basins. However, some of the reservoirs discovered offshore Brazil present oils that are heavier and more viscous than those which have already produced in the EWTs.

The successful history of Petrobras in developing deep water technology encourages the company to the challenge of producing offshore heavy oil. The recently created Offshore Heavy Oil Program, PROPES, intends to coordinate the development or integrate existing technologies that may turn into reality the challenge of producing the significant heavy oil volumes already discovered in the Campos and Santos Basins.

FREE STANDING DRILL PIPE RISER

This new system is part of the Petrobras' technology program PROCAP 3000 and intends to be an alternative long duration test riser system to the Drill Pipe Riser (DPR 2000) currently operated by Petrobras in Brazil Offshore Campus Basin. The FSDPR system concept (figure 4), that is being studied by Petrobras, utilizes buoyancy cans to provide tension to the riser string rather than tensioning directly from the dynamically positioned FPSO.

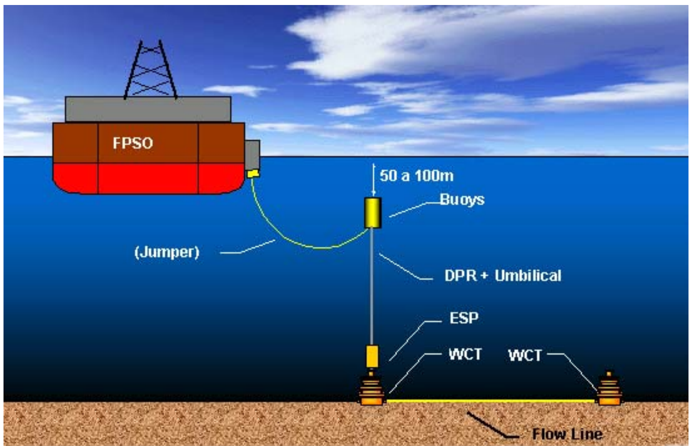

Figure 4

The main objective of the new long duration riser system is to eliminate the need for vessels like the Seillean, thus saving Petrobras the high daily rates of this vessel currently 100% dedicated to the operation of DPR system.

The FSDPR system is based on the DPR 2000 and is used both in tubing hanger mode (through marine riser) and in X-mas Tree mode (through open sea). The new system shall be designed to install the X-mas Tree and the FSDPR itself by a semi submersible rig and after that shall be connected by a VCM to an anchored or DP vessel to start the production. The greatest advantage of this new system is that it doesn't require a derrick on the FPSO, therefore allowing the utilization of a type of vessel which has more availability in the market and lower rates.

The FSDPR is basically composed of the following components, in a top-down sequence:

- Flexible Jumper system composed by a VCM assembly and a flexible pipe in a simple catenary configuration connecting the vessel on the surface to the top of the FSDPR;
- Drill Pipe riser string composed of 2500 m of 6.625" OD x 0.5" WT drill pipe joints with a hub on the top prepared to the VCM connection;
- Buoyancy cans to provide tension to the riser string;
- Bottom end tapered stress joint;
- Subsea Assembly (ESP, EDP, LWRP, TRT and X-mas Tree)

The following design basis shall be assumed for the purpose of the conceptual design:

- design water depth 2,500 meters
- riser pressure rating 5,000 psi
- required fatigue service life TBD
- safety factor for fatigue 10
- required shelf life 20 years

Additionally, the system will be evaluated to operate at water depth of 3,000 meters.

The production flexible jumper as well as the umbilical and power supply cable may be arranged in a simple catenary configuration in order to allow the independent dynamic motions of the riser and vessel. During an emergency condition, the jumpers can be disconnected from the vessel, leaving the VCM hanging on top of the riser string.

Riser Umbilical: An electric and hydraulic umbilical and power supply cable for the ESP may be alternatively clamped to the drill pipe riser during the running operation. The umbilical is composed of 4 x #12 AWG quad-laid pair electric cables, 9 x ¼" ID hydraulic lines and 1"ID line for X-mas Tree annulus access.

Vertical Connection Module: the VCM consists of a hydraulic connector with gooseneck on top where the flexible jumper will be connected. It is installed by cable from an AHTS to the riser string top-hub with an ROV assistance.

The drill pipe riser joint properties are the same as used in previous projects:

- Nominal outside diameter (OD) 6 - 5/8"
- Nominal inner diameter (ID) 5 - 5/8"
- Joint weight incl. tool joint (in air) 54.55 kg/meter
- Joint weight incl. tool joint (in water) 47.45 kg/meter
- Joint length 45 feet
- Specified minimum yield stress 95 ksi
- Specified minimum tensile stress 105 ksi
- Connection – stronger than the pipe V&M thread WO-SR (8"OD).

A second riser system alternative will also be analyzed that would avoid the use of an external umbilical form the VCM to the seabed. This riser is called - Concentric Riser and its characteristics are as following:

- Nominal outside diameter (OD) 7 5/8"
- Nominal inner diameter (ID) 6,765"
- Weight (in water) 73 Kg/meter
- Joint length 45 feet
- Specified minimum yield stress 90 Ksi
- Specified minimum tensile stress 100 Ksi
- Connection – stronger than the pipe thread union nut – FMC UN

A hub assembled on the top of the riser string will allow it to be connected to the running tool and later on to the VCM.

The buoyancy cans shall provide sufficient tension to maintain the FSDPR in a near vertical orientation so that the riser will not be subject to great motions in order to allow installation, production and intervention operations of the VCM. The tension capacity of the system will be limited by the drill pipe riser string. Preliminary study shows that an open-bottom air can type is more applicable for this work and shall be considered in the analyses.

Redundancy in the buoyancy system shall be assumed in the design to be on the safe side in the event of the accidental loss of one buoyancy can. Strakes may be necessary along the buoyancy cans in order to reduce the effects of VIVs. During X-mas Tree installation the air cans will trap air as they enter the seawater, however, this trapped air will compress as they reach the operation water. Once the X-mas Tree is installed, the top tension applied to the riser from the rig or drilling vessel riser tensioners will be gradually moved and kept by the riser buoyancy system. The additional air to keep the air cans fully buoyant will be supplied with ROV assistance.

The preliminary studies showed that air cans could have the following properties:

- Number of cans TBD
- Outside Diameter 2,75 meters
- Length 11,75 meters
- Displacement (per air can) 66 m^3
- Weight (per air can) 13 ton
- Net buoyancy (per air can) 54 ton

The quantity and the distribution of the air cans along to the riser string will be confirmed and verified by the riser analysis.

The subsea stack-up is given with mudline as vertical reference, in a top-down sequence:

Equipment	Height (m)	Top elevation (m)	Dry weight (ton)
ESP+ Capsule	45.50	55.82	10
EDP	2.50	10.32	15
LWRP	1.68	7.82	12
TRT	1.34	6.14	11
X-mas Tree	3.08	4.80	26
Tubing Head	1.72	1.72	32
Housing	--	0.00	--

To define the feasibility limits of the FSDPR the following analyses should be performed:

- Floatation Study
- Preliminary Riser Analysis
- Flexible Jumper Analysis
- VIV Analysis

The riser analysis should be performed, at least, for 7 load cases showed below to determine operational windows. This study includes determining whether or not a stress joint is needed and the sizing of this component. The most critical load cases to operate the system were sketched and described as follow:

Load case #1 – Running of the X-mas Tree (figure 5).

The full 2,500 meters riser length has been deployed and the last drill-pipe joint is hung off in slips, spider or gimbal. The full subsea stack (X-mas Tree/ TRT/ LWRP/ EDP/ ESP) is connected to the bottom end of the riser. The X-mas Tree is still disengaged from the Tubing Head.

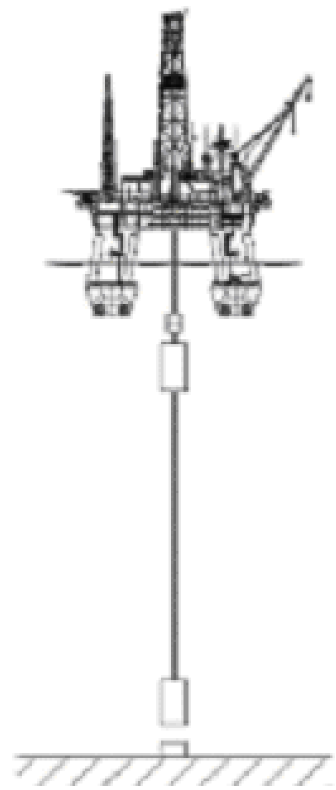

Figure 5

Load case #2 – Storm induced EDP disconnection

The drill pipe string is hung-off in the hook through rotary table. The EDP and ESP are connected to the bottom end of the riser. The stack up composed of X-mas Tree/TRT/LWRP is still connected to the Tubing Head.

Load case #3 – X-mas Tree installed.

The X-mas Tree is connected to the riser string top. This case also covers the X-mas Tree Workover and well intervention operations.

Load case #4 – The Drill- pipe riser has already been installed and abandoned. The VCM has not been connected yet.

Load case #5 – FSDPR on production.

Load case #6 – FSDPR connected in heavy weather condition.

Storm induced a flexible jumper disconnection from the vessel. The flexible jumper, umbilical and power cable are attached to the VCM still connected to the riser string top.

Load case #7 – Tubing Hanger Mode

The feasibility analyses covering the most critical Tubing Hanger operations conditions at water depth of 2500 meters has already been performed in other Petrobras development. The drill pipe riser string assumed in these analyses is the same used in the FSDPR system.

Flexible Jumper Analysis: Preliminary analysis of the behavior of the flexible jumper connected to the top of the riser based on existing available data of previous projects will be used for the analysis. It is also expected a recommendation on the type of flexible jumper, umbilical and power cable to be used in the system.

VIV Analysis: For load cases #4 and #5 a VIV fatigue assessment shall be performed for the 5 most frequent current profiles of less than 1 year return period informed by Petrobras. The analysis shall be preferably made by use of one of the existing software packages. Appropriate S-N curves shall be used together with the stress concentration factors (SCF) to determine the fatigue life of the connector and of the weld areas. In the case of significant fatigue contribution from VIV, a preliminary strake design will be proposed, along with assessments of the beneficial effect of strakes. The damages will be combined with the damages caused by wave and vessel (from global riser analysis).

Sensitivity analysis will be performed for the most critical load case, as identified through the performed riser analysis. The sensitivities covered will be:

- analysis of the riser in 3000 m water depth (excluding specific analysis of the jumper, umbilical and cable)
- increased riser pipe weight and cross section dimensions, for base case water depth.
- VIV analysis for 2 additional water depths (depth to be agreed with client), no redesign of riser is included.

Design Codes: the integrity of the riser will be checked against the design code and practices outlined in ISO/DIS 13628-7 “Petroleum and Natural gas industries – Design and operation of subsea production systems – part 7 Completion/ workover riser systems”, issued 2001/08/13, by ISO/TC67/SC4/WG6. SN-curves will be taken from DNV-OS-F201 Dynamic Risers, Appendix B Fatigue Analyses, January 2001.

CONCLUSION

Extended Well Tests are necessary to reduce the risks of the definitive system in offshore heavy oil fields, as can be quantified by the Value of Information methodology.

The main objective of this project is to develop a new long duration test riser system concept and eliminate the need for expensive DP vessels with a rig, thus saving Petrobras the high daily rates of this vessel currently 100% dedicated to the operation of DPR system.

This study is in the conceptual phase therefore susceptible into feasibility boundaries. Most of these ideas and concepts are still under study, and some of them will certainly be reassessed, reviewed and possibly improved. Petrobras has been working with some partner companies to develop the conceptual study and assess the system feasibility.

The successful history of Petrobras in developing deep water technology encourages the company to take on the challenge of producing heavy oil in an economical manner offshore.

ACKNOWLEDGEMENTS

The authors wish to thank the managements of PETROBRAS and FMC-CBV for give there permission to publish this paper.

ABBREVIATIONS

AHTS - Anchor Handling Tug Supply
DP - Dynamic Positioning
EDP - Emergency Disconnection Package
ESP - Electrical Submersible Pump
EPS - Early Production System
EWT - Extended Well Test
FSDPR - Free Standing Drill Pipe Riser
FRT - FSDPR Running Tool
FPSO - Floating, Production, Storage and Offloading
LWRP - Lower Workover Riser Package
VCM - Vertical Connection Module
TBD - To Be Defined
TRT - Tree Running Tool
RAO - Response Amplitude Operator
ROV - Remote Operated Vehicle
VIV - Vortex Induced Vibrations

REFERENCES

1. Moreira, J.R.F, Rovina, P. S., Couto, P. , Neumann, B. : “Development and Installation of the Drill Pipe Riser, An Innovative Deepwater Production and Completion/ Workover Riser System”, paper presented at the 1999 Offshore Technology Conference held in Houston, Texas, 3–6 May 1999.
2. Capeleiro Pinto, A.C., Branco, C.C. M.; Matos, J.S., Vieira, P.M., Guedes, S. S.; Pedroso Jr, C., Decnop, A.C. C.; Ceciliano, M.M., “Offshore Heavy Oil in Campos Basin: The Petrobras Experience”, paper presented at the Offshore Technology Conference held in Houston, Texas, 5–8 May 2003.

