

Isolating Naturally Fractured Carbonate Intervals Invaded by Water or Gas

Excessive water cut or a high gas/oil ratio (GOR) in a production interval reduces oil production, often requiring a workover to re-establish oil production. Wells in the Cantarell field, a mature field in the Bay of Campeche in the Gulf of Mexico, are experiencing severe decreases in production and an increase in either water cut or GOR. The high water cut and gas increments have affected the production strategy. New solutions to isolate or abandon production intervals invaded by gas or water were studied to continue production from other zones.

Introduction

In Mexico's Región Marina fields, oil is produced primarily from carbonate formations through a complex network of natural fractures that provides most of the field's permeability and favors production of water and gas over oil. Typically, a rapid advance in water/oil and gas/oil contacts occurs. Movement rates as high as 20 m/a have been reported for the water/oil contacts and as high as 8 m/month for the gas/oil contacts.

The thickness of the carbonate breccia is 150 to 900 m, with permeability as high as 5 darcies and porosity averaging 10%. There is a very narrow window between the fracture- and pore-pressure gradients that results in partial or total losses during drilling and cementing operations; the

pore-pressure gradient is equivalent to 0.55 g/cm³, and the fracture-pressure gradient is equivalent to 0.65 g/cm³ in the pay zone. The temperature ranges from 90 to 115°C.

Three main mechanisms have been identified for the increasing water and gas production:

- ▶ Poor cement bond behind casing that enables communication of the gas or water zones with the productive intervals
- ▶ Highly conductive natural fractures that connect the reservoir with the gas or water zones
- ▶ Normal advance in water/oil or gas/oil contacts that occurs during the productive life of the well

Because of the low fracture gradient of the pay zone, it is not possible to keep the well full of control fluid, resulting in unavoidable losses and overdisplacement of treatment fluids when conventional displacement is applied. The static equilibrium fluid level in the wells is approximately 1300- to 1500-m true vertical depth.

Conventional workovers pumping only gas-tight slurries through a retainer had not solved isolation problems; therefore, a new solution was engineered by integrating a polymeric gel and lost-circulation material with the gas-tight slurries. The solution also used underbalanced displacement on the basis of the hydrostatic pressure that could be supported by the formation.

Problem Scope

The main challenges faced in producing oil in the Región Marina are as follows:

- ▶ Surface water-handling limitations limit hydrocarbon production, especially at the Ku-Maloob-Zaap field where water content greater than 5% cannot be handled. Facilities in other fields, including Cantarell, can handle higher water cuts, but oil production suffers.
- ▶ Cantarell is a depleted mature field that produces by use of a nitrogen-injection system to pressurize the reservoir.

In the Cantarell field, approximately 100 wells have been shut in as a result of high GORs and high water cuts, and the Ku-Maloob-Zaap field is starting to show incipient profiles of unhandled water and high GORs.

Solution

In the first phase of this project, workovers were performed through drillpipe with a workover rig in the Ku-Maloob-Zaap field. The production pipe was pulled out of the well, and a mechanical retainer was set in the top of the interval to be isolated. A solution of organically crosslinked polymeric gels, lost-circulation technologies, and gas-tight slurries was applied. To increase the potential for successful zonal isolation, the fluids were underdisplaced according to the hydrostatic column the formation could withstand, thus avoiding overdisplacement too far into the formation.

The second phase took place in the Cantarell field, where isolation jobs were performed without a workover rig, and the production assembly remained in place. The treatments were pumped through the production tubing and coiled tubing because it was not possible to run and set a mechanical retainer. In this phase, the underdisplacement method was used only for the placement of the gel

This article, written by Dennis Denney, contains highlights of paper SPE 168165, "Engineered Approach To Isolate Intervals Invaded by Water or Gas in Naturally Fractured Carbonate Formations," by J. López, A. Martínez Ballesteros, R. Miranda, C. García, and C. Deolarte, Pemex, and B. Vidick, SPE, R. Girón Rojas, SPE, A. Millán, J.G. Rivas, SPE, A. López, SPE, and E. Miquilena, SPE, Schlumberger, prepared for the 2014 SPE International Symposium and Exhibition on Formation Damage Control, Lafayette, Louisiana, USA 26–28 February. The paper has not been peer reviewed.

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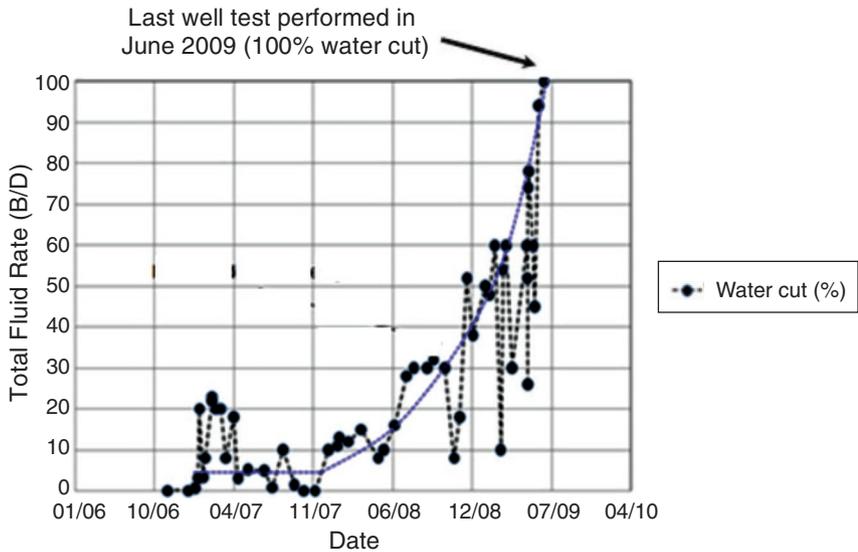


Fig. 1—Water-cut profile in Cantarell Well 475.

and the fiber pill, which were bullheaded through the production tubing. The cement was pumped through coiled tubing, which reduced the risk of slurry contamination. The solution was executed in three main stages.

First Stage: Two Batches of Organically Crosslinked Polymeric Gel. Divided into two substages, the target of

this stage was to block the influxes of water and gas by activating the gel in the fracture network of the reservoir. It would also keep the next fluids (second and third stages) in place near the wellbore to overcome the challenge of total losses.

Second Stage: Lost-Circulation-Fiber Pill. Intended as an intermediate treat-

ment that would support the upcoming cementing stage and prevent losses into the formation, this stage consisted of a lost-circulation system with an added solids package designed to plug the pores by creating a 3D network arrangement of the pill's dual-fiber system.

Third Stage: Gas-Tight Slurry. The final hydraulic seal, not completely achieved during the primary-cementing job (between hole and casing), would be provided by the gas-tight slurry, acting with the gel and lost-circulation pill to prevent slurry loss into the formation.

This design considered the synergic performance of all the technologies and the best method of displacement for each stage. The gel and lost-circulation pill were displaced according to the hydrostatic pressure supported by the formation either through drillpipe (workover rig) or by bullheading (rigless intervention). The slurry was displaced either through drillpipe (underbalanced method) or by use of coiled tubing to minimize the contamination risk, depending on the volume of slurry in the treatments.

Cantarell Field: Rigless Isolation in Well With High Water Cut

This well was originally perforated from 2800- to 2830-m measured depth (MD) and produced from a Cretaceous formation (containing 48% dolomite, 47% calcite, and 5% limestone) with 7% porosity. In 2009, the well was shut in when the water cut reached as high as 100%, as shown in Fig. 1. A rapid increase in the water cut was observed in the last months before the shutdown.

In 2011, an intervention was performed to isolate the invaded interval and perforate a new interval from 2785- to 2800-m MD, as shown in Fig. 2. The synergic solution was applied without a rig. The first two stages (polymeric gel and lost-circulation pill) were bullheaded, and the slurry was placed through coiled tubing because the production tubing was not pulled.

First Stage: Organically Crosslinked Polymeric Gel. On the basis of successful interventions performed previously on the well with workover equipment,

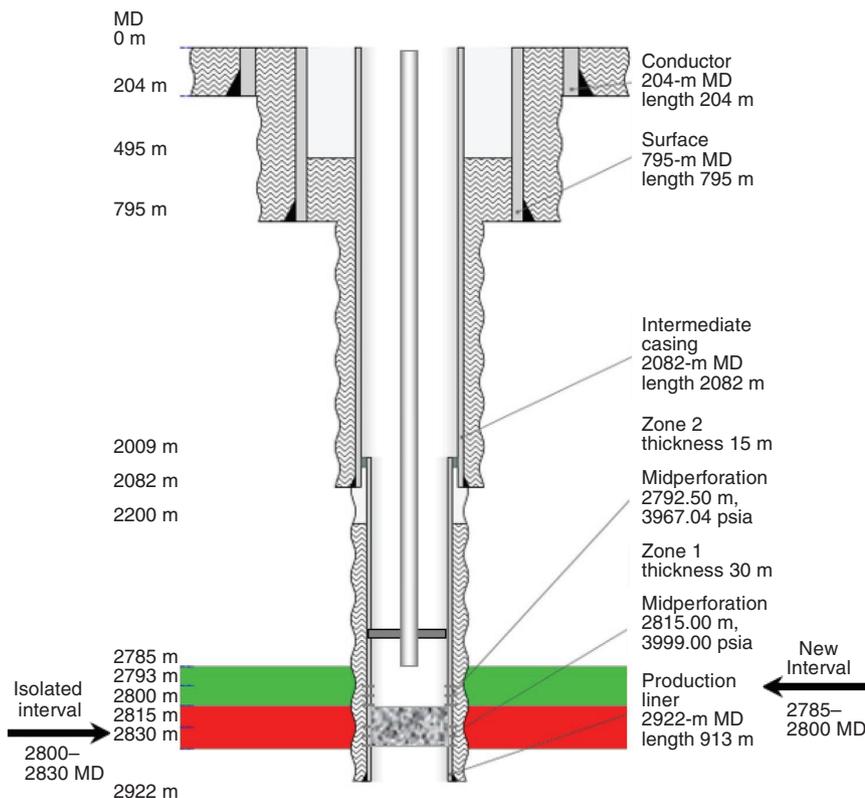


Fig. 2—Cantarell Well-475 schematic after isolation job.

two batches of polymeric gel were displaced by bullheading through the production tubing in accordance with the underbalanced method. In this case, a downhole-pressure log was run just before the treatment.

First, 100 bbl of gel was pumped, allowing 12 hours activation time. This batch was displaced with the amount of seawater needed to achieve a hydrostatic pressure of 1,500 psi, a value acquired from a previous downhole log. After displacement was completed, the cementing line was vented and good suction strength was observed.

After activation of the first batch, another 100 bbl of the same gel was pumped and displaced with the same amount of seawater used in the first batch. An activation time of 12 hours was allowed, and almost the same suction strength was observed in the well.

Second Stage: Lost-Circulation Pill. The second stage consisted of bull-

heading a 100-bbl lost-circulation pill through the production tubing and use of the underbalanced method to displace the pill with seawater according to the hydrostatic pressure of 1,500 psi supported at the base of the open interval. After the displacement, the cementing line was vented, but the well was no longer showing suction. The line was closed and reopened 1 hour later, with only a small amount of suction observed.

The behavior in the well indicates the progressive and effective plugging action of the fluids. The coiled tubing was run into the well in a calibration trip to ensure that the last stage of the treatment could be performed (slurry placement). In this run, the top of the lost-circulation pill was found at 2797-m MD (3 m above the top of the perforated interval) by applying 1,500 lbm of set-down weight. A cleaning trip with nitrogen cleared a length of 15 m along the interval to ensure that the slurry could be placed prop-

erly to provide a seal in the casing/hole annular space.

Third Stage: Gas-Tight Slurry. Coiled tubing was run to 2815-m MD and 8 bbl of gas-tight slurry (right-angle set) was placed as the final stage of this intervention.

Results. After the cement had set, the well was filled with seawater. The top of the cement was observed at 2768-m MD, 32 m above the top of the isolated interval. The cement was milled out with coiled tubing, and the new interval from 2785- to 2800-m MD was perforated. A production test showed an average oil production of 1,400 B/D with 1% water cut, exceeding the client expectation of 1,000 B/D with 50% water cut. A decision was made to stimulate the interval, and the oil production increased to 3,400 B/D. However, the water cut also increased to 24%, a value that is still within tolerance. **JPT**