Statoil uses flotation of 10 ¾-in. liner to reach beyond 10 km in Gullfaks Field

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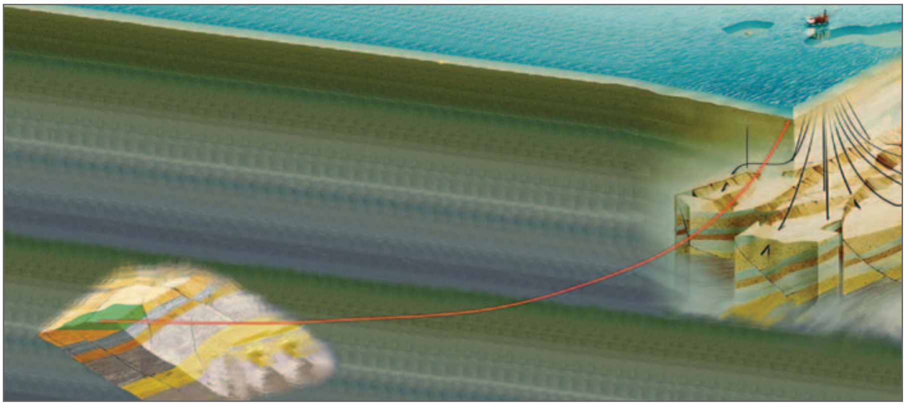

In the Statoil-operated Gullfaks Field, the 4,660-m long 10 ¾-in. liner was floated to section TD at 7,721 m in May 2006. Gullfaks well A-32 C, named Gulltopp, is the longest well planned from an offshore installation, with a planned TD at more than 10 km.

THE REQUIREMENT TO drill longer wells to reach reserves on the boundaries of the **Statoil**-operated Gullfaks Field required new solutions and techniques. The planning of the 10 km-plus long well A-32 C presented a challenge where flotation technology was required.

The 4,660-m (15,285 ft) long 10 ¾-in. liner was successfully floated to section TD at 7,721 m (25,324 ft) on 9 May 2006. The Gullfaks well A-32 C, named Gulltopp, is the longest well planned from an offshore installation with a planned TD at more than 10 km. The simulation in the planning phase indicated it would be very difficult or impossible to run the 5-km 10 ¾-in. liner to TD with conventional methods due to drag and buckling. The flotation method was selected for the 10 ¾-in. liner to overcome drag and buckling problems.

Simulation showed using flotation and running the liner fully evacuated with air gave substantial reduction in torque and drag. This solution required development of new equipment with special floats to withstand more than 360 bar (5,200 psi) differential pressure. Snubbing slips were used to secure the liner during running. It took more than one year to plan and prepare this well.

INTRODUCTION

Reaching reserves at and beyond the boundaries of the mature Gullfaks fields has resulted in planning and drilling longer wells. The longest well planned to date is the 10,010 m (32,833 ft) long well to the Gulltopp field west of the Gullfaks main structure.

The Gullfaks Field is located in the Norwegian sector of the North Sea. The field consist of 3 concrete production and drilling platforms. The original drilling unit was designed to drill wells to approximately 6,500 m (±21,000 ft), which is adequate for wells on the main structure. The longest well drilled so far on the Gullfaks structure is well 34/10-A-47, drilled to 9,052 m (29,690 ft).

Lately, there have been several discoveries nearby the Gullfaks Field, including the Gulltopp Field. The new Gulltopp Field was evaluated for development with individual subsea templates and pipelines to the Gullfaks Field, or with ERD wells drilled from the Gullfaks "A" platform. A Gulltopp development with wells drilled from Gullfaks "A" platform was evaluated to cost a quarter of the subsea development. The big challenge with developing the Gulltopp field from Gullfaks "A" platform was to drill and complete wells at 10,000 m (±33,000 ft) or longer. The ability to master the technology to drill long wells on the Gullfaks Field has huge cost-savings implications, allowing marginal fields to be developed. It will also extend the Gullfaks Field late-life production. The decision was made to develop Gulltopp by drilling long wells from Gullfaks A.

The first well to Gulltopp was planned as a sidetrack from well A-32B under the 20-in. casing at 1,100 m (3,608 ft). All personnel planned to participate in the development of the well was involved in the planning phase early on. This included onshore and offshore personnel from operator, drilling contractor, service companies and consulting companies.

Early in the planning phase, it was recognised that the ±5,000 m (±16,000 ft) long, 13 ½ -in. by 12 ½-in. section was going to be particularly challenging. Running the 10 ¾-in. liner to 8,000 m (±26,000 ft) with conventional methods was simulated to be to very difficult and at the limitations of the rig's hoisting capacity if it became necessary to pull the liner out due to problems of any kind. Running the 10 ¾-in. fully evacuated (i.e., floated) was considered the best solution to case off the 13 ½-in. section.

PLANNING

The well is planned to be drilled to 10,010 m (32,833 ft) in 4 sections. The first section was a 17 ½-in. section to be drilled from 1,100 m to 3,500 m (±11,500 ft), then a 12 ¼-in. by 13 ½-in. section to 8,000 m (±26,250 ft) then a 8 ½-in. by 9.05-in. section to 9,600 m (±31,500 ft) and finally 6-in. hole to TD at 10,010 m (32,850 ft).

RISK EVALUATION

Risk evaluations have been performed throughout the planning and operation of the Gulltopp well. This covers HSE, technical, operational and cost effectiveness considerations.

A work process for continuous improvement was established. The process included use of peer groups, workshops and HAZOP for the running fully evacuated 10 ¾-in. liner. The different methods were evaluated based on technical solution, production rate (Sm3/d), productivity PI (Sm3/d/bar), cost, risk, net present value (NPV) and HSE merit.

All operations on the Gulltopp well were subjected to a risk assessment prior to the operation taking place. The group carrying out the analysis included personnel with detailed knowledge of the equipment/operation being analyzed and consisted of Statoil and supplier/contractor personnel. All risks classified in the red area were accepted by the asset manager. All risk classified in yellow area were accepted by the drilling manager. Risk reducing measures were implemented for red and yellow risks.

• Based on the risk assessment, contingency plans have been established for selected operations;

• Based on risk assessment, quality assurance and quality control were performed on equipment used for running the 10 ¾-in. fully evacuated liner;

• Flow charts/decision trees have been used to aid the decision-making process for critical operations during drilling operations activities;

• Check lists were used to ensure that all aspects of the planning phase have been covered;

• Well barrier schematics were developed to illustrate the presence of the defined primary and secondary well barriers in the well;

• Contingency procedures were established for how to handle well control incidents when running the liner through the BOP;

• Workshops have been performed for all operations on the Gulltopp well where well site and office personnel attended;

• HAZOP was used for the 10 ¾-in. fully evacuated liner.

PERSONNEL

One project goal was to get all personnel involved in the project assigned as early as possible. This covered personnel from the rig contractor, service companies and operator personnel itself. Parallel with planning the ERD well, human relations and ERD drilling practice courses were conducted for all personnel involved in the project. The objective of the human relation part of the training was to build a strong team and to develop the skills required to cope with this big challenge.

Liner flotation was a new technique for most of the personnel. The flotation operation was given high focus by preparing detailed procedures. Special focus was given to the potential risk of an uncontrolled leak or collapse of the liner. Such an incident could result in an uncontrolled filling of the liner with mud and a subsequent drop in hydrostatic head in the annulus. This could result in a well-control incident or a collapse of the wellbore.

THE DRILLING RIG

The Gullfaks "A" platform is 20 years old, and the drilling rig itself was originally designed to drill wells up to 6,500 m and at 60° maximum inclination.

The rig has been upgraded during the last 20 years to cope with new regulations and growing tasks. A criticality study of the drilling facility was required prior to start drilling a record well beyond 10 km. The drilling rig was upgraded for the job with modifications in the mud-processing module, complete overhaul of the drawworks, installation of an extra mud pump, and elevated focus on general maintenance.

CASING DESIGN

The highest risk during the flotation operation was a collapse or leak in the air-filled liner leading to a well-control incident. To reduce risk, all items of the liner were extensively tested and quality-controlled.

Burst load (in a tubing leak scenario) was the dimensioning criteria for the 10 ¾-in. liner. Governing documents required a safety factor of 1.1 minimum for burst loading. The selected 10 ¾-in., 65.7 lb/ft, Q125 liner had a safety factor against collapse of 1.35 under dynamic conditions (including surge pressure while running in) with the well filled with 1.59 sg fluid. A higher safety factor was selected to reduce risk of liner collapse and allowed room for pressure and mud weight variations.

Procedures were also made to thoroughly check all liner joints when run for any damages to treads or joint body. Any liner joint weakness may have resulted in an uncontrolled filling of the 10 ¾-in. liner.

WELL PATH

The well path was planned in 2D with maximum 2° doglegs to reduce drag. For the same reason, a rotary steerable system were selected to get as smooth a well path as possible.

SIMULATIONS

Several simulations were performed with multiple design variations, to achieve the final well design. The decision was based on robustness in selected plan and flexibility with several contingency solutions. Simulations showed that running the +5,000 m long 10 ¾-in. liner conventionally filled with mud would allow a very small tolerances to less-than-ideal friction factors. The well needed to be in very good condition, with an average friction factor of <0.20 to succeed, which was considered impractical, base on offset experience. Simulations indicated the liner could not be pulled after below 6,500 to 7,500 m (point of no return), depending on the actual friction factor. This is based on the net lifting capacity on Gullfaks A, which is limited to 310 metric tons (680 kips).

Simulations showed the liner could not be rotated during a conventional run, due to torque limitations of the top drive and casing connections. The small margins to run the liner to TD and the possibility of not being able to pull liner out of well indicated it would be virtually impossible to run the liner conventionally. It was also evaluated to be a more useful tool to rotate the liner past possible obstructions rather than to circulate. Based on the simulations and the possibility to rotate, application of the flotation technique was selected for running the liner.

Simulation with air-filled liner showed that it could be run with an average friction factor of up to 0.5. This showed much better margins than running the liner filled with mud. The downside was that an evacuated liner is very light. Simulated slackoff hook loads were less than the block weight, for >0.48 average friction, indicating the liner would need to be pushed for some distance. Torque simulation showed the maximum expected torque was 14 kNm with a friction factor of 0.4. Optimum make-up torque of the Vam TOP connections was 31 kNm, giving a good safety factor for rotating the liner.

BUOYANCY

Flotation is used as the description of an operation running the liner empty rather than filled with mud. The liner is ideally not supposed to "float" but rather be lightened by substituting the mud inside with air or nitrogen. In the Gulltopp case, the 10 ¾-in. liner was close to positive buoyancy, and the mud density was adjusted to 1.59 sg for this reason. The casing weighs 3 lb/ft submerged in 1.59 sg drilling fluid using nominal ID. The actual ID was measured 0.1 in. larger (9.66 in). The casing was also weighed, confirming the weight was close to nominal at 65.7 lb/ft in air. The slightly larger OD and ID resulted in increased buoyancy.

Using the actual measurements, the submerged weight in 1.59 sg mud is only 2 lb/ft. The 10 ¾-in. liner would be neutrally buoyant in 1.64 sg fluid.

Poor hole condition and hole collapse resulted in a failure running the 10 ¾-in. liner to TD at first attempt. The liner was run to ±550 m (1,800 ft) below the 14-in. casing shoe before it stopped. The experienced down weight was lower than simulated values almost immediately as the liner was run. Real-time diagnosis suggested that the annular mud density was much lighter than nominal in the vertical part of the hole and much heavier than nominal in the high-angle part of the hole, suggesting barite sag (which was confirmed with light and heavy mud density at the flow line). Below the casing shoe, slack-off weights deviated severely from predicted values, indicating poor hole condition. It was required to push the liner with the entire block weight when the 10 ¾-in. liner entered the open hole. Approximately 0.5 m of upward movement was observed as compression was released from the casing prior to setting the slips.

MUD OVER AIR

Mud over air (selective flotation) was evaluated early in the planning phase but not considered a necessary technique. Experience gained in T1 led the team to reconsider selective flotation as a means to deal with neutral and/or positive buoyancy.

GLASS PLUG

Use of glass plug in the 10 ¾-in. casing was evaluated for use but was excluded due to uncertainty related to how many pressure cycles were required to detonate plug. Also, the amount of debris from the detonators caused some concern with regards to possible plugging of the reamer-shoe outlets.

SNUBBING SLIPS

During the planning of the re-drill of the 12 ¼-in. by 13 ½-in. section, it was discussed what could be done to secure the liner if it became positively buoyant. The risk for injury to personnel and equipment if the liner started to float out of well were high. This risk was also elevated by the plans for increasing the mud weight from 1.59 sg to 1.64 sg for hole stability. With a mud weight of 1.64 sg, the liner should in theory be neutral buoyant.

Filling mud at an early stage helps for a short period until the liner is in the highly deviated section. Mud in the bottom of the liner would then mostly give increased drag, making it more difficult to slide the liner to TD. Mud was planned to be filled into the liner above a flotation collar. The flotation collar would prevent the mud to flow to the shoe track and was planned to be installed 200-300 m below the liner hanger.

It was decided to use a snubbing slips mounted above rotary table to secure the liner. The challenge is that the master bushing were not designed to handle pipe-light loads. This problem was solved by designing a frame secured to the lifting arrangement for he rotary table. The actual loads on the slips were expected to be less than 10 tons (22 kips), and the frame was designed to handle 20 ton (44 kips). The slips used were a standard hydraulic snubbing slips designed for loads up to 300 tons (660 kips). Controllers for the slips were mounted in the driller cabin for easy operation by the driller. New procedures were made to prevent interlock between the standard rig slips and the snubbing slips during operation.

When running of 10 ¾-in. liner at second attempt, the pipe became positively buoyant and the snubbing slips were required from ±3,000 m (9,800 ft) until installing the liner hanger at 4,650 m (15,250 ft). Pipe-light weight were from 5 tons to 15 tons. The snubbing slips became a vital piece of equipment to secure a successful run of the liner. Why the pipe became 10-15 ton lighter than expected is not fully understood but is interpreted as a function lighter than nominal casing weight and/or the drilling fluid being slightly heavier when cooled down (or sagged slightly). A distinct change in loads at 4,650 m is due to filling 30 tons (66 kips) of mud in the liner above the flotation collar.

After installing the liner hanger and filling 25 tons (55 kips) of mud above flotation collar, the liner was run to TD in pipe heavy mode.

Floated Liner - Effective Weight Calculation

Liner OD (in)	Liner ID (in)	Liner Weight (lb/ft)	Mud Weight (sg)	Buoyant Weight (Floated Liner) (lb/ft)
10,75	9,56	65,7	1,59	3,0
10,75	9,66	65,7	1,59	2,0
10,75	9,66	65,7	1,61	1,2
10,75	9,66	65,7	1,62	0,8
10,75	9,66	65,7	1,63	0,4
10,75	9,66	65,7	1,64	0,0

In the above table, flotation is used as the description of an operation running the liner empty rather than filled with mud. The liner is ideally not supposed to "float," but rather to be lightened by substituting the mud inside with air or nitrogen. In the Gulltopp case, the 10 ¾-in. liner was close to positive buoyancy, and the mud density was adjusted to 1.59 sg for this reason. In the table, it can be seen that the casing weighs 3 lbs/ft submerged in 1.59 sg drilling fluid using nominal ID.

10 ¾-IN. LINER SYSTEM

Equipment essential in the "floating" of the 10 ¾-in. liner included:

- Reamer shoe without float;
- Float collar – flapper – cast iron;
- Float collar – pump-off plug – cast iron;
- Landing collar for flotation collar inner sleeve;
- Flotation collar with inner sleeve;
- Liner hanger – 10 ¾-in. by 14-in.;
- Drill floor mounted special slips system that could handle weight downwards and upwards;
- Top Drive to allow for rotation while RIH with liner;
- Swedges to be used between top drive and top of 10 ¾-in. liner as backup means with regards to rotation while RIH with liner.

OPERATIONS

First liner running attempt – misrun: 12 ¼-in. by 13 ½-in. hole was drilled from the 14-in. casing at 3,299 m (10,820 ft) to 8,009 m (26,270 ft) MD in one run. While circulating at TD, a washout in the string was recorded. The 5 7/8-in. DP string was backed off at 1,345 m (4,411 ft) with "string shot," and the damaged DP was laid out. Started lubricating OOH with BHA after ±5 days.

Ran in hole with fully evacuated 10 ¾-in. liner. The liner had to be pushed into the hole from 2,600 m (8,500 ft) MD using a push plate. The remaining 10 ¾-in. pipe was loaded onboard the platform from boat after RIH to 2,800 m (13 hours WOW). When entering open hole, the push force to run the liner increased from approximately 7 to 12 tons (15-26 kips). From 3,739 m (12,264 ft) the liner had to be rotated into open hole using a circulation swedge. The liner was pushed into open hole from 3,755 m to 3,923 m (12,316 to 12,867 ft) using a push plate; and rotated again from 3,923 m.

The well packed off from 4,049 m (no return while RIH). The liner stopped completely at 4,056 m (10 RPM/max. 30 kNm torque and used the entire bock weight of 43 tons). Stripped out 4 joints by closing the BOP annular and held 15 bars on the annulus to prevent swabbing. Made a new attempt and rotated the liner down but came to a final stop at 4,060 m (13,317 ft). The liner was stripped out to 3,206 m (10,516 ft). Unable to shear the plug to establish circulation. Continued stripping out to 1,737 m (5,697 ft). Opened the BOP bag and pulled wet to 1,591 m (5,218 ft). Rotated the liner and enabled to shear out the plug with 80 bar (1,200 psi). POOH with liner.

Second liner running attempt - successful run: 12 ¼-in. by 13 ½-in. hole was drilled using a 14-in. whipstock from 3,218 m to 7,727 m (25,344 ft) in 2 runs. Circulated at TD and POOH. Installed snubbing slips on frame prior to run fully evacuated 10 ¾-in. liner. The liner had to be pushed into the hole from 1,800 m (5,904 ft) MD using push plate.

The liner stopped at 2,658 m (8,718 ft) caused by the wear bushing in wellhead. Pulled up, XO to DP and pulling tool. Pulled and removed the damaged wear bushing on second attempt. Engaged snubbing slips from 2,922 m (9,584 ft). Entered open hole at 3,218 m (10,558 ft). Pushed liner with maximum weight (43 tons block weight) from 3,631 m to 3,752 m (11,910 to 12,306 ft). Rotated the liner from 3,752 m. Installed flotation collar at 3899 m (12,789 ft) and filled 6 cu m (38 bbls) of 1.64 SG (13.7 ppg) at 4,064 m (13,330 ft), which is 10 tons (22 kips) equivalent weight. Pushed the liner with push plate from 4,108 m to 4,650 m (13,474 to 15,252 ft). Filled the liner with 9 cu m (56 bbls) of 1.64 SG mud.

The hook-load weight increased from -10 to + 5 tons. Installed liner hanger and rotated the liner down with 6 5/8-in. drill pipe with 10 RPM and 30 kNm (40k ft-lbs) max torque.

The liner was rotated to TD, and hook-load weight gradually improved from 0-8 tons at 4,650 m (15,250 ft) to approximately 5-15 tons the last 1,000 m (±3,300 ft) RIH. The liner had to be run with approximately 2 min/stand to enable smooth running and rotation of the liner. This resulted in mud losses. Lost totally 26 cu m (163 bbls) while running liner on DP. The liner was picked up to 7,718 m (25,315 ft), filled with 1.64 SG mud and set the liner hanger.

CONCLUSIONS

- A 10 ¾-in. liner was successfully floated in to 7,718 m.
- Risk assessment was used as the basis for well planning and contingency solutions.
- A rig survey was performed to find bottlenecks/rig limitations.
- The flotation required development of special cast-iron float and pump-out collar due to high differential pressures.
- New equipment was tested with downhole conditions prior to field application.
- The 10 ¾-in. liners deviated from nominal size, resulting in higher buoyancy and requirement for snubbing slips to secure pipe.
- Rotation was possible at all times when floating in the liner.
- The flotation technique reduced torque and drag substantially compared with conventional liner running.
- The liner could not be moved after being filled with mud at section TD.
- A failure in an air-filled liner may result in a serious well-control incident.

For nomenclature and references, please go online to www.drillingcontractor.org.

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