SUCCESSFUL WATER SHUT OFF TREATMENT OF AN OFFSHORE EXTENDED-REACH WELL LED TO MAXIMIZE HYDROCARBONS PRODUCTION

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Abstract

This essay describes the success of the Water Shut-Off operation into an offshore extended-reach well by Rig-less Zonal Isolation via Conformance Technology. The well was drilled and completed to produce oil from multiple zones. Due to cement channeling behind the 9–5/8" casing shoe, undesired water production was flowing down behind the casing from upper reservoir, through the intermediate reservoir until it reached the annular section of the well and was cross flow circulated down into lower reservoir.

A customized intervention solution was designed to reduce the water cut and bring the well back to production. The Intervention recommended followed the steps below:

It was established an injectivity path between the well and the desired zone to be isolated by performing a TCP perforation across the 6–5/8" liner. A selective placement system was introduced by setting a straddle packer across those perforations to be able to squeeze Water Shut Off treatment (diesel based cement slurry) behind the casing. Finally, the straddle was unset, and retrieved to surface to allow the diesel based cement slurry to cure and proceed to flowback the well to evaluate the results.

Keywords: *Water Shut-Off, Well Integrity, Cement Channeling, Coiled Tubing, Horizontal well, rigless operation, Conveyed Perforating Technique, inflatable retrievable production packer*.

1. Introduction

A rigless operation is a well-intervention conducted with equipment and support facilities that precludes the requirement for a rig over the wellbore. Coiled tubing, slickline and snubbing activities are commonly conducted as rigless operations [1, 2].

As it is known, an extended-reach well is one in which the ratio of the measured depth (MD) versus the true vertical depth (TVD) is at least 2:1. A big problem during oil-producing reservoirs is water production. As with most things in nature, fluids also tend to follow paths of least resistance which, in reservoirs, are often created by the heterogeneous nature of the rock. There are two levels to this heterogeneity. The first is microscale heterogeneity, which could be represented as a simple porous feature distribution, and the second is macroscale heterogeneity which includes layering, natural or induced fractures, and high vertical and horizontal permeabilities. Both can lead to poor conformance and, therefore, need to be controlled. If conduits for water flow are available then they need to be blocked in order for production wells to continue operation [3, 4, 5].

By mean of a review, based on production data, workover, completion history and mechanical condition of the well, the possible cause of water production can be identified. Considering how much hydrocarbon remains, the ease of access to hydrocarbon and other economic parameters, if a remedial work is economical, supplementary investigation to find the source of water and to define the production mechanism is made through a wireline run (RST, PLT, etc). Based on the logs, the type of problem is identified and possible remedial work is recommended. Then, a detailed economic and technical feasibility is performed to justify the treatment proposed [10, 11, 12].

The extended-reach well (ER-Well) were the treatment was done is an oil producing well drilled in the lowest reservoir R-3. It has shown water production since reactivation day at an almost constant rate of 550 barrels per day. Several analyses conducted by the owner of the well have evaluated the cement quality of the 9–5/8" casing, production on nearby producing wells, characterization of produced water, temperature surveys, etc. All data suggests that the source of the water stems from Water Injector Wells at the Upper reservoir R-1.

As per the owner of the ER-Well, Rig options posed financial and logistical challenges and were not available for the rest of 2017 locking up

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approximately 3500 Barrels of oil per day. Previous attempts to revive the well were unsuccessful.

2. Problem Identification

The ER-well was selected for water treatment consideration. Brief well data can be seen in Table 1. The well was producing 100% water cut at surface. Offset well performance analysis and fluid samples from the ER-Well indicated that the main cause for excessive water production was due to flow behind the 9–5/8” casing. Cross flow was detected behind the casing, therefore, inter-reservoir communication from R-1 to R-3 reservoir through cement channeling behind 9–5/8” casing was taking place. Such water was produced along with the oil. Hydrostatic pressure eventually killed the well. A well schematic can be seen in figure 1.

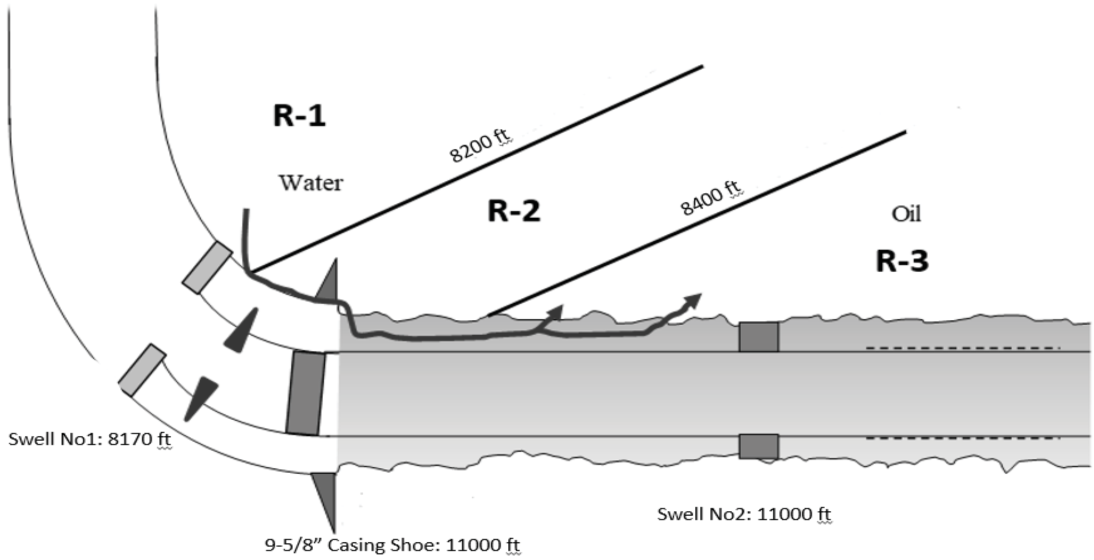

Fig. 1. *Cross Flow given by cement channel at Casing shoe (ER-well schematic)*

Through interference testing, it was shown that the nearby injector well IW-02, which injects into R-1 reservoir, was seen to have direct pressure communication with R-3 in ER-well completion.

In 2016 a wireline logging program consisting of high resolution temperature, water flow log, and noise log was run to 8530 ft MD (just past top of R-3 reservoir top). The ER-well and nearby injector well IW-02 were both shut in during the logging operations (resulting in minimal pressure differential between R-1 and R-3 in this region). The analysis of this temperature data highlighted a cooling effect from base of R-1 into top of R-3, suggesting crossflow downward into R-3. Water flow stations detected fluid movement down across the R-1 zone; however the flow measurements were at the threshold of detection.

In 2017 a time lapse logging program was run to investigate any changes over time. This second log was run with the ER-well static, and with the nearby injector IW-02 actively injecting into R-1. The logging program consisted of high resolution temperature, water flow log, and spectral noise log. Logging was conducted over the interval between 7000 and 10000 ft MD. The analysis of the second logging program corroborate the results of the initial logging program and conclude that crossflow from R-1 down into R-3 is occurring.

Table 1. *Brief ER-well data*

Porosity	20 to 25%
Permeability	5 to 7 md
BHP	3000 to 3200 psi
BHT	190 to 205 °F
Geothermal	2.5 to 2.8 °F/100 ft

3. Treatment design and preparations

This work was done in one of the islands used as Oil and Gas installations in the United Arab Emirates, in the Persian Gulf.

The job design involved selecting the suitable slurry for the cement plug and proper placement method to ensure the correct set of the cement plug [6, 9]. The owner of the extended-reach well and Halliburton collaborated to design a rig-less tailor-made Conformance solution to stop the cross-flow between R-1 and R-3 Reservoirs. Through Coiled Tubing deployment.

The objectives of the treatment were:

- To remediate the behind pipe crossflow from R-1 into R-3 due to a cement channel behind the 9–5/8” shoe.
- To install a cement plug between the two reservoirs to isolate, or at least to minimize the flow between the two reservoirs to delay a rig intervention for as long as possible.

- To isolate the lower perforations and revive oil production from R-3 Reservoir

4. Slurry selection

Diesel based cement slurry was used taking advantage of its selective reaction properties to water. This cement slurry minimizes undesired water production addressing channelling, cresting or conning conditions and providing optimum zonal isolation and reservoir Integrity. The Integrated approach was designed involving: CT-logging, CT-conveyed perforation, mechanical isolation with IRPP and Conformance Technology [6, 11, 12].

The diesel based cement Slurry technology is specifically designed to penetrate more efficiently in narrow gaps without bridging or dehydrating during placement, therefore is a solution for water control and loss of circulation problems. The diesel based cement Slurry uses hydrocarbon–based micro–matrix cement slurry to selectively shutoff water intrusion. The system reacts only to the presence of water and can be deployed using coiled tubing. Diesel based cement Slurry is applicable for temperatures as high as 400°F and can provide excellent casing integrity when it is used to repair leaks. Other applications of this kind of slurry include: sealing highly permeable zones, stopping unwanted water or gas production coming from channels behind casing, sealing pinhole leaks in the casing, sealing water-bearing formations with fractures, among others [6, 7, 9].

Diesel based cement Slurry is the best option for remedial cement plug since it will ensure that any channels in the previous plug will be sealed completely and at the same time preventing future channeling due to its low set-cement permeability [7, 9].

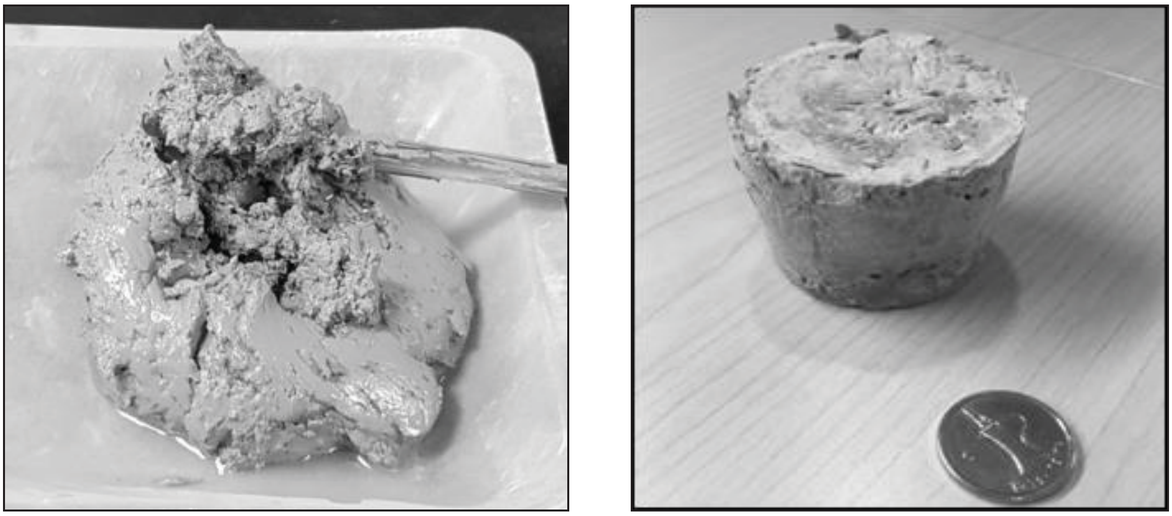

Fig. 2. *Diesel based cement Slurry formulation tailored for pumping time*

5. Placement Techniques

The use of coiled tubing was required to ensure proper placement of the cement plug across the zone to be repaired. With coiled tubing, it was easier to ensure that the cement was squeezed into the cavity behind casing and into the channels in the previous cement plug [6, 8, 9].

Once the cement slurry was spotted across the R-1 reservoir, excess of cement was circulated to ensure the correct top of cement. Pumping continued slowly to attain squeeze pressure. This was to ensure that cement would stay in place [8, 9].

Below is a summary of the main steps that were followed during the water shut-off operation:

- Run #1 – Memory CCL tool for wellbore correlation and drift for IRPP/TCP
- Run #2 – TCP (millennium gun) to perforate 6–5/8" liner
- Run #3 – Set CT-Straddle Packer, started to pump the Diesel based cement Slurry treatment
- Run #4 – (contingency) – Wash nozzle / Milling Motor to clean tubing
- Run #5 – Wellbore isolation and pressure test
- Rig down coiled tubing unit.

The following fluid was pumped in sequence:

Table 2. *Sequence of the pumped fluids*

Stage	Fluid	Rate (bpm)
1	Organic Solvent 1	2 to 2.5
2	Cement Slurry and 4 to 5% Surfactant	3 to 3.5
3	Cement Slurry and 2 to 3% Surfactant	1.5 to 2.0
4	Organic Solvent 2	1 to 1.5
5	Organic Solvent 3	1.5 to 2.0

6. Execution

In order to isolate the lower section of the wellbore and eliminate the cross flow between R-1 and R-3 reservoir, a sequence of steps were proposed in order to access the annular section between liner and the formation via Tubing Conveyed Perforating Technique (TCP) and squeeze a sequence of Water Conformance systems [6, 8, 9].

First, a CT run was done with CCL memory gauge in order to accurately correlate against the well completion. Second, a 2 inches Millennium gun was run with Tubing Conveyed Perforating Technique to perforate the 6–5/8" liner causing little damage to the 9–5/8" casing at the R-2 Dense depth. The firing depth was chosen within the top of the R-2 Dense layer and the 9–5/8" casing shoe (8238ft – 8295ft). The reason was to make sure that all treatment went downwards when entering the annulus maximizing chances of filling up from the casing shoe to the top of the swell packer [6, 8, 9].

In a subsequent run a CT straddle packer was run to isolate the lower wellbore while allowing pumping through circulation ports located above the element. Once the lower section was isolated, the Water Conformance squeeze was pumped. The system proposed consists of diesel based fine cement slurry pumped at different rates for setting purposes [6, 8, 9].

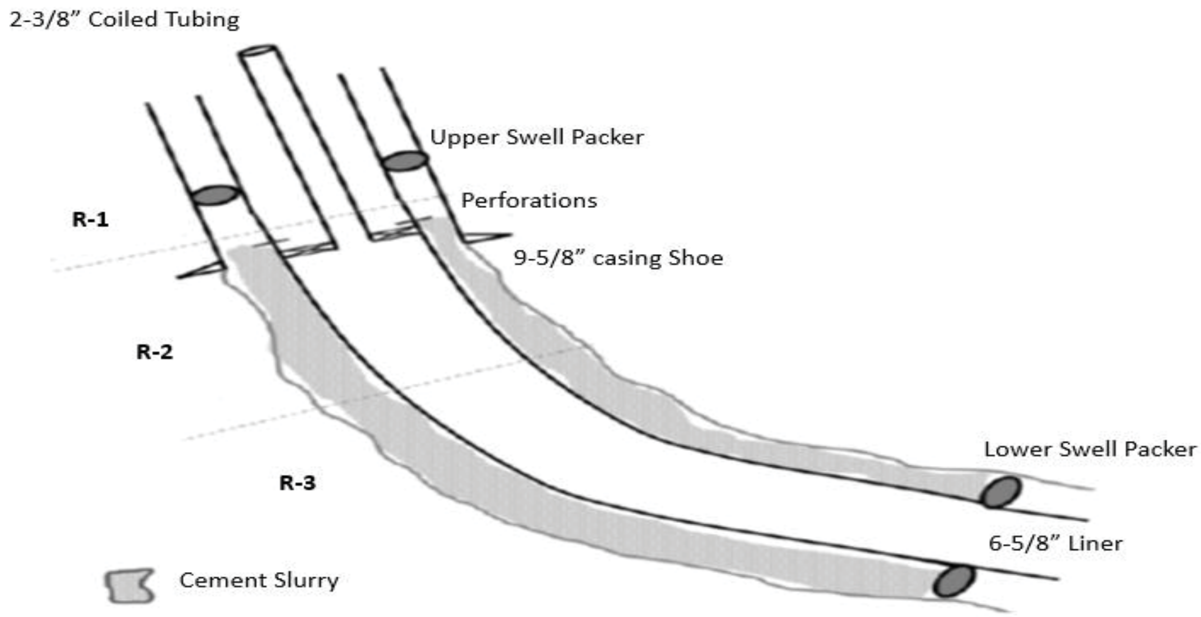

Fig. 3. *Diesel Based Cement Slurry spotted across the R-2 reservoir*

7. Conclusions and results

High water cut in produced fluid remains as one of the greatest challenges in petroleum industry. Water shut-off and conformance control in heavy oil production are more challenging both technically and economically

The success of the water shut off treatment mainly depended on the proper problem identification. With adequate information from the well and its associated reservoir, the best treatment fluid and method of placement could be designed to ensure successful job execution.

In this case, the job was overall successful in delivering the main objectives. The use of Diesel based cement slurry with an engineered method of placement ensured that the remedial cement plug was placed correctly across the perforations. 100% reservoir integrity by successfully squeezing 70 barrels of diesel based cement behind the liner.

Lock-up pressure achieved 40 minutes after squeeze started (Matched laboratory design). Unlocked deferred production of approximately 3500 Barrel of oil per day and reduced cost by approximately $1500000 USD compared to an alternative Rig Operation.

Regardless of the initial success of this operation in shutting off water from R-1, a rig workover must be performed in the future to permanently and mechanically isolate the open perforations in the 6-5/8" blank liner.

Nomenclature

CT – Coiled Tubing
MD – Measure Depth
WC – Water Cut (%)
BHA – Bottom Hole Assembly
BHP – Bottom Hole Pressure
BHT – Bottom Hole Temperature
CCL – Casing Collar Locator
TVD – True Vertical depth
RST – Reservoir saturation Tool
PLT – Production Logging Tool
EOT – End of Tubing
WHP – Wellhead Pressure
IRPP – inflatable retrievable production packer
TCP – Tubing-Conveyed Perforating

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