Long-Term Zonal Isolation for Onshore Gas Wells by Use of a Monobore Cemented Completion

A cemented completion provides an excellent opportunity for low-cost drilling techniques and simple well designs to reduce well-delivery costs without affecting safety or well integrity. In this concept, the completion is run straight into the open hole and cemented in place. There is no need to run a liner and perform a traditional clean-up. The cement effectively replaces the production packer. Achieving a good cement job is essential to a successful operation.

Introduction

The cemented-completion concept is a simple one whereby the reservoir openhole section is drilled to the required depth. Following electric logging (if required), the completion tubing is run into the open hole and cemented back inside the previous casing shoe or window. The Christmas tree then is installed and the well perforated in the normal manner.

Cemented completions already have been used in low-cost operating areas around the world. Well CA-28S2 drilled from the Cormorant Alpha platform in June 1999 marked the first cemented completion to be performed in the North Sea by Shell. Well CA-28S2 was selected as the ideal candidate for evaluating the method because of its short 6-in. openhole length (708 ft) and near-vertical inclination. Since then, openhole lengths have been increased progressively, culminating in Well CN-28S1 that was successfully completed with 6,500 ft of $8^1/_2$-in. open hole at 67°.

This article, written by Assistant Technology Editor Karen Bybee, contains highlights of paper SPE 107433, "New Approach To Ensure Long-Term Zonal Isolation for Land Gas Wells Using Monobore Cemented Completion," by ***Salim Taoutaou,*** *SPE, and* ***Ron Schreuder,*** *Schlumberger, and* ***Martin Bosma,*** *SPE,* ***Jules Schoenmakers, Rob Van der Vegt,*** *and* ***Dave Stewart,*** *NAM B.V., prepared for the 2007 SPE Europec/EAGE Annual Conference and Exhibition, London, 11–14 June.*

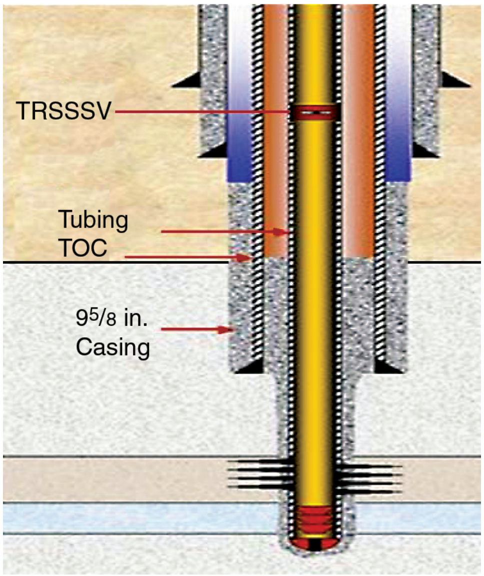

Fig. 1—Monobore cemented completion.

In 2003, 79 cemented completions were installed by Shell globally, yielding considerable savings. In The Netherlands, after an initial trial with 5-in. completions in 2003, the land assets have adopted a $3^1/_2$-in. cemented completion as a base case to the slimwell low-cost land drilling campaign that began in 2005 **(Fig.1).** By the end of 2006, the $3^1/_2$-in. cemented completion had been used successfully in eight gas wells.

Benefits

The advantage of a cemented over a conventional completion is that it saves 5 to 6 days of rig time during installation by eliminating such operations as running and cementing the liner, wellbore cleanup, and packer-setting procedures. In addition, the amount of liner and completion accessories required such as packers, liner hangers, polished-bore receptacles, and nipples is reduced. Savings depend on the completion and well design.

Design Considerations

Although the basic concept is simple, careful planning and attention to detail are essential if the operation is to be performed effectively. The first step is to quantify the stresses to which the cement will be subjected. This enables the design engineer to choose the right mechanical properties for the set cement. Computer-aided stress-analysis software is key to understanding stresses in the cement sheath. This software can model as many as 10 strings simultaneously, analyzing the stress caused in each string by a well event, such as pressure testing. Stress

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analysis of radial and tangential stresses can determine cement-sheath performance in compression, tension, or both, and can determine the formation of a microannulus, enabling the design of the set cement to be optimized.

Simulating the pressure test to full design pressure revealed that conventional Portland-cement slurry is inadequate for the cemented completion. The radial stress generated by the pressure test will crack the set cement. The solution to this is use of an engineered flexible- and expanding-cement system based on an optimized particle-size-distribution system at a 13.7-lbm/gal density. This cement system uses fewer cementing additives than a conventional system. This system, with reduced water and high solids content, ensures a good displacement profile, low permeability, and high resistance to chemical attack. Cement-job design and simulation software is used to model the placement efficiency and the equivalent circulating densities (ECDs).

Job Execution

Rigorous well-site procedures also have been developed for cleanout of surface lines before cement displacement. Fallback options have been developed for the likely failure scenarios. If the top of cement (TOC) is not back inside the previous shoe, one potential fallback option developed is to cut and recover the tubing above TOC, then recomplete with an overshot and conventional packer.

Field experience demonstrated that the early concerns about the passage of cement and plugs through an unprotected tubing-retrievable subsurface safety valve (TRSSSV) have proved to be unfounded. To date, no serious problems with the TRSSSV have been experienced. The tubing is pressure tested on bump to typically 4,640 to 5,510 psi; the TRSSSV is inflow tested.

Cement Evaluation

After the cement slurry has achieved adequate compressive-strength development, a nominal annulus-pressure test is performed to ensure adequate well integrity before removing the blowout preventer and installing the Christmas tree.

Wireline runs are performed rigless to drift the tubing and set a dummy or protection sleeve in the TRSSSV at this stage. The cement-bond-log (CBL) tool is run to evaluate the cement before perforating the well.

Case Histories

Well 1. This well, completed in July 2005, was the first in The Netherlands where a cemented monobore completion was used successfully. The well design was changed from a conventional design to the new design to save time and money.

Geological pressures dictated that the slim contingency scheme had to be followed. The last section was drilled through using a bicenter bit to generate a $4^1/_8 \times 4^1/_2$-in. hole to a total depth of 12,074 ft to meet cement-sheath thickness requirements and reduce ECD.

The $3^1/_2$-in. completion was run and cemented successfully using a flexible- and expanding-cement system. To minimize surge/swab and give the optimum standoff for the cement job, $4^1/_2$-in. slim centralizers were used.

The challenge was ECD management during the cementing operations and during mud removal; fluid rheologies and pumping rates during the cement job were crucial to avoid lost circulation. The well was logged successfully and subsequently was perforated and put in production.

Well 2. The 6-in. openhole section of Well 2 was drilled to 10,397 ft with a deviation of 24° at the total depth. The $5^1/_2 \times 5$-in. tapered string was run across formations, with the shoe set in the base formation and cemented using the flexible- and expanding-cement system across the production zone and up into the previous 7-in. casing. The estimated TOC was at 7,546 ft.

The main objective of the cement was to provide a long-term zonal isolation, preventing the flow of gas and/or liquids to the annulus.

To ensure good mud removal and cement coverage around the tubing, mud-removal software based on neural-network technology was used to optimize spacers.

The centralization program consisted of placing three centralizers per two joints over the entire length of the cement column. This ensured a standoff of 90% between the centralizers and 98% at the centralizers. Because of the small annular clearance between the 6-in. open hole and the 5-in. tubing, controlling the ECD during the cement job was critical. The fluid rheology and the pumping rate were tailored carefully to suit this case. The wellhead pressure during the cement job was approximately 5,842 psi.

Evaluation. The CBL is used to check the quality of the cement-to-casing bond. It is performed by measuring the loss of energy of a sound wave propagating through casing steel. The CBL tool records the amplitude (usually measured in millivolts) of the first half-cycle of the signal issued by a transmitter located 3 ft from the receiver. The results of the CBL for this job indicated a very good cement bond.

Well 3. Well 3 was drilled in May 2006. The $3^1/_2$-in. cemented completion was run and landed. The well was circulated for $5^1/_2$ hours. The bottom plug was bumped. A rapid increase of pressure to 6,382 psi was seen at the surface, and the cement job was aborted. The completion was pulled out immediately, cut, and inspected. It was found that no cement passed the shoe track below the landing collar. The following were the findings of the investigation.

- The pumping rate to bump the plug was twice the rate used in the four offset wells (identical operations).
- In this job, the cement slurry was used to shear the bottom plug instead of using the weighted spacer. The slurry has a high solids content that may have contributed under the high rate and acceleration to plugging the bottom-plug orifice.

A new completion was run, and by adhering to the agreed procedures, the repeated operation was successful.

Conclusions

1. The cemented-monobore-completion concept has been refined as a proven method of delivering cost-effective gas wells in The Netherlands.
2. Meticulous planning and attention to detail are critical to minimizing the risks.
3. To date, eight cemented monobore completions have been executed successfully in onshore wells in The Netherlands.
4. The use of the stress-analysis software coupled with the engineered flexible- and expanding-cement system was essential to achieve the required zonal isolation on all wells. **JPT**