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Roncador Field Early Production System - A 2000m Water Depth Challenge

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Abstract

Roncador is a giant field located in the northernmost part of Campos Basin, offshore Brazil, in water depths ranging from 1,500 to 2,000m. The field was discovered in October 1996 and is composed by light and heavy oil reservoirs. Due to the reservoir complexity, Petrobras decided, at the beginning of 1998, to implement an early production system in this field. The main objectives were to acquire more data from the field and to test new technologies.

An FPSO (Floating, Production, Storage and Offloading) unit, a rigid production riser and a wet Christmas tree compose the Roncador EPS. The Seillean FPSO that was operating in 140m waters in the North Sea was upgraded to work in water depths up to 2,000m. Seillean is a unique production unit, that it is equipped with a Dynamic Positioning System and is able to install the production riser and the Christmas tree by itself.

The FPSO entered operation by the end of 1998, and the first oil was achieved less than one month later braking two records: the world's deepest subsea well completion and the stationary unit producing in the greatest water depth in the world (1853m). It was the first time when the ANM-2000, a wet Christmas tree designed to operate in up to 2,000m, was used. It was also the pioneer utilization of the DPR-2000, a Drill Pipe Riser designed for completion and production in 2,000m waters.

This paper describes the upgrade of the FPSO Seillean, giving an overview of the whole production system. The challenge to develop a fast-track project that incorporates so many new technologies is highlighted here.

Introduction

Roncador Field was discovered by the wildcat 1-RJS-436 in October 1996, that showed the presence of Cretaceous sandstone saturated with good quality oil (31^0 API). The field is located in the northernmost part of the Campos Basin (see Figure 1), 20 km north of Albacora field, at 130 km from shore, in water depth ranging from 1,500 to 2,000m, covering an area of 132 km^2.

In October 1997 it was drilled the second exploratory well in the field, the 1-RJS-513, located in the Southwest part of the field, in 1559m waters. The oil characteristics in this well were different (18^0 API) from the characteristics found in RJS-436. This well also indicated the presence of a gas cap in the reservoir, what was not expected.

A third well was drilled in February 1998, and a forth one in the next month. The last one, located in the northern part of the field, detected an oil-water contact in a different elevation from the contact verified in the RJS-436. The information gathered from the exploratory wells confirmed the geological complexity of Roncador field.

This geological complexity was an important factor in the decision to implement Roncador EPS, that is composed by main three parts: the FPSO, the x-mas tree and the production riser, as can be seen in Figure 2. This paper is complemented by another one that will be presented by Petrobras at OTC'99, which focus on the development and installation of the x-mas tree and production riser for Roncador EPS (ref. 3).

Seillean FPSV

Seillean was originally built as an FPSV (Floating, Production and Storage Vessel) in 1990. The ship was owned and operated by BP up to 1996 when it was bought by Reading&Bates Corporation (now R&B/Falcon). The ship worked in the North Sea in shallow waters (less than 200m) up to 1997 in a concept called SWOPS (Single Well Oil Production System). In this system the ship stays over the production well using its Dynamic Positioning capability and deploys the production riser that is mated to the wellhead. The ship is provided with a derrick (see Fig. 3) to handle the riser joints and a heave compensation system (riser carriage, tensioners) to hang off the riser during operation.

After going through the separation stage in the process plant, the produced oil is stored in the ship's cargo tanks and the gas is used to fuel the turbine generators that provide the necessary power for the ship's thrusters. The ship is able to process up to 20,000 bpd of light crude and store more than 300,000 barrels of oil.

Originally, the ship did not have facilities to offload the production while in location. So, when the oil tanks were full, the ship had to unlatch from the well so the oil could be conveyed to an onshore terminal.

A New Horizon for Seillean

A Petrobras team visited Seillean in September 1997, when the ship was operating in Donan field. In this visit we realized that Seillean was a very useful vessel for short-term production systems, being much more flexible than a conventional Single Point Moored FPSO. One point that immediately called our attention was the fact that Seillean was nearly independent of critical resources like Anchor Handling Vessels (AHV) for installation of the mooring lines and Pipelaying Vessels (PLV) for deployment of the flexible lines. Also, with small modifications, the ship could deploy its own x-mas tree, without nedding a rig for the final completion of the well. So, the ship could be relocated much quicker than a conventional FPSO and had the additional advantage of allowing light interventions in the well. The power available in the ship from its three turbine and three main generators feeding the seven thrusters indicated that the ship had a good station keeping capability allowing it to stay long periods of time without disconnection.

The ship had also some drawbacks, like the limit in the number of wells it could produce at same time. On the other hand, compared to drilling rigs usually adapted for testing wells, Seillean also presented some advantages like its bigger processing and storage capability. Another advantage was the use of produced gas that is usually burned in EWTs, as a main power source.

With this characteristics in mind we concluded that Seillean was very suitable for EWTs and short term Early Production Systems (EPS). However, the ship would need first to be upgraded to operate in Campos Basin, where fields are commonly located at 1,000 m and even deeper waters. Moreover, the most attractive location for Seillean was Roncador, at nearly 2,000-m waters.

Roncador Development Plan

At the time of our first contact with Seillean, a complete production system for 180,000 bpd, the semi-submersible platform Petrobras-36 (former Spirit of Columbus) was beginning to be upgraded for operation in Roncador (a detailed description of the Roncador development plan can be found in Ref. 1). Anyway, considering that Seillean's upgrade would take between 6 and 8 months, an EPS installed in Roncador RJS-436 well could operate for at least one year, before the arrival of P-36. The main objectives of implementing an EPS in Roncador would be to gather more information from the reservoir and test new technologies that could be employed in the development of other production systems in Campos Basin deep waters. Besides, the high productivity of RJS-436 would provide an early cash flow that would pay off the initial investment in this system. This way, Seillean could be used later in other fields presenting less attractiveness or greater risk, without a high capital exposure.

The greatest bottleneck to implement this system, however, was the production riser. It was Petrobras intent that Seillean's operator also supplied the production riser. However, as they would need to start from scratch so as to get a riser for such deep waters, this could put a serious setback in the project schedule. So, negotiations to charter Seillean stalled for a while.

Fortunately, there was a solution at hand. Petrobras had a Technological Co-operation Agreement with KOS for supply of a drill pipe riser for 2,000 m. This project could be easily adapted for a production riser.

Supply of the x-mas tree would be even easier, since Petrobras was already in the process of purchase of some christmas tree for Roncador that could be used by Seillean, with small modifications.

Roncador EPS

After overcoming the difficulties related to the production riser supply, PETROBRAS decided, in February 1998 to use the FPSO Seillean as an Early Production System in Roncador. A letter of commitment was signed and in June 1998 a 4-year chartering contract was signed. The ship was intended to begin operation in RJS-436 location before the end of 1998. The delays suffered by the P-36 project, now scheduled to begin production in the third quarter of 1999, would allow Seillean to stay in this location for almost one year. After that, the idea is to relocate Seillean to the western part of the field, in order to test the production of the heavy crude.

Drill Pipe Riser-2000. The DPR-2000 was originally a project to use a 6 5/8" Drill Pipe Riser for x-mas tree and tubing hanger installation in deep waters. The DPR was developed by a Technological Co-operation Agreement with KOS that works as an EPC contractor. A detailed description of this project can be found in Ref. 2. The main systems of the DPR-2000 are the following (see Figure 4):

- the 6 5/8" drill pipes and its accessories, like the bottom stress joint, the pup joints, x-overs, etc.:
- the topsides control system that comprises a Master Control Unit, a Hydraulic Power Unit (HPU), the Remote Control Panels and an Uninterruptible Power Supply (UPS);
- a 9-function control umbilical with an integrated 1" annulus access. The umbilical is spooled by a hydraulic winch and it is clamped to the drill pipes;
- a Subsea Control Module (SCM) that is mounted on a Transition Joint and distributes the function lines to the tree and tools.

For the Roncador EPS this project was adapted for production and the EPR-2000 (Early Production Riser – 2000) was born. The main differences between the EPR the DPR are:

- introduction of a slew ring adapter plate below the Surface Flow Tree (SFT) to allow the riser to be hung by the ship's riser carriage;
- the change of the bottom stress joint by a flexible joint and the introduction of another flexjoint at the riser top;

- the use of a special coating (aluminium spray) to protect the drill pipes.

The riser bottom angle is measured by an ARA (Acoustic Riser Angle) mounted in the EDP (Emergency Disconnection Package) and the signal is sent directly to the ship's DP system. The constant monitoring of both bottom and top riser angles will permit the minimisation of the riser stresses. So, the fatigue life is increased, what is of paramount importance in this project where the riser is required to stay as long as one year before being retrieved and inspected.

Ref. 3 gives a more detailed description of the EPR innovative project.

ANM-2000. The ANM-2000 (where ANM stands for Wet X-mas Tree in Portuguese) was developed by a Technological Co-operation Agreement with CBV with a main focus in Roncador field. The ANM-TLD-2000 (where TLD stands for Extended Well Test in Portuguese) is a tree specially designed to work with Seillean. The tree has a compact design that allows it to be handled by Seillean and it is provided with a Vertical Connection Module that makes easier the tie-in with a second well in piggy-back fashion.

The system also comprises an Emergency Disconnection Package (EDP) to allow a quick disconnection of the riser in case of problems such as the ship driving off location and so on. Ref. 3 presents also a detailed description of this project.

Seillean Upgrade Requirements

In order to work in Roncador, Seillean would have to be upgraded, specially to be able to operate in almost 2,000-m waters. The installation of facilities to allow the offloading of the vessel while in location was also considered vital for the Roncador project. It was also necessary to install some new equipment to process Roncador oil. Finally, Petrobras required some small modifications to increase vessels' reliability and operationability.

Deep Water Upgrade. The water depth 10 times bigger than Seillean former operational limit demanded some a big upgrade in the vessels' riser handling and storage facilities. The existing derrick that could handle only 30' joints was replaced by a second hand, full size derrick that allowed the handling of the DPR-2000 45' joints that were being used to minimise the riser deployment time. The new structure also allowed a better arrangement of the derrick area. The other modifications caused by the increas of the water depth were:

- installation of new riser tensioners – the tensioning capacity was increased four times, from 140 kips to 600 kips;
- installation of a new travelling assembly (drawworks, crown block, travelling block, hook) and riser carriage, all designed for 600 kips;
- reinforcement of the derrick sub-structure for the new loads;
- expansion of the riser storage area to allow the storage of 2,300 m of drill pipes;
- upgrade of the acoustic system.

Offloading. Since the beginning, Petrobras feared that the time required to recover and deploy the riser in this water depth could impair the economics of the project as well as increase the wear and tear of the delicate components of the riser and EDP. So, it was required that the vessel had facilities for offloading while in location without temporarily stopping the production. The main components of the offloading system are the following:

- a hydraulic driven hose reel for a 12", 350 m long full floating hose;
- a hawser winch for a 10", 150 m long mooring hawser;
- a hydraulic chain stopper that allows onload release;
- a new discharge line from the tank header to the hose reel.

Roncador Oil Process. Due to the relatively low temperature of the oil in the reservoir and the temperature drop in the production riser, it was necessary to install a couple of process heaters to increase the oil temperature. The increased temperature allows the separation of the highly paraffinic oil of Roncador avoiding the tendency to foam formation.

As most of the fields located in Campos Basin deep waters are heavy crude producers and Seillean was not intended to produce only in the RJS-436 location, it was also required by Petrobras that the ship could process heavy crude.

Finally, in order to increase and optimise the steam supply for the heaters, it was decided to install a new steam generator in the ship.

Vessel Reliability and Operationability. In order to increase the vessel reliability and redundancy Petrobras required the existing DP control system to be replaced by a new, triple voting system. The upgrade of DP system comprised the following items:

- destruct of existing Control System and installation of three DP Operator Consoles;
- installation of a third Anemometer;
- installation of a third Gyro Compass (spare);
- installation of a two new VRUs;
- destruct of existing two UPSs and installation of three new UPSs;
- new cabling, etc.

In order to increase vessel's station keeping capability during offloading operations, Petrobras required that the measured hawser tension could be used as an input to the DP system.

Considering the necessity for tree handling, it was also required the replacement of the port aft crane by a crane with greater lifting capacity. Later, Petrobras realized that the old port aft crane could be relocated to the area located ahead of the derrick, if a new base and lay-down area were built for it. So, it was found a good use for this area of the ship that was formerly under-utilised. This new operation area will speed up eventual interventions in the well since it allows simultaneous operations in the ship and will make easier operations with coil tubing.

Design Phase

The most part of the difficulties that were faced during the design phase were caused by the lack of time for more detailed studies in this fast track, new technology project. An example of those difficulties was the change of the bottom stress joint for a flexjoint. This was decided in the middle of the project, aiming at increase the reliability of the riser and maximise fatigue life. The problem was that we had a very short time to decide for this modification and evaluate its impact on related equipment, what could have put a setback in the project schedule.

Another modification during the design phase was related to ROV operations. In the beginning it was thought that a ROV installed all the time in Seillean would represent an unjustified cost since the ROV would not be required during normal operation. So, the initial idea was to give ROV support for the tree installation with a special vessel. Later, it was decided that the bad quality of the video link and the uncertainty in the frequency of disconnection justified the installation of a dedicated ROV on board Seillean (at least for the first months of operation). As Seillean's ROV moonpool area was not fitted for a 2,500 m ROV, the ROV (that was mobilised from a Petrobras AHV) had to be installed on the aft lay-down area and a fixed a-frame had to be built to launch the ROV.

Another complicating factor during design was the great number of interfaces that had to be managed, in special between the DPR EPC contractor and its suppliers and Seillean operator suppliers. Petrobras had often to intervene to solve small conflicts and break stalemates when divergent interests were involved.

Technically, one of the greatest problems was to assess the feasibility of the offloading operations with conventional tankers under Campos Basin environmental conditions. Offshore Campos you can observe very often the wind and currents coming from different directions and sometimes the swell coming from a third direction. Due to the lack of time to perform model tests and the uncertainty associated with full dynamic analysis (particularly under our environmental conditions), we could not have full confidence in the operation with conventional tankers. In the end, we decided to hire a DP shuttle to operate with Seillean because we did not want to take any unnecessary risk in this project.

Upgrade Work

The upgrade work was executed mainly in Scotland and completed in Holland, during the ship's statutory dry-dock. The dry-dock work comprised essentialy the maintenance of thrusters and painting of the hull. Petrobras main role at that time, was to co-ordinate the receipt and installation of the materials from KOS and CBV that were arriving from all over the world. We can say that the project had a just-in-time characteristic at that point. The ship was about to leave shipyard in October 12^{th} and almost all the EPR components were scheduled to arrive within the last 3 days before ship's departure. The drill pipes, pup-joints and the stress joint (kept as back-up) were manufactured in Germany, sent to Aberdeen for the internal coating and then to Stavanger for the external coating and arrived in Rotterdam in October 10^{th}. The flexjoint was finished in Dallas on the 2^{nd} October and arrived in Rotterdam a week later. At the same time the SFT, swivel, quick connector and x-over were finishing fabrication in Houston and were expected to arrive in Rotterdam in October 9^{th} but only arrived 3 days later. Finally, the Strengthened Joint was to be finished in Sheffield at October 7^{th} and needed 3 days more to be sent to Rotterdam. It only arrived on the 16^{th} October but fortunately the ship was still in Rotterdam due to a delay in the painting.

The work in the wet dock and dry-dock suffered from small delays, what we attribute to the fact that the scope of work was much greater than originally foreseen. Anyway, the beginning of operations before the end of 1998 (only 10 months after the project commitment) is an achievement we would like to highlight here.

The final commissioning of the EPR control system was done with the ship already in Brazil, but this had a very small impact on the schedule.

Installation and Operation

The RJS-436 was completed up to the tubing hanger by the rig Sedco-707 in October 1998. Seillean upgrade was concluded by the end of this same month. In November 16^{th}, after the thrusters set-up and a short period of DP tests offshore England, Seillean sailed to Brazil, arriving in Rio de Janeiro in December 7^{th}. After customs clearance, the ship sailed to Campos Basin where the final commissioning of the control system took place. The FPSO operations started officially in December 28^{th}, less than 10 months after the project commitment. The riser was lowered and the x-mas tree latched. The well completion was finalised, with the oil put on stream in January 23^{rd}.

In this phase we had some small problems in the subsea equipment which can be considered normal in a new technology project like this. Considering the challenge of operating in such deep waters, we can consider the performance of the new equipments a great success.

Conclusion

The use of a Dynamically Positioned ship for production is a window that was opened in the offshore exploration area with Seillean's construction, in 1990. With Roncador EPS we think we stretched the limits of this window in a way no one had ever figured out. The Seillean+EPR+ANM-2000 system is unique not only by its flexibility but also by its agility. If we want to relocate this system we can move it to a new field located in waters from 80 to 2100 m, producing light or heavy oil, with low or high BSW. This relocation can be done quickly and independently of critical resources. Additionally, in the case of well testing, it can not be forgetten the ship's capability of doing light workover in the well.

The implementation of a record-breaking, new technology project in less than 10 months was made possible by a series of factors:

- Petrobras expertise in deep water equipments and operations;
- partnership with recognizably experienced companies;
- spirit of collaboration among the partners to minimise conflicts and speed decisions;
- flexibility to withstand project changes in the middle of the process;
- constant attention to the project interfaces.

Acknowledgements

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In addition, I would like to dedicate this paper to the memory of Bill Thain, Coordinator of the EPR-2000 project, who could not see the result of his work because of a tragic car accident where he lost his life.

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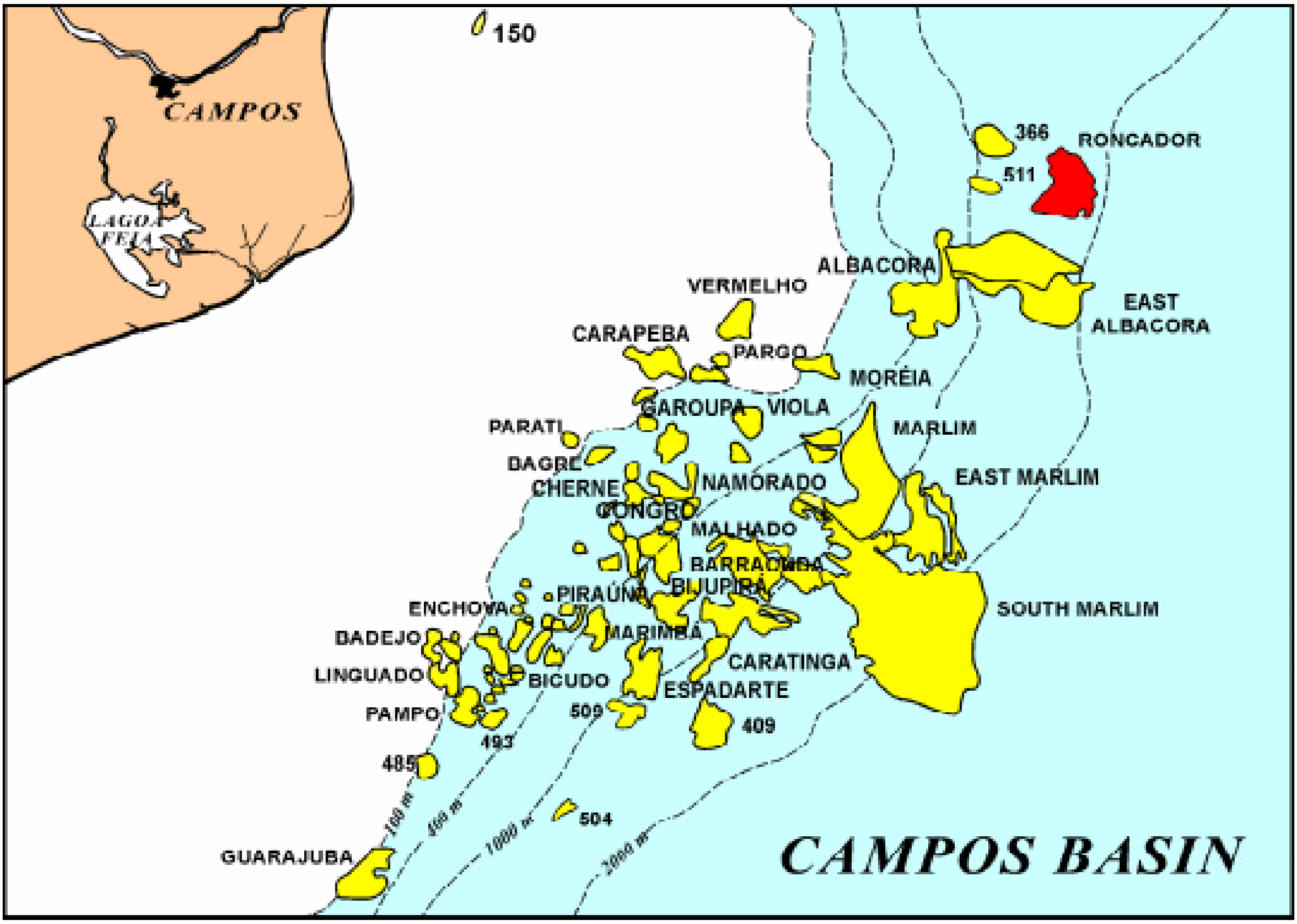

Figure 1 – Campos Basin

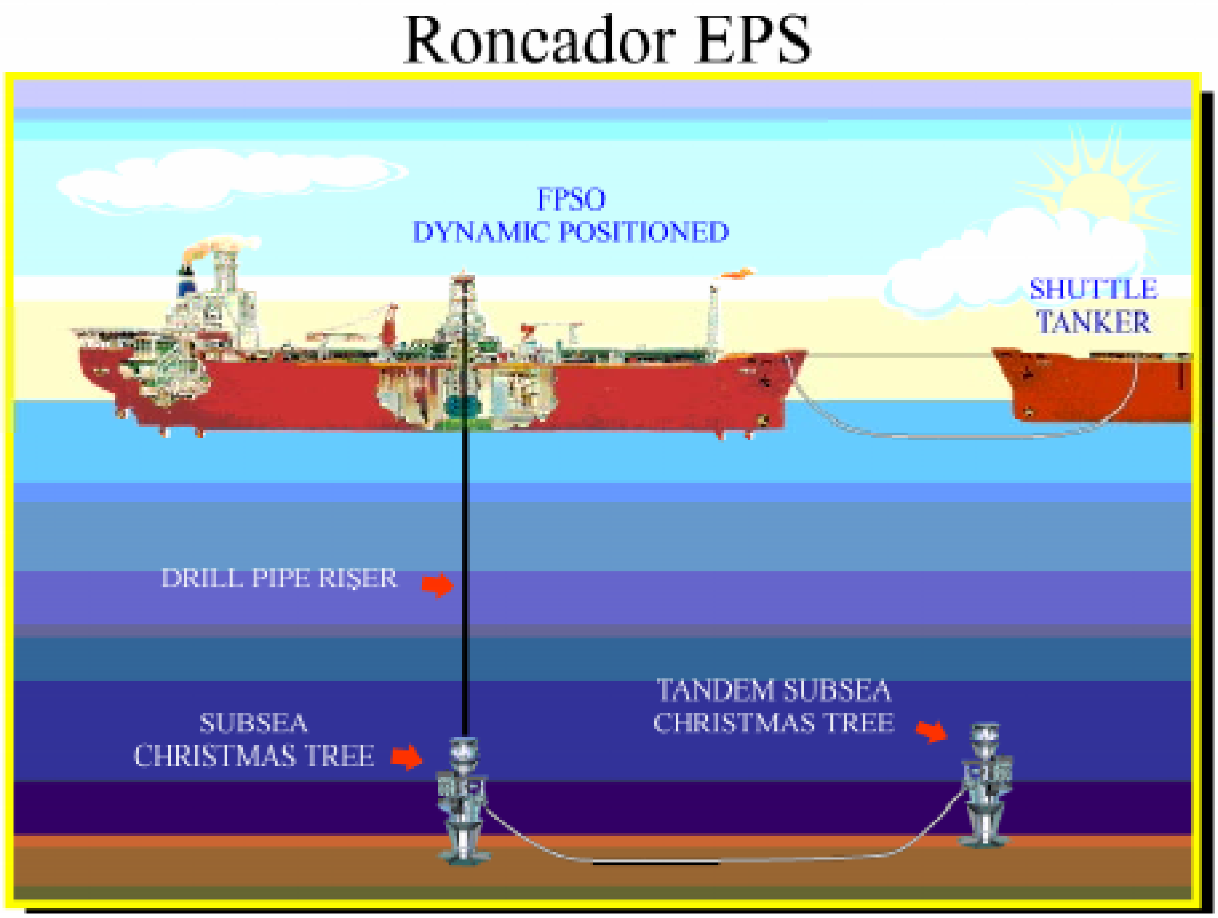

Figure 2 – Roncador EPS

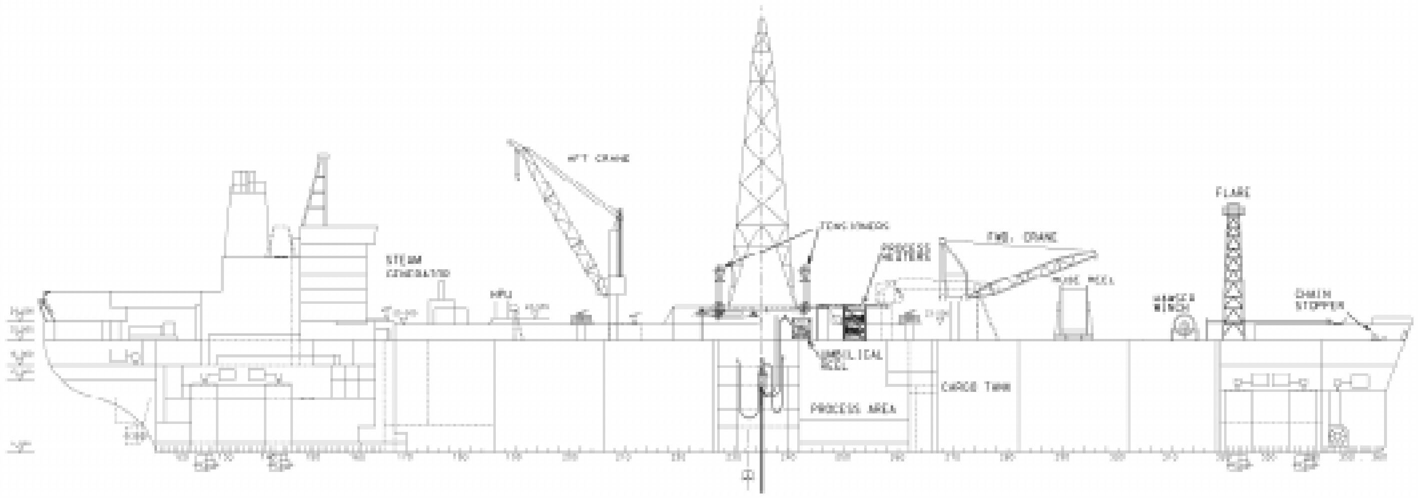

Figure 3 – FPSO Seillean – Sectional Elevation

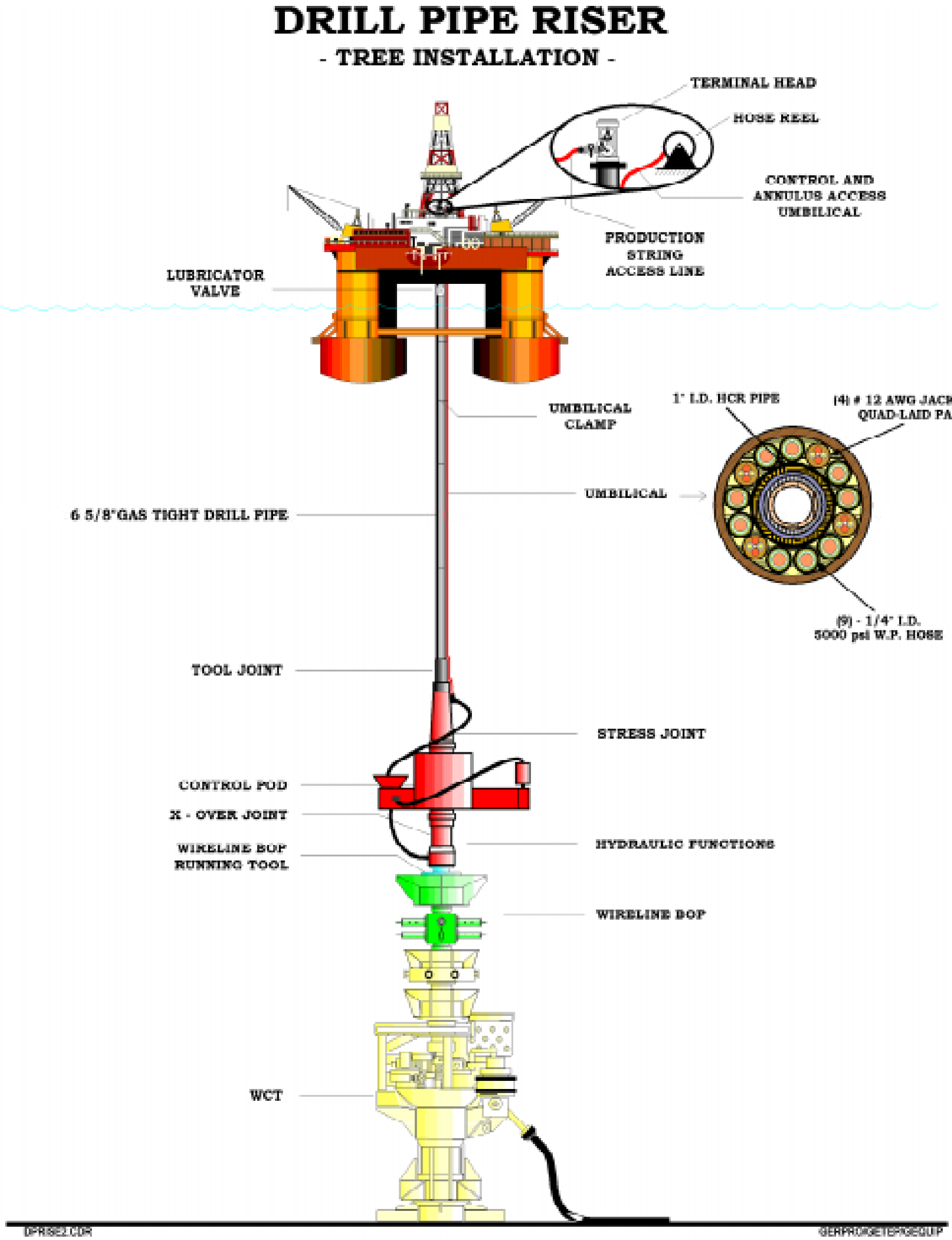

Figure 4 – Drill Pipe Riser - 2000