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TWENTY YEARS OF FPSO OPERATION IN THE NORTH SEA

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Abstract

Petrojarl I started its operation in August 1986, as the first FPSO in the North Sea. It has since produced from 10 different fields. This paper presents the experience gained in developing, building and operating this FPSO in the North Sea. Particular challenges which are covered are: Vessel design and structural strength, turret, risers, mooring, production equipment, offloading, rules and regulations.
The paper also covers experiences from constructing and operating subsequent FPSOs such as the Petrojarl Foinaven in the North Atlantic West of Shetland.

1. Introduction

20 years ago – 30 August 1986 – an important milestone event took place offshore Norway. The first FPSO in the North Sea – the purpose built Petrojarl I started test production of oil for Norsk Hydro of the Oseberg field. The vessel started a new way of producing in this oil province and set the standard for the FPSOs which followed.

Petrojarl I is today producing its 10th consecutive field – the Glitne field for Statoil in Norway – and is, due to continuous upgrades, still an efficient and up to date production facility.

I have had the privilege of managing the development and construction of the unit and have since been responsible for the operation of Petrojarl I and the three other units which followed. I will in this paper discuss the challenges we faced during design development and construction and some of the experiences we have had since with developing, upgrading and operating FPSO's in the North Sea and the Atlantic.

2. Petrojarl I

The Petrojarl project started in April 1983 when we entered into an agreement with a small Norwegian engineering consultant, Tentech International, to fund the cost of bidding their concept production vessel Tentech 685 for the provision of a floating production system for Philippines-Cities Service's Galoc field. In return we were given the option to build, own and operate the vessel. The bid was submitted in May 1983 in competition with 9 others and was not successful.

We decided, however, to continue with the project and used considerable resources to market, model test and develop an outline construction specification. The project was now marketed as the "Production and Test Ship" (PTS) and one of the proposals we submitted was to Arco in June 1983 for operation in the Gulf of Alaska. The intended wells proved, however, to be dry and the project shelved.

In September 1983 an invitation to bid for the construction of a Production and Test Ship was sent out to shipyards. Evaluations, discussions and negotiations proceeded with a declining number of yards continuing through the first part of 1984. Seminars for potential oil company customers were held in Trondheim and Houston and invitation sent out to

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potential investors for investing in the PTS. Investors and financing came into place and on the 26th June a contract with Nippon Kokan was entered into for the construction of a Production and Test Ship at their Tsurumi yard in Japan.

The ship did not at that time have any contract for employment in place and marketing the concept continued to be challenging, but essential.

We came early in contact with Norsk Hydro, who was interested in using the ship to test the Oseberg field. There was, however, much skepticism both within Norsk Hydro and from their partners, in particular Statoil. The experience with ship-shaped drilling vessels in the North Sea had not been good and it was difficult to get acceptance for our claim that the PTS should be able to stay on location, produce and offload throughout the winter with high regularity. We carried out a study which was delivered to Norsk Hydro in April 1984 and received positive reception.

Norsk Hydro decided to establish a group to evaluate the PTS and they presented their first report to their management in January 1985. Contract negotiations commenced and after a lengthy process a Letter of Intent for the use of the PTS at the Oseberg field for a 18 month period was finally signed 14th June 1985. The scope of our delivery also included a shuttle tanker and a suitable product tanker was acquired and converted.

The vessel was delivered from the shipyard 23rd May 1986, 23 months after contract awards, as Petrojarl I, transferred to Norway for inshore testing and commenced oil production on the Oseberg field 30. August 1986. In Figure 1 is shown a photo of Petrojarl I at its present location at the Glitne Field in the North Sea where it is under a contract with Statoil.

Figure 1. Petrojarl I at Glitne.

3. Petrojarl I project challenges.

3.1 Vessel design

The original Tentech design featured a hydraulically lowered damper plate aft and a bow “lip”, both to minimize vessel motion and in particular heave. The operational and maintenance issues of the damper plate caused concern. We decided, following model tests with and without, to remove it. The bow “lip” was constructed – but created during the transit to Norway a “hydrodynamic hammer effect” with resulting damage to structural elements in the bow. It was therefore removed prior to starting operation. Neither feature has been missed since.
The original design was for a ship with a breadth of 28 meter. Stability concerns during the design phase, before construction start, led to the decision to increase this to 32 meter.

3.2 Structural strength

The ship was built with Det Norske Veritas classification and to comply with the Rules for Operation on the Norwegian continental shelf. The interpretation of these Rules was carried out by DNV for the yard and ourselves and by a daughter company of DNV, Veritec, for Norsk Hydro. Veritec disagreed with the classification part of DNV on what magnitude of maximum wave bending moment the hull girder should be designed for and recommended strengthening. Other specialists were introduced who supported our view that the strength was adequate but this was not accepted by our customer. In the end doubling plates reinforcements were installed in deck and bottom.

Cracks did, however, develop during the first years of operation and were repaired while in operation and during yard stays for upgrades between contracts. The main reasons for these were the use of high tensile steel and stress concentrations caused by construction details.

During the upgrade for the Glitne field in 2001, doubling plates were removed and 800 t of steel replaced with a quality suitable for the environment. The fatigue life of the hull was as a consequence increased to a total of more than 30 years.

3.3 Turret

A turret of the type we were looking for, installed sufficiently forward of the midship to secure automatic weathervaning, had not been used before. There were some experience from drillships with hull installed turrets and installed in the bow on converted tanker production vessels, but none which were directly applicable for our hostile environment. The bearing system which had been proposed by Tentech proved not to be able to give us the low friction coefficient we required for automatic weathervaning. We therefore developed together with the yard, our own patented turret bearing system based upon hydraulically actuated wheels which makes it possible for the turret to move free or be rotated by a rack and pinion system. When weathervaning is not required, the turret is lowered down on its rest seatings.

The technical evaluations made by Norsk Hydro prior to commencement, pointed out concern over the dependability and maintenance challenges of the turret bearing system. The operations over the next 20 years have shown that this system is one of the most dependable features of the ship and we have with success also used it on the Petrojarl Foinaven.

Transfer of fluids, electrical power and signals between the turret and the ship was also one of the challenges we faced. We did not have any high pressure multipass swivel we could use and therefore had to depend on a system for fluid transfer of jumper hoses which could be changed over when the ship rotated over a certain limit versus the turret. A similar system was used for electrical power and in addition power generation was installed in turret. Control signals were transferred through a telemetric system.

The systems worked well but later installation of multipass swivels has resulted in a more efficient transfer requiring less labor.

3.4 Risers

It was a requirement, due to the well testing, that the ship should have a rigid riser. This meant that riser handling and tensioning equipment had to be designed and installed. We used our experience as a drilling contractor to develop an efficient system with a short derrick, drawworks and riser tensioners. The ship was also designed with sufficient ballast capacity, in segregated tanks, to maintain constant draft.

The ship was also equipped with a flexible riser for the second well test at the Oseberg field. This was the first time a flexible riser was used for production in Norway and extensive technical verification was therefore required.

The rigid riser was only used for the initial operations of Petrojarl I. Subsequent operations have only used flexible risers and the capacity to handle such has been increased to 8.

3.5 Process

One of the main concerns over the process system was initially the effect of the ship's motion on the effectiveness of the plant. This has proved, however, not to cause any significant problems. The initial design capacity of the three stage separation plant was 22.000 bbls/day. This was increased to 30.000 bbls/day before first contract and is today further increased to 46.000 bbls/day.

Later upgrades to the process have introduced gas lift/injection, water injection and more efficient water handling equipment.

3.6 Offloading

There was obviously no experience with offloading from FPSOs in the North Sea when we started and no standard solution. Shell had installed an offloading crane/boom system on their Fulmar storage tanker and we decided to use the same system. This proved fortunate when the Fulmar FSO drifted away in 1989 and we could take over the offloading operation with Petrojarl I within a few weeks and after only minor modifications.

A concern over the risk involved with offloading was the heat load and possible carry over from the flare system. We decided therefore to install the offloading as far to the port side as possible and to install a ground flare on the starboard side for gas disposal. These features have operated without problems ever since.

3.7 Rules and Regulations

The Petrojarl I was the first of its kind on the Norwegian Continental Shelf and application of existing and forthcoming Rules and Regulations from the petroleum and maritime authorities proved a major challenge. A new Petroleum Act was adopted in mid-1985 but it became apparent that the consequences of its implementation and the associated costs had not been properly evaluated. We had the vessel classified by Det Norske Veritas with additional class notation Drill (N) and "Production and Storage Vessel or Tanker for Oil". This was expected to cover compliance with all Norwegian regulations. The problem was, however, that the Operator has the ultimate responsibility to see to that the installation complied with the regulations. When there was difference of opinion between the oil company and ourselves on the interpretation of the rules, one would expect that the authority who had issued the rules would be able to advice us. Such advice was, however, not forthcoming. This lead to several changes during the construction, some sensible and useful and some more difficult to understand and justify.
Looking back one can see how the process we went through was contributing to the more efficient and predictable process we have today. There is, though, still room for improvements. It is also interesting to see how we set the standards for the FPSOs to come.

3.8 Oil Price Fluctuations

The project took place in a period with large fluctuations in oil price. The commercial viability of production testing was partly influenced by the income which could be generated from selling the produced oil. When we started in 1983, the price of Brent crude was stable around USD 30 per barrel. In 1985 it was still relatively stable with an average of USD 27.60 per barrel. In July 1986, however, it had fallen to USD 11.00 per barrel. We had a contract which could be cancelled if we were not on contract before the end of August 2006, and the Petrojarl I was at that time at a shipyard in Germany installing reinforcements to the hull and removing the "bow lip". I still remember the stressful period we had up to the ship went on contract in the field 29th August 1986 at 20.00 hours and started oil production the following day.

4. Petrojarl Foinaven

The Foinaven field is located in the Atlantic 190 km west of Shetland in water depths ranging from 400m to 600m. The field was discovered in late1992. Reservoir oil is sweet with an API gravity of 26 degrees, some wax content and relatively low viscosity. The location was characterized by a lack of infrastructure as there was no existing oil production. The region is also subject to severe environmental conditions with maximum wind and waves similar to those encountered in the Northern North Sea. 100 year return figures indicate wind speed of 40 m/s and a significant wave height of 18 m. Interaction of the warm Gulf Stream and cold Atlantic waters, creates strong and complex currents which can reach up to 2 m/s and vary greatly with water depth. The seabed is relatively soft and the seawater temperatures can occasionally fall below zero degree Celsius. Operational weather windows outside the summer season are difficult to predict and usually of short durations.

The operator, BP, investigated several different development concepts and decided eventually for a leased FPSO. We received, after having prequalified, the tender documents in May 1994, and decided to offer a converted Russian owned, Finnish built heavy lift ship, the Anadyr. The earlier plans were for an Early Production Solution and we proposed to convert the cargo holds into cargo tanks, relocate the four 6 MW diesel engines and insert a new section with our own designed turret system. The requirement was for a single train capable of stabilizing 50.000 bbls/day of Foinaven crude.

During the summer it became apparent that BP had changed their plans to a Life of Field FPSO with capacity increasing to 95.000 bbls/day and with water injection and gas compression added. Our original ship conversion plans had to be discarded. Increased requirements to topside weight carrying capacity necessitated complete redesign and we now decided for a complete new center section containing the cargo and ballast tanks and the turret. An extension was also made to the aft end to get more deck space, resulting in a 250 m long vessel with a mid section width of 34 m, 4 m wider than the forward and aft parts of the vessel.

In Figure 2 is shown a photo of Petrojarl Varg as it finally became.

Figure 2. Petrojarl Foinaven

We received a letter of intent from BP in the summer of 1994 and signed a contract with Astano shipyard in Ferrol, Spain, in August the same year. Design started immediately and in October Field Development was sanctioned by the Foinaven partners. The FPSO, before commencing operation, become capable of producing 140.000 bbls/day of dry oil at peak plus 114 mmscf/day of gas and to treat 165.000 bbls/day of seawater for reservoir injection.

Petrojarl Foinaven left the yard in Spain in November 1996 and sailed under own power to the Foinaven field for mooring installation. The FPSO is held on station by a 10-point mooring system, spreading symmetrically from windlasses located on the geostationary turret, around which the hull is able to rotate. Each line, which had been partly preinstalled the year before, consists of 1140 m of 135 mm wire, buoyed subsea, plus 1200 m of 111 mm diameter chain leading to a 35 t drag anchor in the seabed. Equipping each line with a windlass onboard the FPSO, while involving greater capital expenditure, provide considerable flexibility during mooring operation both during initial installation and during later inspections and replacements of components. Although the initial mooring operation took place in winter, all ten lines were hooked up and tested within two and a half days.

All twelve risers were preinstalled on the seabed prior to the arrival of the FPSO. These comprise four 10 inch production risers, four 8 inch test/production risers, one 8 inch gas injection/export riser, one 10 inch water injection riser and two control umbilicals. During riser pull-in operations, the outer sheathing of eight risers and one umbilical suffered different degrees of damage leading to potential water ingress. This is believed to have been caused by contact with installation aids on the seabed. A riser preservation program, involving the application of leakproof outer clamps and injection of corrosion inhibiting chemicals into the riser annulus to prolong component life, was undertaken. This solution has proved successful.

Although the vessel was installed and ready to receive production in March 1997, technical problems with subsea equipment delayed production startup until November the same year. The problems were related to hydrogen embrittlement of stressed components in hub connectors and valve stem seals on subsea trees and manifolds. Components were retrieved from the seabed and repaired or replaced.

The FPSO’s 7 m high swivel stack, containing six toroidal flow paths to transfer fluids, gas and control signals between seabed and the vessel, was at that time one of the largest yet manufactured. During high pressure testing a static seal blew on one of the flow paths. Working with the supplier, an innovative method of pumping a proprietary sealant into the swivel’s o-ring annulus was developed to avoid dismantling the 100 t unit offshore. The operation, including onshore testing on an equivalent swivel component, was concluded in less than two weeks, immediately prior to startup. This was accepted as a permanent repair solution and the swivel has continued to function correctly.

Petrojarl Foinaven has a storage capacity of approx. 260.000 bbls of stabilized oil. This means that offloading is necessary every three to four days with a full FPSO cargo requiring 12 to 15 hours to transfer. We operate two shuttletankers which transport the cargo to the Flotta terminal at Orkney. The tankers are operating in dynamic positioning mode when connected to the FPSO and are generally able to operate in up to 6 m significant waves, although the connection to the FPSO requires 4,5 to 5 m. The tankers transfer oil in batches and wait in the field until it has a full cargo. During offloading, oil is transferred from the FPSO at the stern of the vessel through a 16 in diameter hose to the tanker some 85 m astern. Although long wave period swells from the Atlantic create a background to local conditions and can take several days to subside, offloadings have proceeded smoothly. In the near to nine years we have produced, an offloading efficiency of 99,4% has been achieved. We have until now from our four units carried out approx. 3300 offloadings without any problems.

The basis for the sanctioning of the Foinaven development in October 1994 was recoverable reserves of 250 mill bbls oil. We have already produced this. Recoverable reserves based upon presently drilling program, has been increased to 327 mill bbls. Future drilling programs will most probably increase this and lead to a major extension to the life of the field. Maximum daily production was achieved in September 2001 with 138.991 bbls and is presently 60 – 70.000 bbls/day.

5. Petrojarl Varg

The Petrojarl Varg was ordered in 1996 by the Norwegian oil company Saga Petroleum on behalf of the licence holders of the Varg oil field from KeppelFELS in Singapore. The FPSO, which is of the Tentech 700 design, started production in December 1998. We bought the vessel in July 1999 with a charter back for minimum 3 years. We also took over most of the Saga personnel working on the vessel. Saga was taken over by Norsk Hydro who in 2002 informed us that they did not intend to produce the field beyond the same summer. We decided to acquire the field through the PGS oil company subsidiary Pertra, and were able to get a 70% interest by taking over the shares held by Norsk Hydro and Statoil. The remaining 30% is held by the Norwegian state oil company Petoro.
Pertra took over as operator and started a successful drilling campaign which resulted in a major increase in oil production and life of field. Pertra was sold to Talisman in March 2005, but we continue to own and operate the FPSO with no oil company representative onboard. In Figure 3 is shown a photo of Petrojarl Varg during offloading.

Figure 3. Petrojarl Varg, shuttle tanker and Stand-by vessel

6. Petrojarl Banff

Petrojarl Banff was constructed as the Ramform Banff by Hyundai Mipo yard in Korea and AkerMcNulty in the UK, following a contract awarded to PGS by Conoco in January 1997 for producing the Banff field on the UK continental shelf. The vessel is based upon the Ramform B-380 design, having a triangular shaped hull with high deckload capacity but low storage capacity. The management of the construction of the vessel was carried out by an internal PGS group and an UK operations company which subsequently became a PGS subsidiary. The latter company was also responsible for the operation of the vessel.
The FPSO started oil production on the Banff field in January 1999. The vessel experienced operational problems with its motion characteristics and offloading system during its first 18 month of operation. When it also became apparent that there was a problem with water ingress in some risers, the decision was taken to bring the vessel to a Blohm & Voss shipyard in Hamburg for necessary modifications.
Petrojarl, at that time known as Golar-Nor Offshore, had been acquired by PGS in May 1998. We were now asked to take over responsibility for the FPSO. Bilge keels were installed and other improvement work carried out on the vessel, risers repaired and the offloading system replaced with a permanently moored storage vessel, the Nordic Apollo FSO. Production recommenced in March 2001. Since then the Petrojarl Banff has operated successfully with an uptime performance of 99%.

In Figure 4 a photo from the Banff Field presents Petrojarl Banff, the FSO Nordic Apollo and a shuttle tanker.

Figure 4. Petrojarl Banff, the FSO and shuttle tanker.

7. Health, Safety and Environment

Health, Safety and Environment have had an ever increasing focus and importance since we started our North Sea operations and the results shows that our efforts together with authorities, oil companies and our own personnel are working. It requires, however, the continued highest priority from management and everybody involved to maintain. The highest standards in this area is required to maintain our ability to produce the offshore petroleum resources with community acceptance.

The offshore petroleum activities in the North Sea started in earnest in the early 1970-s and much of the personnel commenced their offshore work at that time. An ageing workforce represents challenges to the health of the employees. Continuing focus on physical and mental health and welfare is giving results in motivated staff and low sickleave rates.

Both the authorities and the industry are continuing to introduce regulations and campaigns to maintain and improve on a high Safety level. Petrojarl I was one of the first installations to have its Safety Case approved by UK authorities and we find that the continuing challenge and control from the Authorities is having a positive effect.
It is essential to have equal focus on the management of risk for major disasters and the avoidance of more limited accidents to individuals. We believe that accidents can be prevented and have seen a continuous improvement to our safety record. When one of our employees broke two fingers in an accident on Petrojarl Foinaven in May, this was the first Lost Time Accident on that installation in near to 6 years.

The focus on the effect to the environment from our industry is ever increasing. We were one of the first FPSO operators to be given the environmental ISO 14001 certification. Produced gas was flared without anybody asking questions when we started our production operation 20 years ago. Today the amount of gas flared is minimal. All our FPSOs are today either reinjecting or exporting the gas through pipelines and Petrojarl Varg has a cold flare system which is only ignited when needed. Petrojarl Foinaven was the first FPSO to use fuel efficient dual fuel diesel engines for power generation and we have continued to use this concept on later FPSOs and for upgrades.

Produced water quantities increase with the maturity of the North Sea fields and with this the challenges of keeping the quantity of oil below a new limit of 30 ppm. There is also a concern over other unwanted substances in the produced water and the tendency is now to reinject all produced water. Petrojarl Foinaven has just had a major upgrade completed while operating, making it possible to reinject all produced water from that field.

8. Conclusions

Floating Production, Storage and Offloading was introduced to the North Sea facing much skepticism twenty years ago. Experience has shown that production from such units can be carried with the same high uptime and safety level as for the fixed installation. Offloading with shuttle tankers can be carried out with the same regularity as with pipelines. Concerns over the influence of the movements on the efficiency of the separation process have proven unfounded.

Petrojarl I is today producing its tenth consecutive field, showing that the FPSO concept is a robust, reusable and efficient production solution. I believe that a major number of new North Sea developments will be carried out with leased mobile production solutions operated by contractors.

Petrojarl ASA has established a company in Brazil and is actively seeking contracts here. We are looking forward to use our North Sea background together with the experience you have gained through your pioneering FPSO projects, to also deliver a safe and efficient operation in this important arena.

10. References

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