

## **Deepwater cementing at the Gjallar ridge offshore Norway.**

Due to under-cooled return currents from the Arctic Ocean, the seabed temperature in the area has been measured down to  $-2,3^{\circ}\text{C}$ . The average depth of the block is the deepest in Norway.

In addition to the low temperatures, additional deep water cementing hazards presented at the Gjallar ridge well included potential wellbore difficulties (*unconsolidation, instability and hole enlargement*), potential shallow flow zones, hydrates and the ooze sediments that were present.

## **Geotechnical conditions in deepwater**

### **Sediment Consolidation, Formation Integrity**

Underlying a 100meter thick Quaternary sequence from seabed, a massive, 600m thick ooze sequence was prognosed. This sequence had not been previously experienced by any of the other deepwater wells offshore Norway. Information limited to minimal data acquired from shallow drilling by the Norwegian Deepwater Programme (NDP) and other research programmes.

Due to the low prognosed density of these sediments, i.e. 1.4-1.6 SG, the formation integrity was predicted as very low. This was to prove particularly challenging during cementing operations of the 20" casing. The objective being to cement the surface casing in its entire length with returns to seabed.

The key issues in cement design in an environment like this are low slurry density, dynamic filtrate, shallow invasion (i.e. pore blocking), rapid (integrity) strength development and as short transition times as possible, permitting no migratory paths.

The quality of the lithological and pressure prognoses is very important to perform safe and efficient drilling operations. Despite being 75 km from the nearest well and the complex geological ties in the area, the pressure and lithological prognoses proved to be very accurate. The main reservoir turned out to be slightly younger than prognosed (Late Campanian vs. Maastrichtian), and the TD of the well seems to be in the Santonian while the prognosis suggested a Turonian age.

A special focus was put on the "open water operations", where the drilling and cementing operations are performed without riser and returns to surface. This had been proved to date in Norway as being the most critical part of the well where significant loss, re-spuds wells had occurred prior to and after cementing. *E.g. Prior to Gjallar 75% of deepwater wells on the Norwegian sector were re-spudded due to problems during the open water operations.*

The following major cementing risks were identified for the top hole sections in the planning phase:

- Hydrates
- Shallow flows during and after cementation (water/gas)
- Wellbore difficulties (losing return, hole enlargement, & instability)

The drilling and cementing programme was therefore designed to reducing hazards presented. Contingent plans were also prepared should envisage difficulties arise. The planning proved to be successful and no major problems were encountered during the top hole sections.

### **Shallow Flow(s)**

Shallow water/gas flows had been experienced on three deepwater wells on the Norwegian continental shelf to date. The shallow flows resulting in re-spud of the wells with significant additional cost and time spent on the well.

For Gjallar a contingent 16" liner below the 20" casing was planned in case of hole problems in the shallow and more unconsolidated sections. If shallow water flow, shallow gas or major hole problems had occurred. Then the 20" casing would be set shallower than programmed and the 16" liner could be run and cemented to the depth planned for the 20" casing.

Drilling of the 26" hole, running and cementing of the 20" casing was performed without any indications of shallow flow. However, close to TD (total depth) of the 17" hole section indications of shallow flow was observed. Since full mud circulating system at this stage was established, the mud weight was raised from 1.10 SG to 1.13 SG and the shallow water flow was controlled. No further problem of shallow water flow was encountered on the Gjallar well.

The two critical elements of a cement design to inhibit shallow flow are early compressive strength development and the thixotropic ( gel – strength ) characteristic of the slurry. The low temperatures found in a deepwater environment greatly reduce the hydration rate of Portland cement. Because of this temperature effect, steps must be taken to increase the reactivity of cement slurry used in deepwater applications. Historically, this has taken the form of adding either micro-fine cement or gypsum to a conventionally accelerated cement design.

### **Hydrates**

The oil and gas industry has been aware for several years of problems arising from the formation of hydrates, ice-like structures of water and natural gas, during well-control and especially deep water drilling operations. The potential for these problems has expanded during recent years with deepwater exploration moving into ever increasing water depths. *(Hydrate formation is favoured by conditions of low temperature, high pressure, free-water and natural gas, and environmentally favoured use of water based rather than oil based muds (water is the main constituent of gas hydrates)).*

Laboratory experiments have identified heavier hydrocarbons, found in oil and gas condensate systems, which can form hydrates and also a new hydrate structure; two factors which may increase the possible hydrate formation region.

Gas hydrates are solid ice-like compounds of natural gas and water. They can exist at temperatures some 20 or 30°C ( 68 to 86°F) above the freezing point of water at high pressures. Although hydrates have long been recognised as a problem in oil and gas production operations the potential for encountering hydrates whilst drilling is a new phenomenon in offshore operations owing to exploration activity on the Norwegian sector.

Gas forming from hydrates produced was also reported on another deepwater well on the Voering Plateau. The gas was migrating from outside of the 30" conductor and hydrates were formed immediately when the gas entered the seabed. The BOP connector was completely frozen up and the BOP could not be disconnected from the wellhead. Therefore the 20" and 30" casings were cut and retrieved with the BOP still connected to the wellhead. At approx. 300 m water depth the temperature had risen sufficiently such the hydrates melted until the connector could be operated.

In the planning phase of the Gjallar well concerns regarding hydrates were addressed. To prevent hydrates forming and naturally formed hydrates to destabilise during drilling and cementing operations as well as potential well control activities, also the mud system had to undergo special studies.

The critical element of a cement slurry design to inhibit destabilisation of hydrates is to have as low heat of hydration as possible, and the ability to keep the possible free gas from migrating through the cement slurry.

During the Gjallar deepwater operation, no naturally formed hydrates were encountered and no hydrates were formed or destabilised during the drilling and cementing operations.

## **Project execution**

Detailed planning of the Gjallar well started in the Saga drilling department October 1997 and a small team, which also included Saipem rig management, continued the planning process until June 1998. The planning included drilling plans as well as plans for the upgrading of the rig. This planning process terminated in June 1998 because the drilling operation was postponed to 1999.

A new planning process started in February 1999. Important objectives from the start were to reduce costs and ensure a safe operation both for those involved and for the environment. To optimise the planning process and make further improvements, Saga engaged John de Wardt to apply his Lean Drilling program. This is a planning method based on giving 'ownership' of the project to all involved parties, in the operator, drilling contractor and service companies, both offshore and onshore. Each party is required to take full responsibility for their input, both in the planning and execution phase, in contrast to the usual approach in which 'ownership' is concentrated mainly on those in charge in the operating company. De Wardt's method also puts great emphasis on risk management and contingency planning.

Due to this planning, all the well objectives were met below AFE and under planned time. This planning process contributed to the drilling success of the Gjallar deepwater well.

## **Cementing operations**

As described above, it is clear that a deepwater location poses a number of additional challenges to a cementing operation that compared with operations on the continental shelf. BJ Services initiated a project in co-operation with Saga Petroleum and Norsk Hydro in 1997, to develop a cement slurry system that could perform as good as possible under these extreme conditions. The already existing BJ Deepset™ foam cement system was used as a reference system during the development of the specific cement system used on the Gjallar ridge. As a part of the development project, laboratory equipment in BJ's laboratory in Stavanger, Norway was utilised with a special cooling device allowing thickening times and compressive strength development tests to be performed at temperatures down to  $-2^{\circ}\text{C}$ . The final slurry system was developed in the Stavanger laboratory in co-operation with BJ Region laboratory in Aberdeen, Scotland and BJ's Research and Development laboratory in Tomball, Texas. In the spring 1998 BJ was awarded the contract of performing the cementing operations on the Gjallar ridge.

The cementing operations on the Gjallar well was a major focus during the planning of the well because of the 600 meters of low density, low strength, ooze sediments. The density of the sediments was confirmed by MWD to vary between 1,40 SG and 1,60 SG. Special emphasis was given to plan how to perform a successful cement operation in these zones without loss of circulation.

## **Installation of the Conductor**

A 12 ¼' pilot-hole was drilled to the TD of the Surface casing section @ 2.162 mTVD RKB before the top hole was opened with a 17 ½ x 26" x 36"x 42" hole opening combination. The 36" hole was drilled to 1.477 m TVD RKB.

On the 7<sup>th</sup> of June`99 the 30"x 36" Conductor casing was cemented in place from the shoe at TD back to the seabed at 1.377 m TVD RKB. ( 1.352 meters MSL ). 72 m<sup>3</sup> of 1,45 SG gas tight slurry was pumped through an inner-string, with full returns. Fluorecein tracer and cement was observed on the surface by an ROV. The temperature on the seabed was measured to  $-2,3^{\circ}\text{C}$ .

Four hours after the primary job, a planned top up job was performed, using the TITUS top up tool. Another 10 m<sup>3</sup> of the same cement slurry was pumped.

Firm cement was observed as the shoe was drilled out. The Conductor casing had a stick-up of 3 meters and the angle was 0,5 degrees. No slumping of the conductor was observed and a successful cementing operation was achieved.

## Installation of the Surface Casing

The drilling commenced, and a 26" hole was drilled to 2.162 meters TVD RKB. The 600 meters of soft ooze sediments were drilled in this interval without any complications, due to the very well planned, controlled and very specific best drilling practices applied.

On the 10<sup>th</sup> of June`99 the 20" Surface casing was cemented from the shoe at 2.162 meters TVD RKB to seabed. A one-plug sub-sea wiper plug system was used to displace 187 m<sup>3</sup> of 1,40 SG lead and 33 m<sup>3</sup> of 1,60 SG tail cement. The ROV observed full returns during the cement job. The slurries were designed to perform as good as possible in the potential shallow water flow, low density, low formation strength interval. Both slurries had gas tight properties. The BOP and riser was then run, and the shoe was drilled out. An successful FIT test was performed and the drilling of the 17" section commenced without any delays.

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## Figures

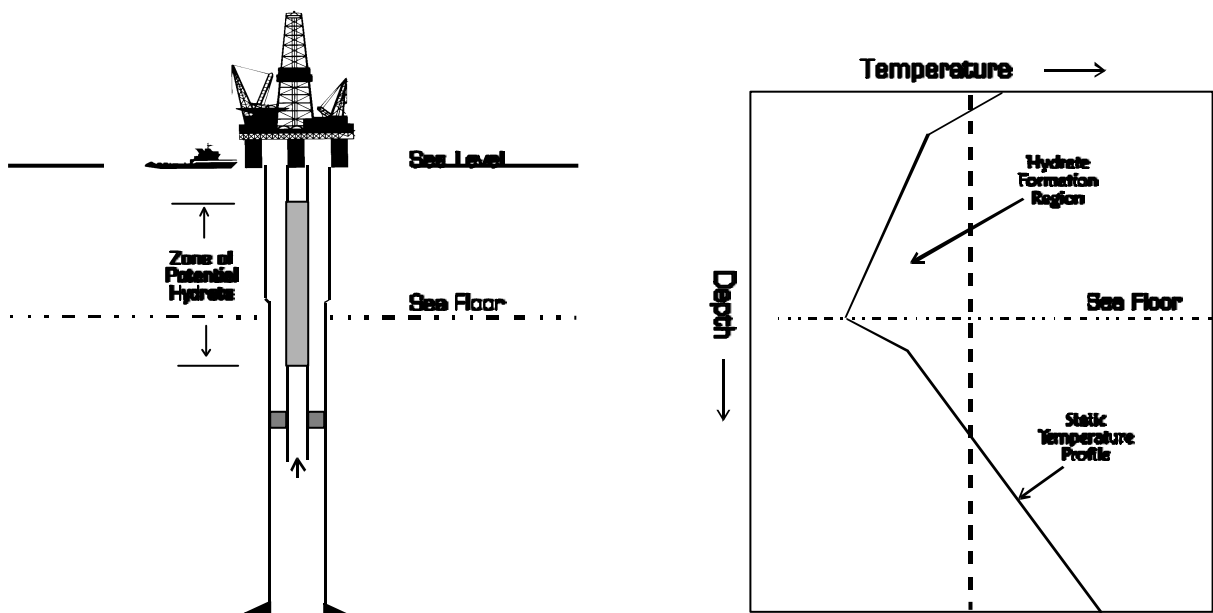
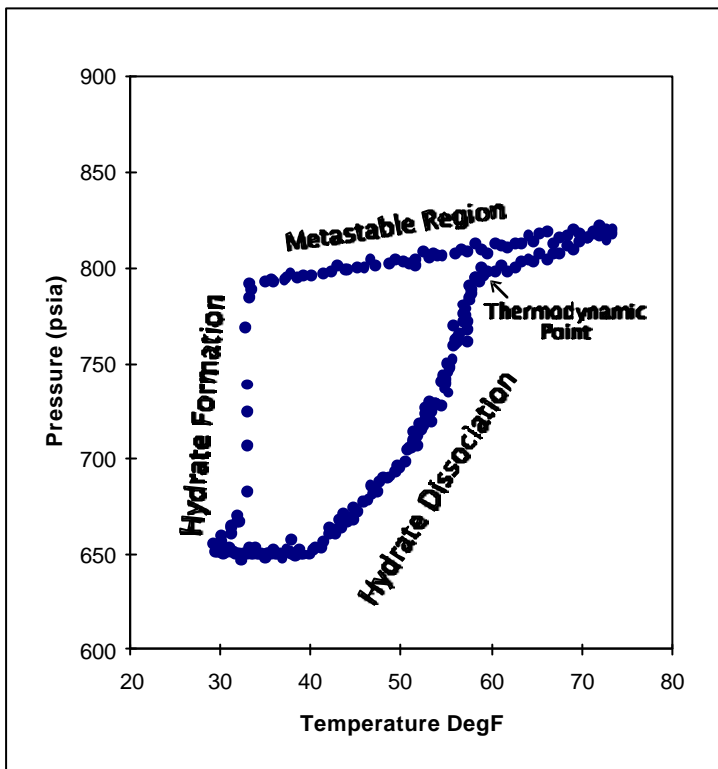


Figure 1: Zone of potential hydrate formation in ocean sediments



**Figure 2: Hydrate formation/dissociation measurements**

## References

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