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The Siri Production Jack-up Platform

Morten Bærheim, Statoil; Dirk Manschot, MSC; Torgeir Olsen, KOGAS; Henning Eide, Enterprise Oil

Abstract

The Siri field is located in 60 metres water depth in the Danish sector of the North Sea. It was developed by a purpose built three legged jack-up standing on the top of a steel storage tank. The tank was installed in May 1998 and the jack-up was installed six months later.

The reservoir development requires a maximum of 12 well slots, and these will be placed inside a wellhead tower connected to the side of the storage tank and hinged to the deck

This paper will give a brief technical description of the field development and highlight the challenges in design and installation with an emphasis on the steel structures.

Introduction

The licence for exploration and production of the Siri Central / North structures was given medio May 1995 to the Statoil Group. The group consist of the following companies :

Statoil E & P A/S (operator)	40.0 %
Enterprise Oil Ltd.	20.0 %
Dansk Olie og Gasproduktion A/S	20.0 %
Phillips Petroleum Company	12.5 %
Denerco K/S	7.5 %

The first exploration well in Siri Central was spudded at the end of November 1995, with a second appraisal well drilled in August 1996 on Siri Central. The two wells gave the basis for establishing the reserves for the field development studies. A third appraisal well was drilled on neighbouring Siri East proving non-commercial reserves in that area.

A "fast track" field development strategy was established in February 1996. Screening studies of alternatives were done, and the first feasibility study of what later became the selected field concept was initiated in July 1996. Conceptual studies linked with competitive bidding with three contractors for a full EPCI bid for the complete platform including an oil offloading system was concluded at the end of December 1996. After some further development work, the EPCI contract was signed with Kvaerner Oil and Gas (KOGAS) at the end of March 1997. The storage tank was installed medio May 1998, after which drilling started with the Noble George Sauvageau jack-up drilling rig operating in cantilever mode. The 8700 t jack-up production deck was installed medio November 1998 after 7 weeks waiting on weather. This gives a time span of 18 months from signature of EPCI contract to deck ready for towage, which is considered to be very quick for a project of this size.

The Siri field

The Siri field is located in block 5604/20 in the north-western part of the Danish sector of the North Sea, some 220 km from the coast line. The field is marginal, and various development options were investigated in the middle of 1996 to find an economically attractive solution. These included:

- Jacket full process platform with storage tanker
- Concrete full process platform with storage
- Combinations of steel and concrete solutions
- Combinations of wellhead and process platforms
- FPSO ship with sub sea wellheads
- Converted jack-up platform with storage tanker
- New built jack-ups with storage tanker

The infrastructure around the Siri field is limited, and the most attractive solution for oil export was via a shuttle tanker. In august 1996, the concept of a new built jack-up standing on a steel or a concrete storage tank with a wellhead tower extending from the tank to the deck was chosen for further study. This is shown in figure 1. The wells are drilled by a jack-up rig operating in cantilever mode. Well maintenance is to be performed with drilling equipment (coiled tubing or snubbing) lifted onboard by platform crane. A 400 m2 deck at the end of the platform towards the wellhead tower is provided for this purpose.

This concept was further evaluated through the winter 1996 / 1997, and a contract for engineering, procurement, construction and installation (EPCI) was signed on the 21st of March 1997 with Kvaerner Oil and Gas (KOGAS).

Design data

The main data for the field development is given in table 1 below.

ENVIRONMENT	
Water depth	60 metres
100 year wave	25.7 metres at15 sec.
Current	1.25 m/s at the surface
Wind	39.5 m/s (10 min mean –10 m)
PRODUCTION CAPACITIES	
Max. oil production	8000 Sm3/sd
Max. water production	11000 Sm3/sd
Max. liquid production	12000 Sm3/sd
Gas compression	0.75 MSm3/sd
Water injection	13000 Sm3/sd
STORAGE / OFFLOADING	
Storage volume	50000 m3
Offloading time	20 hrs.
Offloading system	Single Anchor Loading (SAL)
TOPSIDES	
Deck weight	11000 t operational 9300 t installation (design limit)
Gross deck area	2800 m2
Living quarters	60 beds
WELLS	
Number of well slots	12 (6 prod., 3 SWAG, 3 spare)
Well arrangement	In circle with c-c 1003 mm
RESERVOIR	
Depth	2070 m palaeocene sand
Recoverable reserves	60 MMbbls

Table 1. Main data for field development

Platform description

The Siri jack-up is a fully integrated platform containing wellheads, process equipment and living quarters. The deck is shown in figure 1. The deck layout is traditional with fire and explosion walls separating the three main areas. A flare tower of 96 metres height is installed on one corner of the platform. The height is dictated by the closeness to the drilling rig. The main hull of the deck is 50 m wide and 60 m long. The height is 6.7 m. A "fork" structure at one end of the deck connects the wellhead tower to the hull. The fork arms extend 12 m from the side of the hull and support the well manifolds. The living quarters are cantilevered out some 7 metres on the opposite side of the platform.

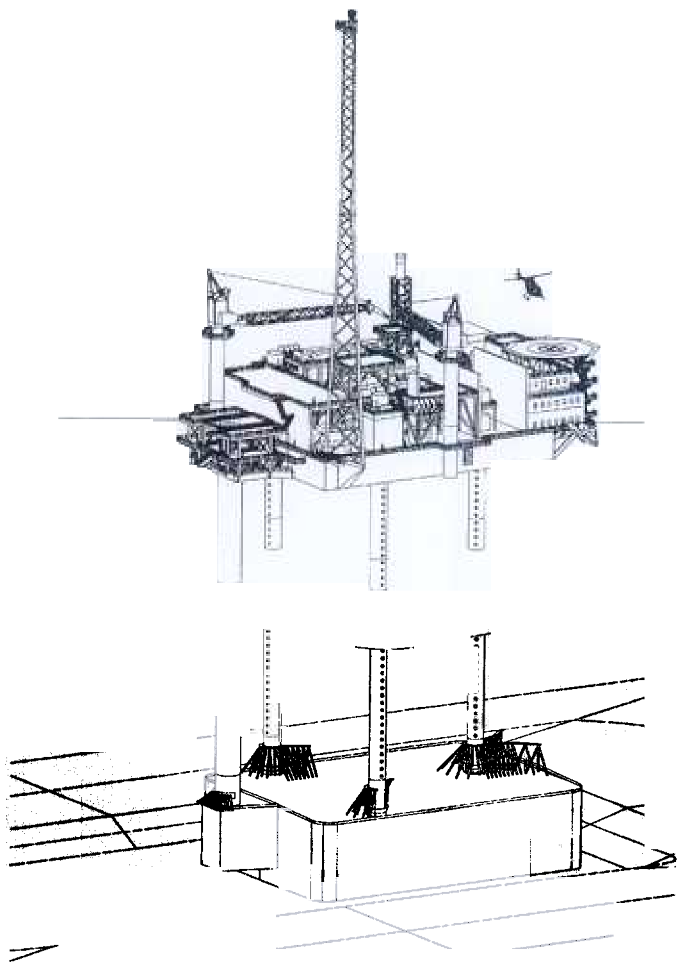

Figure 1. The Siri platform

The deck is supported by three tubular legs of 3.5 meters diameter. The legs stand in 13 metres deep sleeves in the tank structure. The gap between the legs and the sleeves are grouted to provide moment restraint between the legs and the tank. The grout is not designed to carry vertical loads from the legs.

The jacking system is a hydraulic ram pin-in-hole system. Three jacking units are placed around each leg, as shown in figure 2. Each jacking unit contains two hydraulic rams operating on a beam which houses one jacking pin. The three beams are welded together such that they form a ring. There is an upper stationary holding ring that are connected to the top of the jack house and a movable lower working ring around each leg.

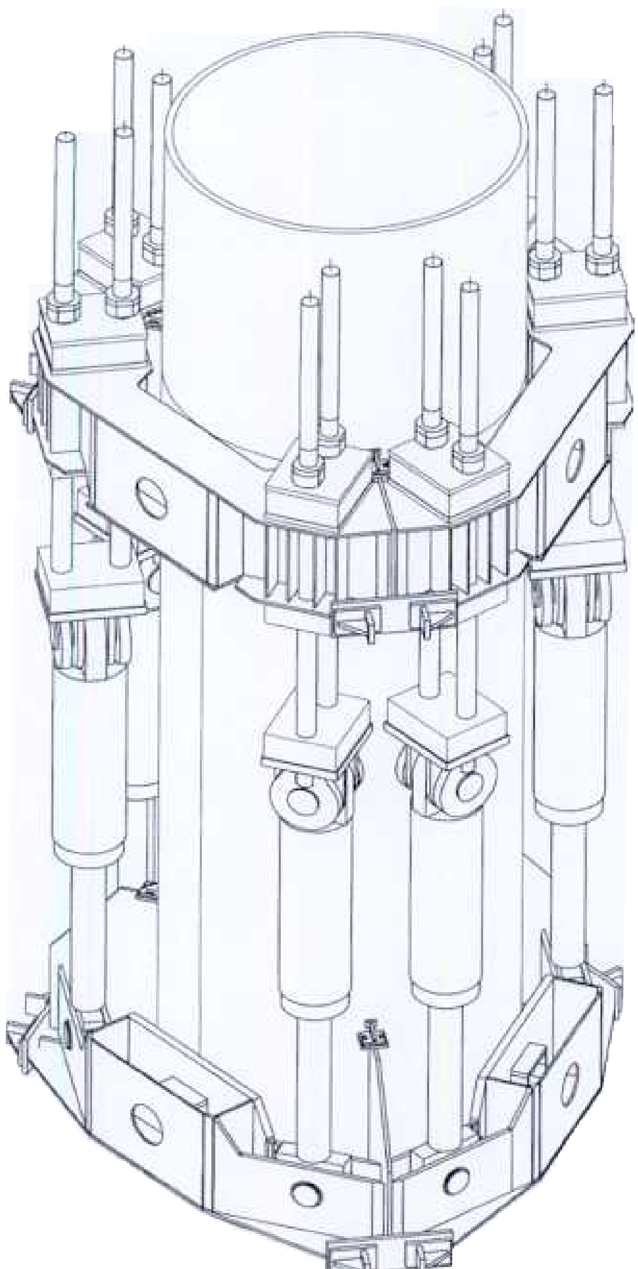

Figure 2. The jacking system for one leg

The jacking system has a built in redundancy such that the deck still can be jacked if one of the three jacking systems around each leg fail. After the deck was jacked up to its correct height on the Siri location, the height of the upper ring was adjusted vertically to coincide with the jacking holes on the leg. The hydraulic cylinders holding the lower ring was shimmed off with steel clamps such that the hydraulic pressure could be bled off. Each leg is hence connected to the deck by six pins; three in the upper ring and three in the lower.

The moment between the leg and the deck are transferred by circular steel guides to the upper part of the jack house and the lower part of the hull. The jacks are supported on rubber bearings to prevent the leg moment being transferred to the jacking system.

The tank is 50 by 66 by 17.5 meter and has an effective storage volume of 50000 m3. The bottom of the tank has skirts of 1.6 and 2 meter depth. The skirts divide the underside of the tank into compartments and these assist in transferring the horizontal forces to the bottom. Suction between the seabed and the bottom of the tank was used to penetrate the skirts, after which the remaining space between the seabed and the tank was filled with grout.

The seabed consisted of 5.2 meter of sand above hard clay. The sand was not strong enough to carry the horizontal forces from the waves and wind, and was therefore dredged away to simplify the foundations of the tank. The effect of dredging was twofold, it reduced the skirt length by 5 metres and it reduced the effect of the tank on the wave height. When a wave passes a large object on the seabed in shallow water, there is a build-up effect on the wave height. With the top of the tank 12.5 metres above the seabed, the 100 years extreme wave height is calculated to increase by 5 % as the wave passes over the tank. This value would have been higher without dredging.

Benefits of the Siri jack-up solution

During the evaluation of the various field development scenarios, it became apparent that the jack-up concept had several benefits that would assist in reducing the field development costs:

The jack-up solution allows substantial completeness of the deck structure in the yard thereby reducing the offshore hook-up.

2. The platform installs itself. The cost of an expensive lift vessel is avoided.
3. The combination of a jack-up standing on a storage tank opens up the possibilities of using circular tubular legs since the legs are shorter than without

the tank and the tank gives a fixed bottom connection for the legs. The circular legs are substantially cheaper than similar steel truss legs.

4. The circular legs can use a simple and cheap jacking system.
5. The circular wellhead tower protects the wells from wave forces and allows standard dry wellheads to be used.
6. The tank with wellhead tower can be installed before the deck to allow pre-drilling of wells.
7. All oil piping (to and from the tank and export), sea water lines, risers and J-tubes are located inside either the wellhead tower or the legs. This gives a substantial reduction of wave forces on the structure.
   The hull is large in area and volume, but cheap to fabricate.

Topsides design considerations

The topsides equipment is placed in small modules of up to 500 t on top of the jack-up hull. The hull is in general relatively large allowing ample space for the topsides equipment. The hull size is given by a combination of strength and buoyancy requirements. The deck space itself is hence provided at a relatively low cost.

The initial philosophy was to limit the equipment inside the hull. With a hull size of 50m by 60m and a hull height of 6.7 m, it soon became apparent that the hull volume was too attractive to be left empty. The hull now houses diesel and water storage, electrical rooms, general storage, ventilation and communication rooms. This resulted in a high number of penetrations through the hull, and this gave two major challenges:

- The penetrations were a hazard during tow out, and extensive effort was spent in ensuring a watertight hull.
- Gas ingress into the hull during operation is a very important design condition, and this has affected both design and operational procedures.

The weight of the hull was initially estimated to be 7300 t. During the early phases of the project it became apparent that this weight would increase. Based on expected changes, the new weight limit for jacking was set as 9300 t, and an active weight control system was introduced. The deck, jacking system and legs were designed based on this weight and a maximum operational weight of 11000t. Even though the predicted weight at times during the design phase exceeded the design weight, at the time of installation the deck weighed 8700 t. The increased weight had small effects on the amount of steel in the hull and the legs. It did, however, result in an upgrade of the jacking system. The cost impact was reasonably small, and it showed that this jack-up concept has good tolerance for weight increases when identified at an early stage of the design.

The wellhead manifolds and the "fork" structure

The wellhead manifold structures are placed on two "fork" structures at the bow of the hull, one at each side of the wellhead tower, as shown in figure 3. The forks also provide the connection between the wellhead caisson and the hull. The forks extend some 12 metres from the side of the hull. The forks are extensions of the double bottom, having a height of 1.4 metres.

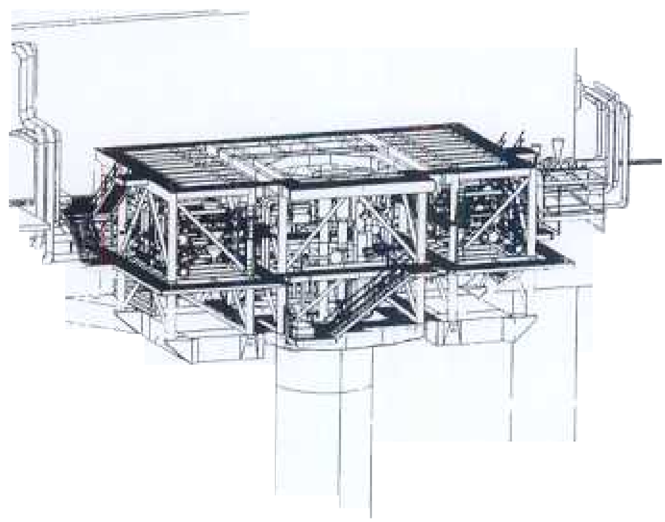

Figure 3. The forks. The wellhead decks are in the middle and the two forks structures with well manifolds are on either side of the wellhead decks.

The wellhead manifolds are designed with a minimum height to allow the cantilever of the drilling rig to pass over it during drilling. The manifold structures at their operational position are therefore marginally higher than the hull. This posed problems both for the fabrication and installation phase. For the major part of the fabrication and the tow out phase the draft of the deck was some 3.7 meters, which means that parts of the manifolds would be below water during both these phases. In addition, they would in the worst case be subject to wave forces from a 10 year seasonal storm wave or, at best, to forces from transport condition waves and the bow run-up effect for towage. This was clearly not acceptable. Various alternatives were therefore investigated for protection. The chosen solution was to hold the 450 t manifold structures 8 metres above the fork and sea fasten them on the adjacent fire and explosion wall. After installation of the deck, the manifolds were lowered down to their final position by continuos strand jacks. The jacks were supported by columns running through the main vertical members of the manifold structures down to the fork. The columns were free standing and the sea fastening was connected directly between the manifolds and the wall. The advantage of this solution was little additional weight and cost. The disadvantage was that all the piping between the manifolds and the deck had to be welded offshore, thereby increasing the offshore hook-up and completion scope considerably.

The connection between the hull and the wellhead tower should give a pinned horizontal translatory connection and at the same time give vertical and rotational freedom for the deck. The rotational freedom was necessary since the wellhead tower is a lot stiffer in rotation than the legs are in translation, such that the tower would be overloaded in torsion if the rotational connection was fixed. The initial solution to this was a steel to steel sliding connection. Soon after installation it was discovered that this quickly wore. The steel to steel connection could also give sparks when moving. Sparks has actually been observed when dark, and sparks as an ignition source are obviously not acceptable in a wellhead area. An alternative solution with two pinned struts, one in the longitudinal and one in the transverse direction, was chosen. This provided a cheap solution to an otherwise complex problem

The platform legs

The legs are 104 meter long, have an outer diameter of 3.5 meter and weigh some 800 t each. The wall thickness of the legs varies from 65 to 110 mm. The lower 27 metres of the legs are without holes for the jacking system and are made out of 390 MPa steel. The remaining parts of the legs have 460 mm diameter jacking holes spaced at 1750 mm and are made of very high strength. The high strength steel was mainly chosen due to the high contact loads from the pins in the jacking system. Each leg was installed as a complete leg with some piping inside while the deck was afloat at the Rosenberg yard in Stavanger. Two floating shear-leg cranes were used simultaneously for this spectacular operation.

The dimensions of the legs are governed by three design conditions:

1. Yield in the jacking holes due to concentrated loads from the jacking pins
2. Static strength due to global axial loads and bending moments due to deck weight and environmental forces.
3. Fatigue in the circumferential girth welds or in the parent metal at the jacking holes.

The minimum yield strength specified for the legs were 690 MPa, and the steel was delivered with an actual yield strength of nearly 800 MPa. This extra strength is beneficial for the yielding in the holes and the static strength conditions. For the fatigue conditions, however, this is negative. CTOD tests of the heat affected zone showed that there were areas of low fracture toughness in the heat affected zones of the welds, and it was shown that very little fatigue crack growth was permissible before a brittle fracture would occur.

Extensive fracture mechanics and crack growth analyses have been performed complimented by laboratory testing of the parent and "as welded" Siri materials. The results of this show that the fatigue life is satisfactory, but not as long as aimed for. This means that the legs will have to be inspected at an earlier stage of the platform life than originally planned.

It is the circumferential welds that are critical, especially where these are linked with thickness transitions and high bending moments. These locations are just above the tank top and just below the lower guide in the hull.

The inspection of the legs is a challenge in itself. Each circumferential weld is 11 metres long, and the outer surface is ground smooth, so there is no weld cap to identify the presence of the weld. The grinding of the welds were done both from a fatigue point of view and from the need for a smooth outer surface of the legs when passing through the guide rings of the jacking system. The requirement for smoothness also resulted in a requirement for constant outer diameter. All thickness transitions are hence made on the inner surface of the legs. Due to the local bending moments arising from the eccentricities at thickness transitions, the highest dynamic stresses in the legs are therefore occurring at the inner surface of the legs.

The outer surface of the leg is coated with hot sprayed aluminium, and the inner surface is painted. Normal MPI at the outer surface will therefore be hindered by the aluminium cover, and access to the inside of the legs is restricted due to equipment placed inside the legs. Even if it in principle is possible to inspect the legs with traditional MPI, the practical problems of access, weld location and surface protection makes it virtually impossible to inspect the legs by traditionally accepted methods to a high standard of quality.

The actual length of the inspection intervals is not yet defined. The method of inspection is also not yet defined, but the aim is to establish a mechanised method that can inspect both the inner and outer surface from the outside of the leg from a control centre above the water surface. Various methods are being investigated at the time of writing this paper.

Installation

The tank was built by Daewoo in South Korea. It was transported to Stavanger on the heavy lift vessel "MS Swan". After offloading from the vessel and a short period of testing it was towed out to the Siri field by three tug boats. The lowering of the tank down to the seabed was successfully done in extremely good weather conditions in the middle of May 1998. The tank was empty during the tow out.

The tank has three separate buoyancy compartments each designed for nearly 60 metres water pressure. The main tank is only designed for the effect of oil buoyancy and wave pressure at the top of the tank. The buoyancy tanks are located around the leg sleeves, and they are used to provide tilt and depth control during lowering of the tank to the seabed. 5000 t of concrete was also installed in Korea in the bottom of the tank to provide stability. The concrete ballast was limited due to the capacity of the heavy lift vessel. Good weather was necessary to observe the effects of the trimming of the tank that had a GM value of only 0.6 metre.

The tank installation was done through the following steps:

a) The main tank was filled completely
b) The buoyancy tanks were filled in increments until the top of the tank was just below the water surface. The tilt of the tank was carefully controlled during this operation.
c) The tank was lowered to the seabed by filling water into the wellhead tower.

The deck was ready for tow on the 1st October. The standard requirement for offshore barge transport of survival in a 10 years storm was used as criteria for the transport. This had a marked effect on the design of the living quarter module. Two criteria were limiting for the deck mating to the top of the tank:

a) Horizontal dynamic forces in the legs as they were hitting the guides on top of the tank
b) Vertical dynamic forces as the legs were hitting the bottom of the tank

The vertical forces were the most critical with respect to weather conditions, and rubber dampers were therefore installed at the bottom of the legs to dampen the impact forces. This raised the permissible sea state during installation to approximately 1.0 m Hs for wave periods less than 7 seconds and somewhat higher sea states for lower periods. The motions of the deck in wave swell conditions were seen from model test to be critical, and this was also experienced during installation.

The deck was twice towed by four tugs to the Siri field; in the beginning and at the end of October, but on both occasions the weather conditions were not acceptable for mating to the tank. On the third attempt in the middle of November, the deck was successfully installed in extremely good conditions for the time of the year. The drilling rig remained on location with retracted cantilever during the installation.

Operation and removal

The Siri platform will, during normal operations be manned by 21 persons. The living quarters have a capacity of 60 persons in single cabins, mainly to cater for maintenance and well work-over operations.

The operational life of the Siri field is estimated to be 10 years, and this is the design basis for the topsides equipment. The life requirement for the structure has, however, been set to 20 years. Being a jack-up, the platform can with relative small cost be reused on other fields of similar or shallower water depth. The removal operation is basically a reversal of the installation, but the deck and tank is to be removed as one piece.

The most critical item in terms of feasibility for reuse is the tank foundations. In some cases it may actually be cheaper to scrap the tank and wellhead tower, and build a new structure as foundation support. If storage is not required on the new location, the foundation support could be a jacket-like structure. This could be built higher than the Siri tank such that the platform could be used in deeper waters.

Project organisation

The project management philosophy of the Siri project was to keep Statoil management to a minimum and to give the whole platform development responsibility to only one Contractor. Statoil had only three full time persons in Contractors office, but Statoil discipline engineers were on a part time basis following up their own disciplines from the home office.

Kvaerner Oil and Gas (KOGAS) was chosen as the engineering, procurement, construction and installation

(EPCI) contractor for the complete Siri jack-up platform with oil offloading system. KOGAS had the responsibility for the quality assurance of the project, while Statoil verified this and ran independent 3. party verification analyses of the main structural steelwork. Lloyds Register was responsible for the 3. party verification analyses. In addition, Lloyds Register was selected as Warranty Surveyor and assisted Statoil in quality assurance activities and adherence to Danish rules and regulations.

The EPCI contract had two major interface areas:

The drilling operations
Statoil Siri operations.

Both interfaces were focused on at an early stage, and the operations department of Statoil had one representative (or at times several) on the project team for the duration of the project.

The project requirements were specified in a 43 pages project design basis. Standard specifications (NORSOK), clear definition of responsibilities and the limited number of interfaces are all contributing reasons for KOGAS being able to run the project on schedule in the short 18 months time span.

The EPCI project cost for the Siri platform and offloading system (but not including drilling) is just above 2 billion Norwegian kroner.

Conclusions

The Siri field development has shown that purpose built jack-ups are cost effective concepts that can be designed and built in a relatively short time.

The jack-up deck can also be placed on top of a jacket that is terminated some 10 metres below the water surface. In this way, the possible water depth of the cost effective jack-up concept can be extended.