Reducción exitosa del corte de agua a través del tratamiento de estimulación matricial en un pozo con terminación no convencional – caso histórico en México costa afuera

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Resumen

En este trabajo se presenta una metodología aplicada durante el diseño, implementación y evaluación de un tratamiento de estimulación matricial en una terminación no convencional, en los pozos Ku-1297 y Ku-75 del campo Ku-Maloob-Zaap. Los desafíos principales durante este tratamiento fueron: (1) estimular y cubrir la zona de interés de manera homogénea a través de una estimulación matricial en un pozo con terminación no convencional , (2) favorecer la estimulación de la zona preferencial de aceite a lo largo del intervalo productor con el tratamiento de estimulación matricial en directo, y (3) la reducción de la caída de presión a lo largo de la zona de aceite, ayudando a prevenir la conificación de agua mediante el uso de la divergencia variando las calidades de nitrógeno.

Cuando se diseña un tratamiento de estimulación de pozos desviados, es importante disponer de información fiable y válida en cuanto a la mecánica de rocas, registros geofísicos, datos de producción, los parámetros del yacimiento, (PWS, PWF, Ty, S), gradientes de presión dinámico o estático de producción, y las condiciones mecánicas y el funcionamiento del pozo.

La selección de los sistemas químicos se basa en un programa de pruebas de laboratorio para identificar los sistemas con un mejor rendimiento para el tipo de estimulación matricial utilizando muestras representativas de formación y posteriormente llevar a cabo la evaluación de la compatibilidad con los fluidos del pozo.

El uso de varias calidades de nitrógeno para llevar a cabo la divergencia en formación, ayudó a estimular las zonas superiores a lo largo de la tubería de revestimiento ranurada/disparada en la tubería de producción extendida. Estos métodos no convencionales ayudaron a prevenir la producción de fluidos indeseables (gas / agua), causadas por la conificación.

La selección apropiada de los sistemas, el diseño óptimo del tratamiento, la eficacia operativa, y la toma de decisiones en tiempo real durante la ejecución del tratamiento, produjo un aumento de la producción de petróleo de aproximadamente 1,000 B / D y la reducción de corte de agua por 95%.

Palabras clave: Estimulación matricial, conificación, producción de agua, terminación no convencional.

Successful decreased water cutoff by setting bullheading acidizing treatment in an unconventional completion well - cases histories offshore Mexico

Abstract

This paper presents a methodology applied during the design, implementation, and evaluation of a matrix acidizing treatment in an unconventional completion in Wells Ku-1297 and Ku-75 of the Ku-Maloob-Zaap field. The primary challenges during this treatment involved (1) stimulating through the unconventional completion to gross pay, (2) achieving the oil preference zone along the producing interval with the principal acidizing treatment, and (3) reducing the pressure drop along the oil zone to help prevent water coning, by using diversion with various nitrogen qualities.

When designing a stimulation treatment in deviated wells, it is important to have reliable and valid information regarding rock mechanics, formation logs, production data, reservoir parameters (P_{WS}, P_{wf}, T_y, S), pressure gradients for production of or shutting in a well, and the mechanical conditions and operation of the well.

The selection of the chemical system was based on a program of laboratory testing to identify systems with improved performance for acidizing the rock type, using representative samples of rock from the reservoir and then evaluating compatibility with formation fluids.

The use of various nitrogen qualities for diversion helped reach the upper zones along the slotted/perforated liner in the extended production tubing. These unconventional methods helped prevent the production of undesirable fluids (gas/water) caused by coning.

The proper selection of the systems, the optimal design of the treatment, operational efficiency, and real-time decision-making during the execution of the treatment, resulted in increased oil production of approximately 1,000 B/D and reduced water cutoff by 95%.

Keywords: Matrix acidizing, water coning, unconventional schematic, production.

Introduction

The Ku field produces from the naturally fractured reservoir formations BTPKS, KM, and KI. The term KM refers to the Cretácico Medio, KI the Cretácico Inferior, and BTPKS the Brecha formation. The Ku field consists of 80% dolomite, 15% limestone, and <5% shale, resulting in high reactivity when acid systems are applied (organic and inorganic). As shown in **Figure 1**, the rock petrophysics are 3 to 5% porosity and 10 to 25% water saturation. According to the geophysical logs from Ku wells, the estimated permeability is approximately 3000 md for the pay interval of 3000 to 3100 m measured depth (MD).

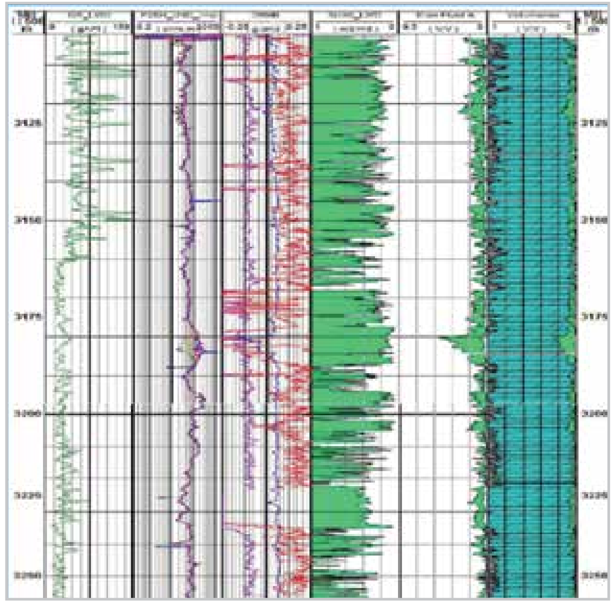

Figure 1. Geophysical logs.

Wells analyzed in the East flank of the Ku field have a complex structure because they are located in an area with several normal faults, approximately 90 m apart.

The Ku field produces black oil of 18 to 21° API below the saturation reservoir pressure (causing the formation of a secondary gas cap); it has an aquifer and an oil pay zone of approximately 130 m.

The primary completions of wells in the Ku field are unconventional. They are completed in a 7-in. 26-lbf-ft, 5.5-in. 17-lbf-ft, and 3.5-in. 9.2-lbf-ft combined production tubing; 7.625-in. 39-lbf-ft perforated liner; and extended 3.5-in. 9.2-lbf-ft production tubing (below packer).

Problem

Because of drawdown pressure caused by skin in the well, the water production breakthroughs generate coning near the wellbore, **Figure 2**.

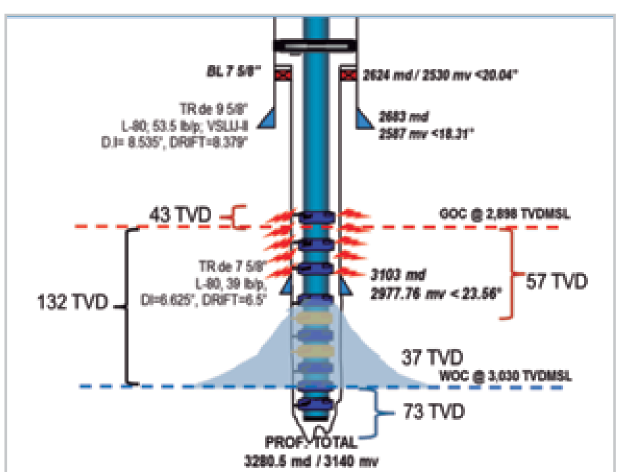

Figure 2. Water coning effect.

Because of the mechanical conditions of the wells treated, conventional stimulation would not ensure success; therefore, unconventional treatments were considered to help ensure the placement of stimulation fluids in the zones of interest.

Well Ku 1297 was identified as the best example after the previous workover and final evaluation, and therefore it was used as a reference point. Ku 1297 has 7-in. 26-lbf-ft, 5.5-in. 17-lbf-ft, and 3.5-in. 9.2-lbf-ft combined production tubing at 2610 m MD. It was completed using a 7.625-in. 39-lbf-ft perforated liner (3009 to 3100 m MD) combined with an openhole (3103 to 3280.5 m MD) and extended 3.5-in. 9.2-lbf-ft production tubing (below packer), at 3244 m MD with eight pressure/temperature gauges and two sliding sleeves, **Figure 3**. The well has a "J" type trajectory ending with a 23.56° inclination, 63.4° azimuth, 3280 m MD [3140 m true vertical depth (TVD)], with 177 m of openhole completion.

During production of the well (workover completion phase), it produced 15% water with 56,000 ppm of salinity, with a production rate of 700 B/D 1/2-in. choked. The oil/water contact (OWC) was at 3030 m TVD below main sea level (TVDMSL) (3066.7 TVD) and gas/oil contact (GOC) at 2898 TVDMSL (2934.7 TVD), Figure 3.

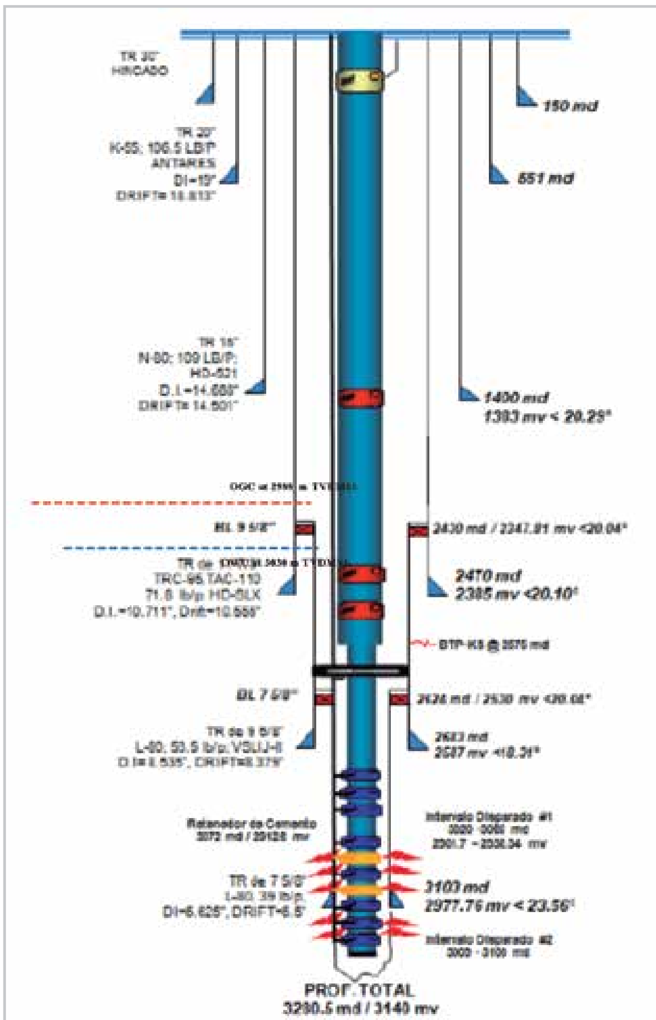

Figure 3. Well schematic.

The design was constructed using a proprietary process, analyzing petrophysical information, well logs, pressures and temperatures obtained using downhole gauges, permeability profiles from well logs, and acid types. These were used to help design a stimulation treatment to decrease the pressure drop along the wellbore, through the combination of varying the quality in the nitrogen flow system and the bottomhole rate obtained to magnify the acidification in the upper regions of the producing interval.

According to calculations, to obtain a 1.5-m (5-ft) invasion radius, 25 m^3 of chemical system was necessary, with 23 m^3 of solvent to clean the formation and prepare it for the contact of acid. This was assisted with nitrogen qualities of 50 and 60% and a bottomhole rate between 10 and 14 bbl/min.

The stimulation treatments were performed using the methodology shown in **Figure 4**. The key to success was obtaining information from wells in the Ku field during production, and from pressure and temperature gauge data.

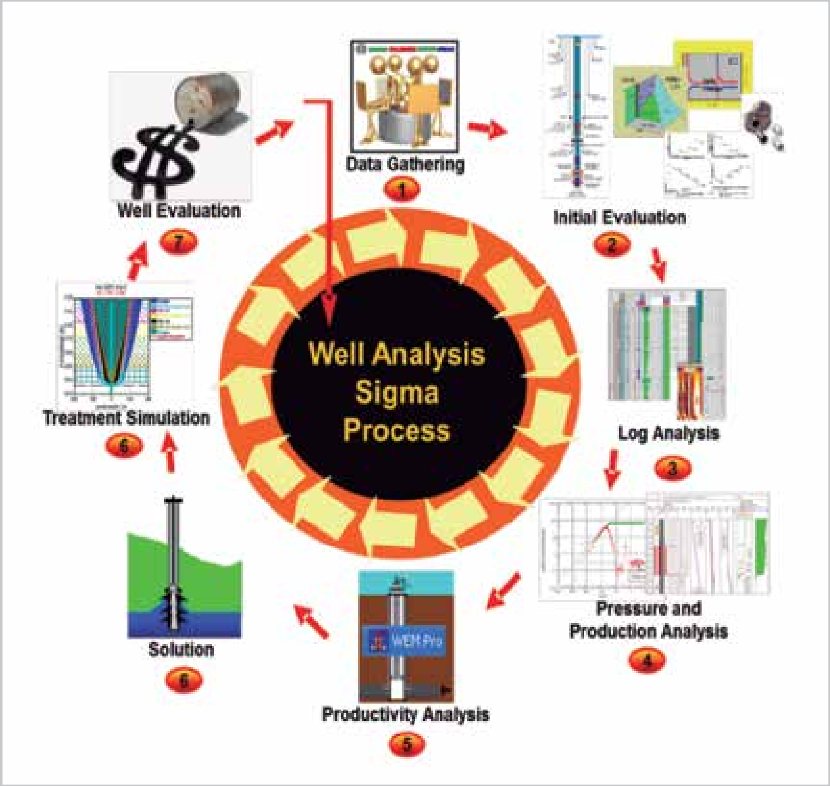

Figure 4. Work flow.

The well data obtained and analyzed included pressure data from surface gauges in the well, well logs, production analysis during production, and post-treatment evaluation.

Laboratory testing

The acid systems were selected based on bottomhole static temperature (BHST) (110°C) and lithology information present in the well; therefore, the base system used was 15% hydrochloric (HCl) acid, in combination with a solvent system to create greater dissolution of the rock (generation of wormholes).

According to the quality control plan for the selection of the systems, a crude oil sample from Well Ku 1297 was recovered from a previous stimulation treatment, and was used for compatibility testing for emulsion and sludge.

The following systems were evaluated:

- Retarded gelled acid system for high temperatures.
- Polymer acid diverter system.
- Primary retarded acid system for high temperatures.
- Relative permeability modifier (RPM) autodiverter system.
- Aromatic solvent system for rock pre-conditioning.

Figure 5 demonstrates the system test results. Systems were selected based on their emulsion breaking point, phase separation, bottle wall cleansing, and the absence of solid particles on the 100-mesh screen.

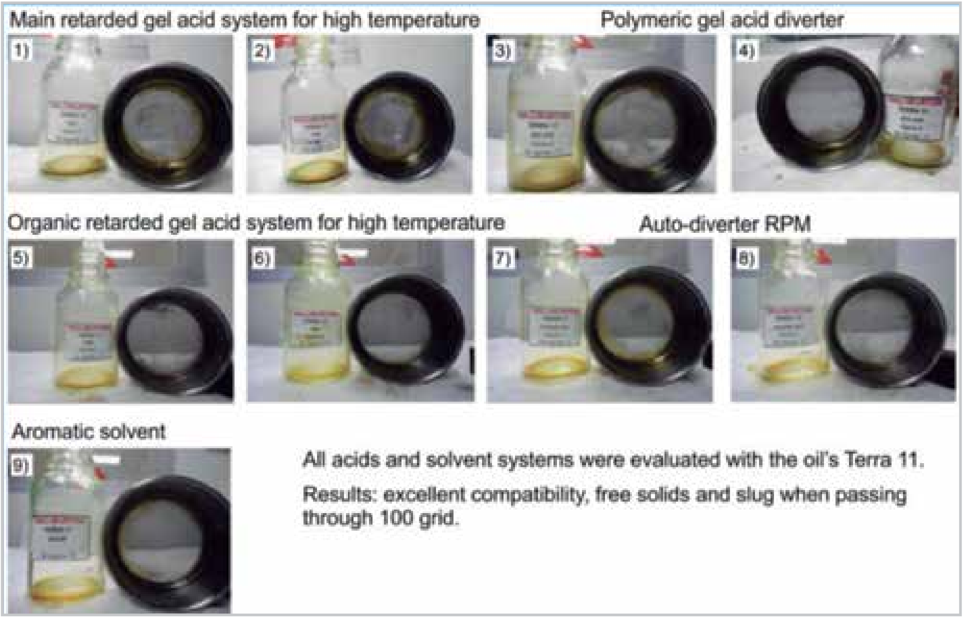

Figure 5. Solid particles on the 100-mesh screen test.

Treatment design

Following are the possible systems that can be used to perform an acid treatment:

- Aromatic solvent.
- Primary retarded gelled acid system for high temperatures.
- Organic retarded gelled acid system for high temperatures.
- Polymeric gelled acid diverter.
- RPM autodiverter.

The stimulation treatment began with injection at moderate rates because the goal was not to achieve deep penetration. The rheology of the necessary fluid required a specific design. This was important because the fluid type and rate are associated with friction pressure.

One of the main techniques for divergence in an acid treatment is the use of commingled systems through pumping acid systems assisted with nitrogen, varying the liquid and nitrogen flow rate (nitrogen quality) to create a dynamic divergence. This technique is helpful for reaching upper zones that conventional treatments cannot reach. The fluid distribution is essentially focused in the upper zones of the interval, as shown in **Figure 6**.

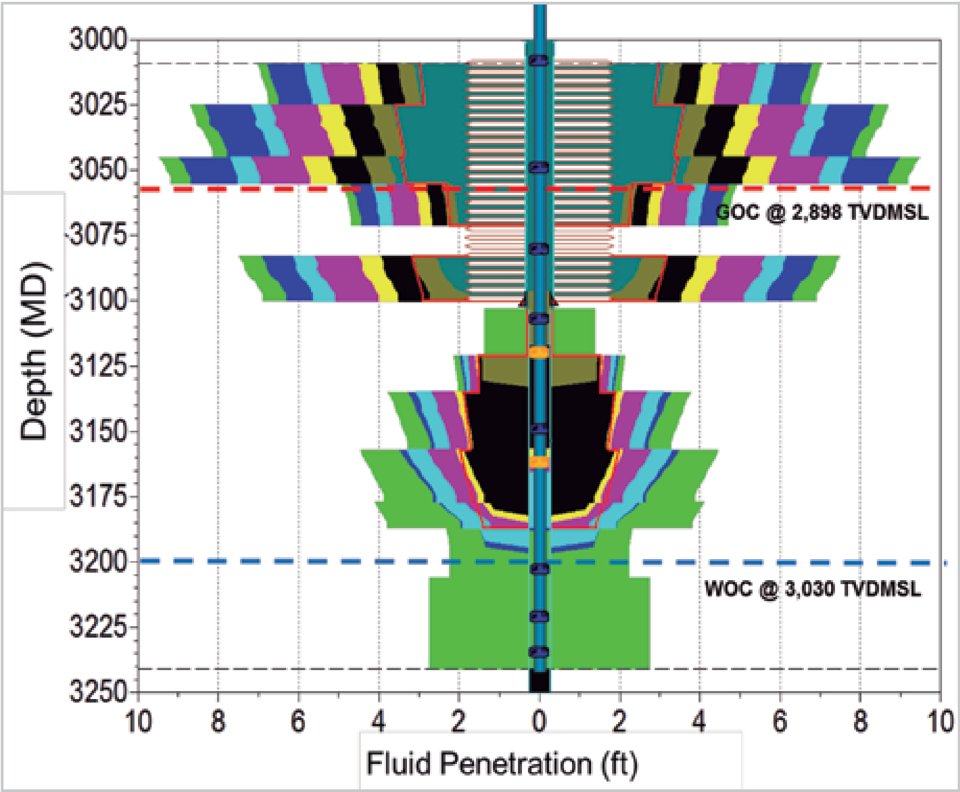

Figure 6. Fluid distribution simulation.

Treatment considerations

To comply with time restrictions, and given the volumes of the acid systems used, it was necessary to derive a work plan and efficient logistics, as well as identify qualified staff and the necessary equipment:

- 5,000 Hydraulic horsepower (HHP).
- One blender.
- One high-rate 2-in. pipe treating string.
- One high-pressure coflex discharge hose, 3-in.
- Storage tanks (for HCl acid and additives).
- One high-pressure unit to back up the annulus.
- One satellite monitoring center for real-time live data transmission.

For offshore treatments, it is necessary to carry personnel and equipment using a well stimulation vessel (WSV). This WSV has regulatory norms to perform these types of quality treatments safely.

Treatment execution

One of the principal parameters to study with respect to the performance of an acid treatment is surface gauge graphs of pressure and rate. These provide the opportunity to analyze treatment fluid behavior.

Because the reservoir pressure is low, it was necessary to energize the fluid systems using nitrogen of 50 to 60% (no damage into the formation) quality. These parameters were determined based on pressure and temperature using a monitoring program to approximately calculate the liquid-gas quality.

All of these variables combined and correlated can help provide an idea of what is occurring downhole; however, final evaluation of oil and water production post-treatment is the best indicator of success.

Real-time evaluation

Real-time evaluation was performed through bottomhole gauge (pressure and temperature) analysis during the treatment.

As shown in **Figure 7**, the fluid distribution observed by the temperature gauges at different depths corresponded to the simulation designed for this treatment, ensuring proper drawdown reduction along the interval of interest.

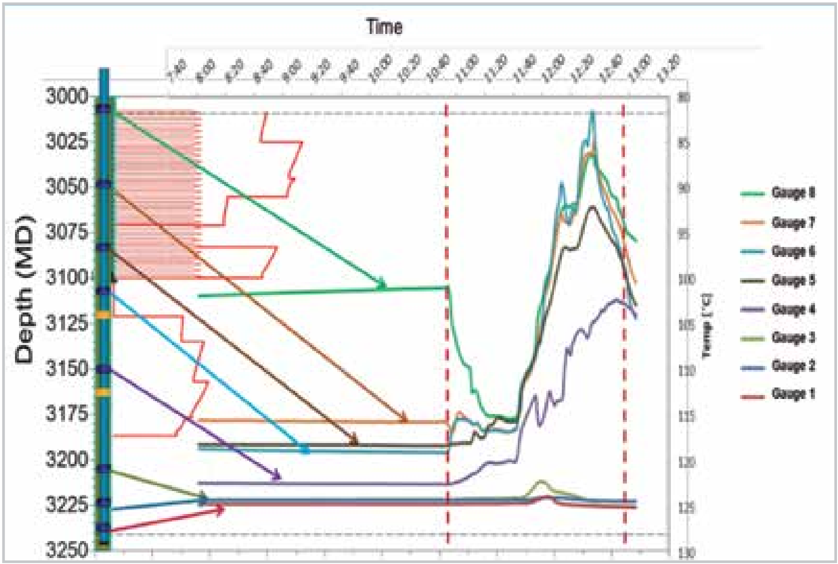

Figure 7. Temperature profile from bottomhole gauges during treatment.

Results

The success of this stimulation treatment can be attributed to the following:

- Integrated formation analysis.
- Laboratory testing.
- Chemical system selection.
- Treatment design based on previous stimulation analyses.
- Field operation monitoring.
- Well monitoring during product delivery.

Figures 8, 9, and **10** show production before and after the acidizing treatment, showing as a result of water fraction decrease.

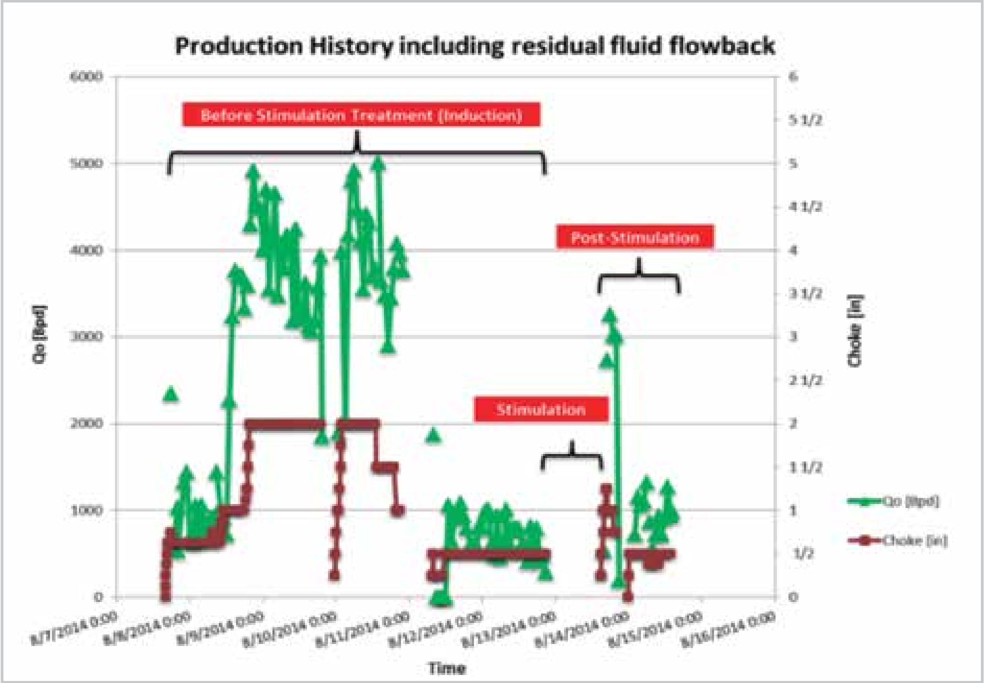

Figure 8. Post-evaluation results.

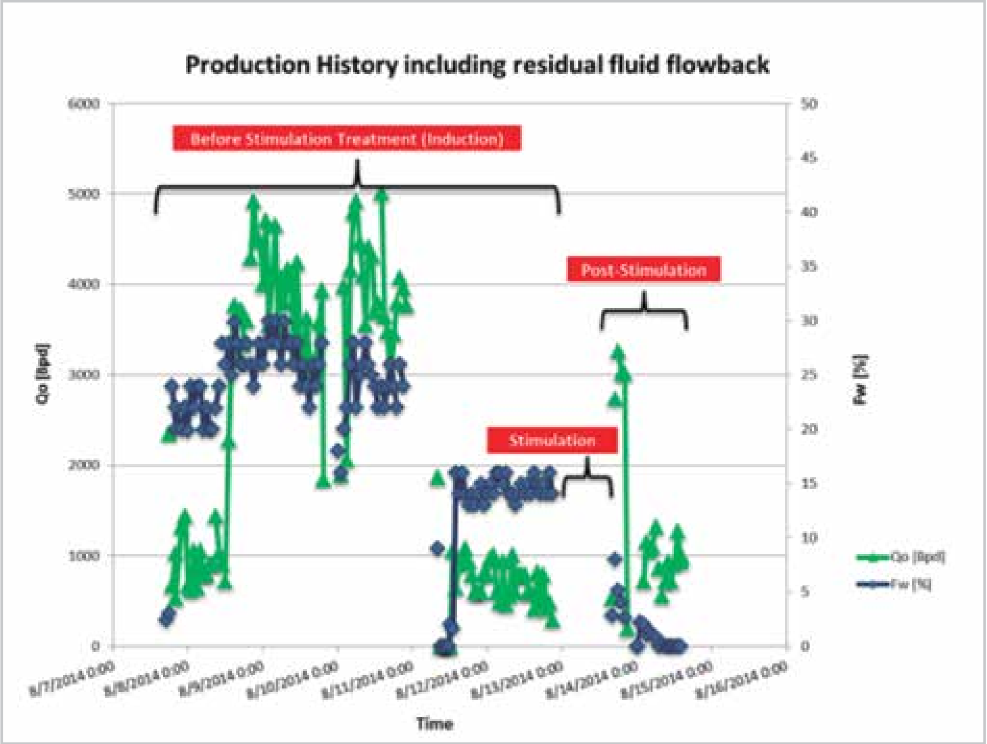

Figure 9. Post-evaluation results.

Oil production was monitored, **Figure 10** to help study drawdown pressure relative to water coning was decreased; as a result, the oil rate increased.

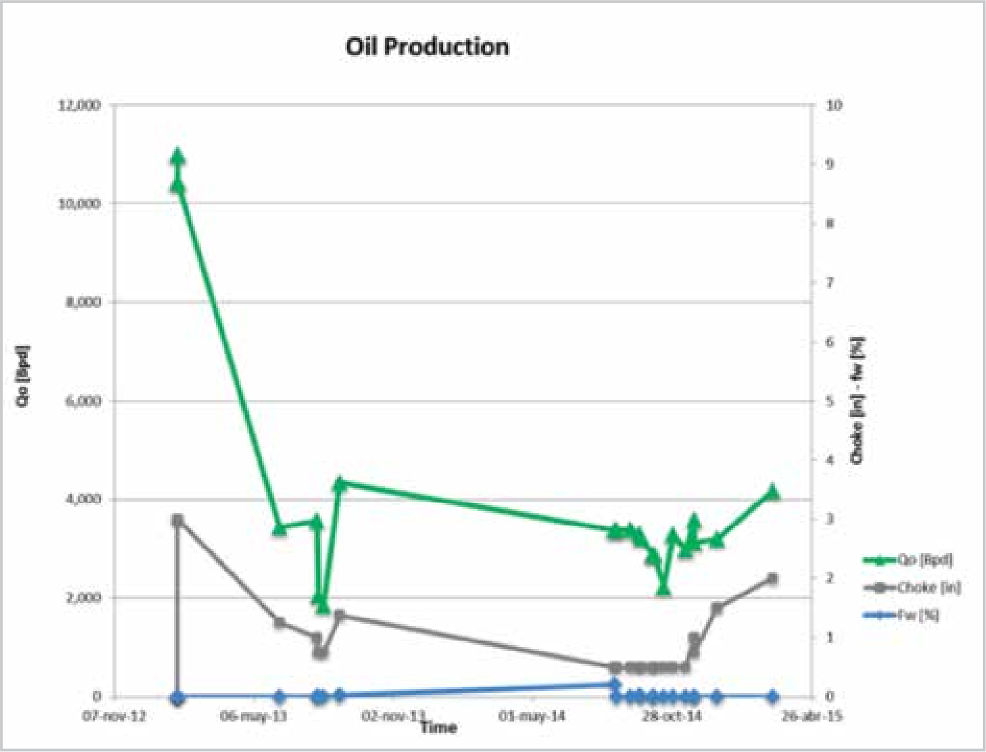

Figure 10. Post-evaluation results.

Conclusions

The following conclusions are a result of this work:

- Successful acid treatments are difficult to achieve in carbonate formations; however, with proper analysis of fluids and acid treatment methods, it is possible to achieve good results in the short and middle range of sustainable production.

- The combined use of diversion techniques and systems helps ensure placement of systems in zones to be treated, mitigating stimulation zones that are not of interest, that might present a risk in the production of undesirable fluids.

- The Ku field has high-density natural fractures and, as a result, high permeability. The principal goal of acid stimulation was to cover the pay zone without increasing water cut. However, it was important to reduce the drawdown pressure, which helped reduce the potential for water coning, while at the same time increasing oil production.

- Real-time downhole multi-gauge evaluation corroborated the treatment performance was in accordance with the designed fluid distribution, ensuring a proper decrease of the drawdown pressure along the interval.

- Oil production after treatment was increased to approximately 40%; however, the principal goal was to decrease the drawdown pressure to mitigate water coning. As a result, water cut was decreased from 15 to 0% (Ku 1297).

Appendix

KM	= Cretácico Medio
KI	= Cretácico Inferior
BTKS	= Brecha
B/D	= Barrels per day
psi	= Pounds per square inch
bbl/min	= Barrels per minute
m^3	= Cubic meters
MD	= Measured depth
TVD	= True vertical depth
TVDMSL	= True vertical depth below main sea level
lbf-ft	= Pounds force per feet
RPM	= Relative permeability modifier

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