Expansion system developed, tested to prove expandable monobore liner extension concept

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INCLUDED AS PART of the initial casing design, the goal of an expandable monobore liner extension is to enable the operator to drill deeper exploration and production wells with larger hole sizes at the reservoir. As a contingency plan, the goal is to enable the operator to isolate zones that contain reactive shales, low fracture gradient formations or other drilling situations without having to reduce the casing and subsequent drilled hole size into the reservoir. A one-trip, top-down expansion system was developed and tested to prove the feasibility of the expandable monobore liner extension concept, providing an optimized, cost-effective casing configuration without reducing drilled hole size.

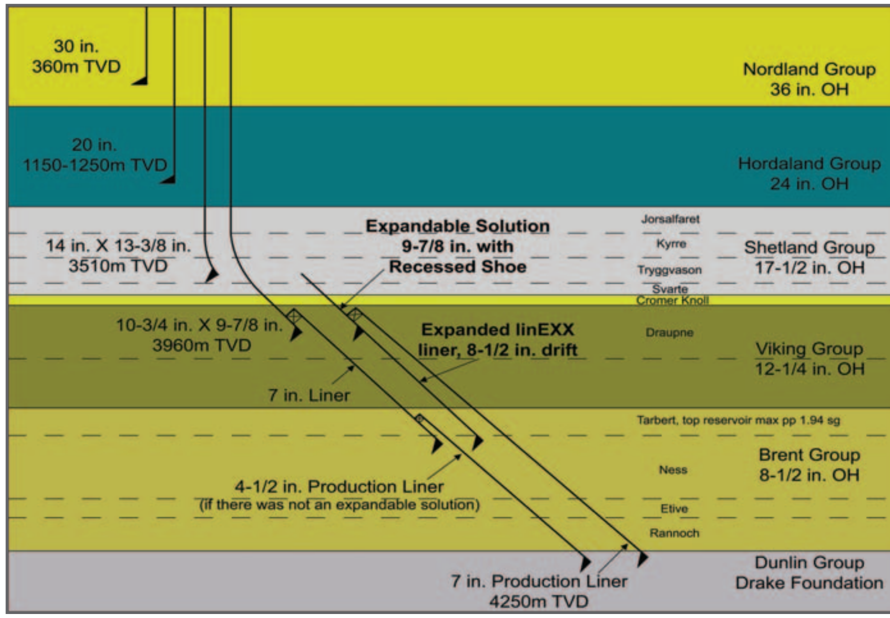


Figure 1: The Kristin and Kvitebjørn fields in the North Sea are HPHT gas and condensate field developments. Kvitebjørn began production in September 2004, and Kristin started production in November 2005.

INTRODUCTION

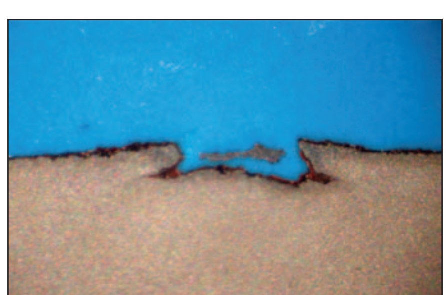
The Kristin and Kvitebjørn fields (Figure 1) are both HPHT gas and condensate field developments located in the Norwegian sector of the North Sea. Kristin lies in the southwestern part of the Halten Bank while Kvitebjørn lies east of Gullfaks. Pressures and temperatures at Kristin are at 13,000 psi (900 bar) and 340°F (170°C) respectively and are the values that formed the design basis of the expandable system.

Additionally, Kvitebjørn required some elastomers to be Aflas® material for chemical resistance. Kvitebjørn began production in September 2004 while Kristin started production in November 2005. Both fields are depletion drive, with later drilling and completion activities expected to occur in a moderately to highly depleted reservoir.

PROJECT OBJECTIVES

Drilling new wells after significant depletion has occurred may present a challenge in these fields. When zones become depleted, the fracture gradient is reduced. Excessive pressure differential between the drilling fluid's hydrostatic pressure and the pore pressure can create differentially stuck pipe and drilling fluid losses. Even fields with pressure maintenance may experience depleted or overpressured, isolated pockets that can cause drilling problems such as in the Statfjord and Gullfaks fields. Four primary objectives for these fields – safety, openhole pressure and well control, wellbore support (minimizing nonproductive time, or NPT) and economics (requiring a 7.0-in. production liner into the reservoir) – were identified. The challenges associated with maintaining hole stability as well as controlling potential reservoir damage in the development of these fields have required drilling contingencies determined to be unacceptable for economic recovery.

Figures 2 (above) and 3 show that in a second trial run, 2 joints of casing had surface indications, identifying a need for an enhanced pipe inspection.



The conventional contingency method of overcoming the drilling challenges was to run a 7.0-in. liner followed by a 4½-in. completion. While this solution may be acceptable in some fields, for adequate production in a depleted state, the 4½-in. completion would represent a significant restriction.

PREPLANNING

To meet the project objectives, varying technical solutions were evaluated. Well and casing design called for 7.0-in. production liner to be set at 13,944 ft (4,250 m) total vertical depth (TVD). Field histories indicated that, to reach this depth, it was anticipated a possible ΔP of 870-1,450 psi (60-100 bar) could be realized due to depletions. The extent of the actual ΔP would not be known before drilling the shale sections below the planned 9⅝-in. intermediate shoe depth at 12,992 ft (3,960 m) TVD.

To maintain pressures and wellbore stability between the 9⅝-in. casing shoe and the reservoir depth for the 7.0-in. production liner, planners determined that a ΔP less than 435 psi (30 bar) would accommodate the standard well design and objectives. In contrast, a ΔP greater than 435 psi (30 bar) would necessitate implementing a contingency drilling program.

The standard field contingency of isolating the shale zones with a 7.0-in. liner met 3 of the project objectives but did not meet the economic goals as the production liner would be reduced to 4.50 in. Contingency monobore systems were introduced and evaluated for these fields based on the impact on all of the project objectives.

DEVELOPMENT, EVOLUTION

A prototype trial of a new **Baker Oil Tools** expandable liner system was run in February 2004. The 7⅝-in. liner was first ultra-sonic (UT) inspected and then run in the test well and free-end expanded 22%. Surface breaking fractures were noted when the pipe was retrieved post expansion. Following this trial, tubulars were changed from 7 ⅝-in. to 8.0-in. outer diameter (OD), thereby reducing the expansion percentage from 22% to 18% and significantly lowering stresses in the pipe.

In December 2004, another trial was run. Again, all joints received standard UT inspection prior to trial. Following the expansion of these 36 joints of casing, the string was pressure-tested and retrieved for FLMPI (full-length magnetic particle, inside surface) inspection. Two joints were found to have surface indications (figures 2 and 3). Following this result, the need for an enhanced pipe inspection was identified. An enhanced UT inspection was developed utilizing 18 shear transducers. These highly sensitive compression transducers are designed to measure low-level defects just below the OD surface.

In November 2005, another trial was run with 27 joints, utilizing the new inspection method to cull pipe determined not suitable. Following the expansion and pressure testing, the expanded liner was retrieved from the well and inspected. No flaws from near-surface inclusions or expansion were found in the string.

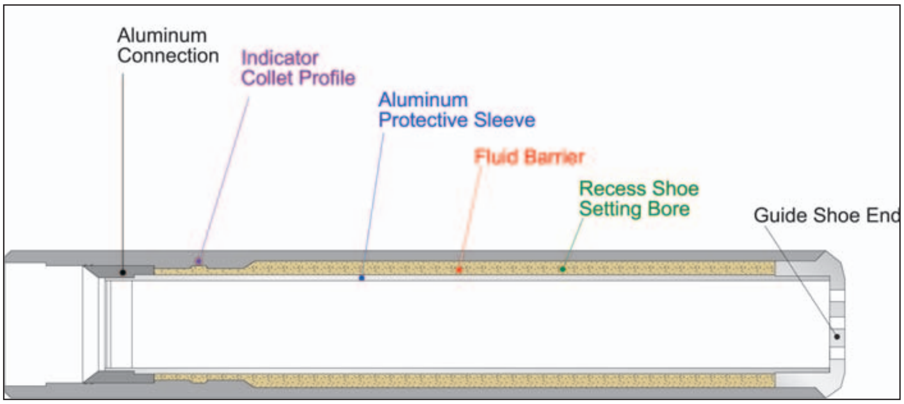
MONOBORE LINER EXTENSION SELECTION

Various monobore systems were evaluated, and extensive prototype testing and system qualifications were performed on Baker Oil Tools' linEXX system to the operator's satisfaction. The contingency system chosen and outlined in this article depicts a staged approach to the monobore well program.

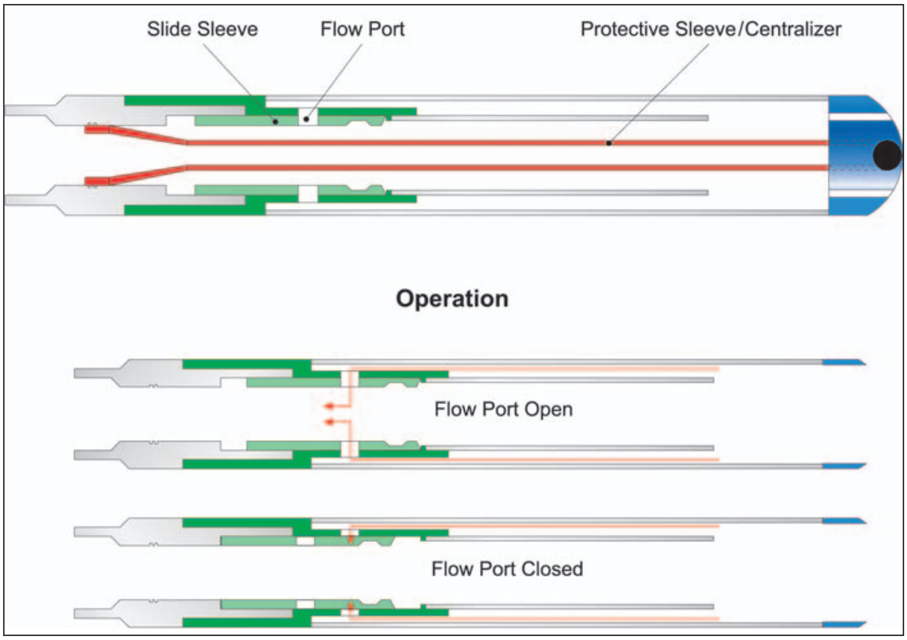
The systems being used for these fields allow for an expandable liner to be deployed through an existing intermediate casing section and run to depth. This new liner is then expanded below the intermediate section and maintains the same inner diameter (ID) as the intermediate section.

The monobore system is connected to the intermediate casing string via a recessed profile in the contingency shoe, which is run initially as part of the intermediate string (figure 3).The contingency shoe run with the intermediate liner functions as a normal casing shoe but also provides a recess area and location profile for the expandable liner if it is required. Once it is determined that drilling program contingencies must be used to obtain the well objectives, the one-trip monobore expandable liner is run and installed using top-down expansion methods. When the hydraulic expansion tool nears the shoe of the expandable liner, a retrieval tool latches onto a retrievable guide shoe and removes the guide shoe on the same trip.

The Kristin field used a contingency recess shoe on the intermediate liner, which does not allow for cementation of the expanded liner (figure 4). The



Contingency Recess Shoe, for non-cementable expandable liner (figure 4): The Kristin field used a contingency recess shoe on the intermediate liner, which does not allow for cementation of the expanded liner.



Contigency Recess Shoe, for cementable expandable liner (figure 5): The Kvitebjørn field used a contingency recess shoe on the intermediate liner, which is ported along with a sliding sleeve to allow for flow area and cementation of the expanded liner.

Kvitebjørn field used a contingency recess shoe on the intermediate liner, which is ported along with a sliding sleeve (figure 5) to allow for flow area and cementation of the expanded liner.

ZONAL ISOLATION

Once the use of monobore liners for drilling contingencies was decided on, the operator addressed the need for potential zonal isolation.

In the Kristin field, the casing program calls for the 9 7/8-in. shoe to be set at the top of the reservoir (Garn). Reduced mud weight could be required to drill the reservoir before running the 7.0-in. production string.

Reducing the mud weight to drill the reservoir may destabilize the Lange shale just above. The contingency liner, if needed, could be set across the shale to maintain hole size. The pressure in the shale is expected to deplete and therefore would not require any specific collapse strength for the application. Cementing the expanded liner would not be necessary, and an expandable openhole packer would provide sufficient annular isolation.

In the Kvitebjørn field, cementation of the long string would be required. In this application, the 9 7/8-in. casing shoe would be set at the top of the reservoir as was Kristin, enabling a 7.0-in. completion through the reservoir. The expanded liner, if used, would need to have collapse strength.

Following cementation of the expanded liner (figure 6) and then drilling through the reservoir, the 7.0-in. production liner run would straddle the expanded section, since the expanded connections do not satisfy production casing criteria. Yield strength in a tensile manner has a tendency to increase through cold deformation of the material, while yield strength in a compressional orientation does not.

This ultimately results in an increase in burst pressure and a decrease in collapse pressure, commonly known as the Bauschinger effect. This reduced rating is a result of stored residual stress following tensile plastic deformation.

SAFETY, ENVIRONMENT

After evaluating the equipment and procedures for the contingency system, it was determined that no additional safety instances would be presented outside the scope of normal drilling operations.

By enabling the contingency system (i.e. running the recess shoe), borehole stability and pressures could be maintained with the contingency system if needed, thus providing a safer well-control environment.

Enabling the contingency system rather than introducing various chemical additives for borehole stability and control means would present no negative impact on the environment. Additionally, implementation of the contingency expandable liner, rather than the previous standard liner step-down contingency, would mean that the 5.0-in. drill string and bottomhole assembly would not need to be pulled out of hole and laid down, and smaller 3.5-in. drill string and bottomhole assembly picked up and run in hole.

CONCLUSION

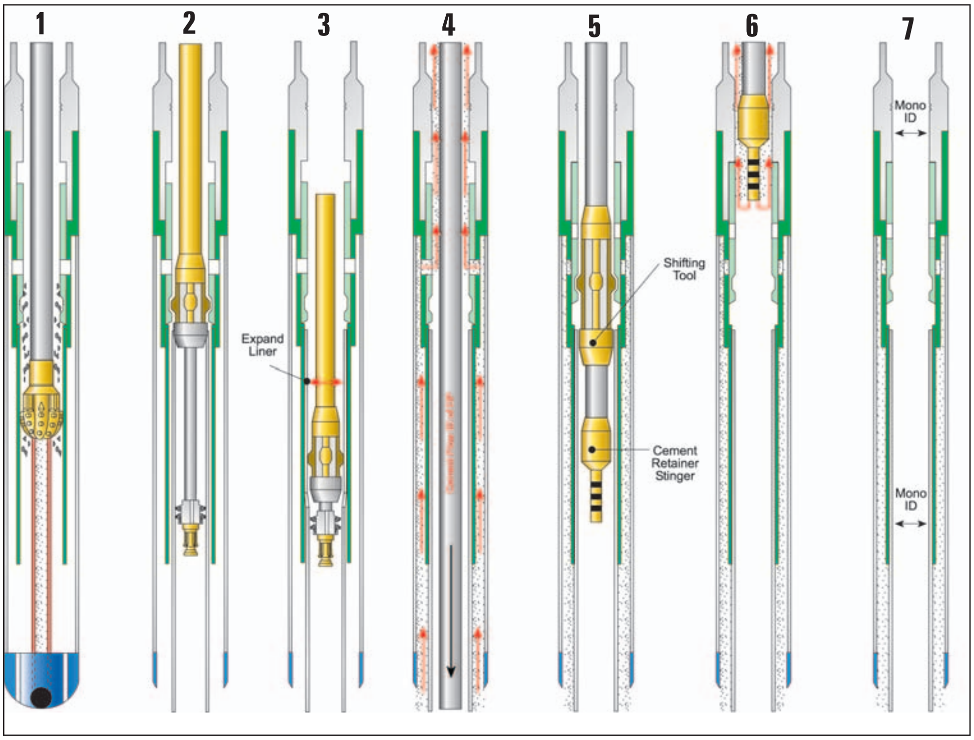
In January 2006, Kristin was drilled to depth for the 9 5/8-in. casing run. The contingency system for the well was enabled by running and cementing the recess shoe along with the intermediate casing string. The well was then temporarily plugged and abandoned and the rig skidded to another slot. In March 2006, the rig was skidded back and the recess shoe drilled out. The openhole section was drilled to the top of the producing formation.

Logs were run to determine if the ΔP would require running the contingency expandable liner. The anticipated ΔP was 870-1,450 psi (60-100 bar). If the ΔP is greater than 435 psi (30 bar), it would necessitate running the contingency expandable liner.

The operator determined from post-drilling analysis that the expandable liner was not necessary on this well. The actual ΔP was only 190 psi (13 bar), which did not require reduced mud weight to drill the reservoir (reducing the mud weight to drill the reservoir would have resulted in an upper shale section becoming unstable). At present, Kvitbjørn has installed the recess shoe that allows for cementing of the expanded liner, if needed, and is in waiting for its possible contingency use.

These 2 contingency system installations represent the first and second commercial runs, respectively, of the monobore contingency system. The following observations and conclusions are offered:

• The extension of liner assemblies while maintaining the same internal diameter is achievable by using the



Contingency Monobore System, isolation provided with cement (figure 6): (1) Drill out shoe protective sleeve and next hole section; (2) Run expandable liner/locate inside RC9-R shoe; (3) Begin expansion process hanging liner off inside RC9-R; (4) Run/set cement retainer/open returns port inside RC9-R shoe with shifting tool and pump cement; (5) Close returns port inside RC9-R with shift tool; (6) Circulate out excess cement; (7) Mono ID Wellbore.

recessed shoe to receive the expandable hanger.

- The use of a recessed shoe allows for both contingency and planned liner extensions, and as such should be considered in the early well-planning processes.
- The use of a recessed shoe does not exclude the use of conventional equipment if the expandable liner is not required.

Indications are that planned monobore systems inclusive of the expanded monobore liner extension will be installed before the end of 2006. In addition, several contingency applications will be installed before 2007, which may further necessitate a monobore liner extension. The installation of the expandable liners for these contingency systems will be determined by situations similar to those as previously defined in this article.

This article is adapted from a presentation made at IADC World Drilling 2006, held 21-22 June in Prague, Czech Republic.