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DST/TCP Operations can be Designed to Reduce Near-Wellbore Damage

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Keywords

Near Wellbore Stimulation, Propellants, Tubing Convey Perforating (TCP), DST, Micro-fracking

Resume

Este trabajo describe el uso de propelentes durante una operación de punzados en un pozo desviado perforado en Brasil.
Teniendo en cuenta la ecuación de Darcy y considerando el reservorio como un yacimiento radial circular puede determinarse la productividad/inyectividad de un pozo ante un diferencial de presión entre la presión estática de reservorio y la presión dinámica en fondo. Esta suposición ideal se ve afectada por las condiciones reales de pozo como por ejemplo invasión de fluidos extraños al reservorio virgen, el punzado realizado o el tipo de completación. Estas alteraciones, llamadas comúnmente daño de formación, resultan en una pérdida de productividad/inyectividad.

En el caso de perforación de pozos con sistema sobre balance, se genera un daño en las proximidades del *wellbore* producido por la invasión del fluido de perforación en la formación, reduciendo la permeabilidad en esa región. Adicional a este daño, las técnicas posteriores de punzado, pueden generar un daño al compactar la roca alrededor de cada túnel abierto que establece la comunicación entre la formación y el *wellbore.*

La combinación de estos factores puede reducir la permeabilidad hasta un 80 % respecto de su valor original, impactando negativamente en la producción del pozo. Sin embargo, pueden ser aplicadas técnicas durante el proceso de punzado para estimular las cercanías del *wellbore* by-*passing* la zona de daño y mejorando la permeabilidad a través de los túneles abiertos optimizando la productividad del activo. Este trabajo describe métodos de punado que proveen una penetración profunda efectiva en la formación y el uso de propelentes para mejorar la estimulación en esa región.

Cuando se utilizan propelentes durante el punzado, al detonar se genera un pulso rápido de alta presión que supera el Stress horizontal de la roca creando micro-fracturas. El pozo de estudio, luego de ser punzado fue ensayado con distintos orificios y luego se lo cerró en fondo obteniéndose la recuperación de presión (*Build-Up*). Realizándose un análisis del transiente de dicha información se obtuvo que las

técnicas utilizadas de punzado habían generado la estimulación esperada teniendo como resultado un daño nulo o incluso negativo.
Este trabajo presenta un caso de estudio donde estas técnicas fueron aplicadas durante la terminación del pozo exploratorio ya que por campos análogos se esperaba un daño alto de formación debido a la invasión del lodo.

Abstract

This work describes the use of propellant during a perforating job in a deviated well drilled in Brazil. Taking into account the Darcy equation and considering the reservoir as a circular radial reservoir, the productivity/injectivity of a well can be determined with the established differential pressure between the reservoir static pressure and the dynamic bottomhole pressure. This ideal assumption is affected by actual wellbore conditions, such as the invasion of foreign fluids into the virgin reservoir, the perforating event, and the implemented completion. These alterations, commonly known as formation damage, result in productiv3456ity/injectivity+7 loss.

When drilling wells with overbalanced systems, near-wellbore damage occurs as a result of the invasion of drilling fluids, reducing the permeability in that region. In addition to this damage, subsequent perforating techniques can generate damage by compacting the rock around each perforation tunnel that establishes communication between the formation and the wellbore.

The sum of these operations can reduce permeability by up to 80% with respect to its original value, negatively affecting the production of the well. However, techniques can be applied during the perforating stage that will stimulate the near-wellbore area, bypass the damaged zone, and improve permeability through the perforation tunnels to optimize asset productivity. This paper describes perforating methods that provide deep effective penetration into the formation and the use of propellant to enhance the near-wellbore stimulation.

If propellant is used during the perforating process, it ignites to generate a rapid, high-pressure pulse that overcomes the in-situ horizontal stress and creates microfractures around the wellbore. This stimulation effect improves conductivity and reduces skin damage. After the perforation event, the well was tested with various choke sizes, then shut in with a downhole tester valve for a predetermined buildup period. After performing a transient analysis of the data, it was concluded that the perforation techniques had generated the expected stimulation, resulting in zero or even negative skin damage.

This paper presents a case study in which these techniques were applied during the completion of an exploratory well were invasion damage was expected as a result of nearby well knowledge.

Introduction

This case study is based on an onshore well in which the generation of a micro-fracture system after perforating provided the critical success factor to bypass the damaged zone. The paper describes a technique that uses propellants to reduce the skin damage, even achieving negative values resulting in a stimulated well demonstrating the value added to reduce workover operations, such as matrix acidizing.

Well Description and Challenges

The completion program was performed in an exploratory well with 12 m pay zone. According to the interpretation of open-hole logs, there is a water contact 2 m below the hydrocarbon zone (Fig. 1).

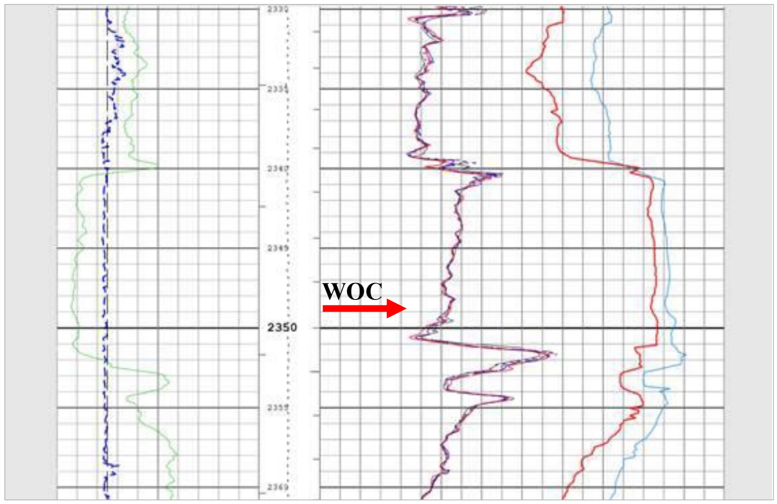

Fig. 1 – Pay zone with near water/oil contact

During the drilling phase, a significant amount of wellbore damage was observed. The formation was tight with high horizontal stress values.

Traditional overbalanced perforating will not bypass the damage, therefore a stimulation treatment (hydraulic fracturing or matrix acidizing) is necessary. As the oil/water contact is nearby, there was a risk of reaching it with these traditional stimulations techniques, resulting in a high rate of water production.

To sum up, the challenge was to reduce the skin factor, achieving sufficient stimulation to provide effective communication between the wellbore and the reservoir avoiding the oil/water contact.

The Solution

To address the challenges, a combination of two near-wellbore stimulations, static under-balance and propellants, was proposed. A static under-balance with tubing-conveyed perforation (TCP) was designed to clean the perforating tunnels using a 4 5/8 in., 12 spf, 16-ft fully loaded gun. In the bottom of the string, a pressure-actuated firing head was installed as the primary detonation device, and a mechanically actuated firing head was installed at the top of the string as a backup system. To stimulate the near-wellbore and bypass the damage zone, 12 ft of propellant was proposed. During perforation, the ignition of the propellant surrounding the guns was expected to create a rapid, high-pressure pulse, which would create micro-fractures around the wellbore.

Information about net pay, porosity, saturations, bottomhole pressure, and oil gravity (which is available from logs, formation pressure measurements, and other sources) was used to run production models and to estimate the production rate. Since this was an exploratory well, a drillstem test (DST) was run to assess the production and determine the next steps for the asset. Depending on the results of the near-well stimulation while perforating, a decision would be made about whether to continue with a matrix acid stimulation or to run the final completion system to put the well in production.

Due to the high pressures generated during propellant burning, it is an obligatory requirement having a good quality of cement in order not to lose isolation behind the casing. To continue with the plan of using propellants, a cement evaluation was performed using a radial bond tool to log with pressure (Fig. 2). A good cement bond was confirmed before entering the well.

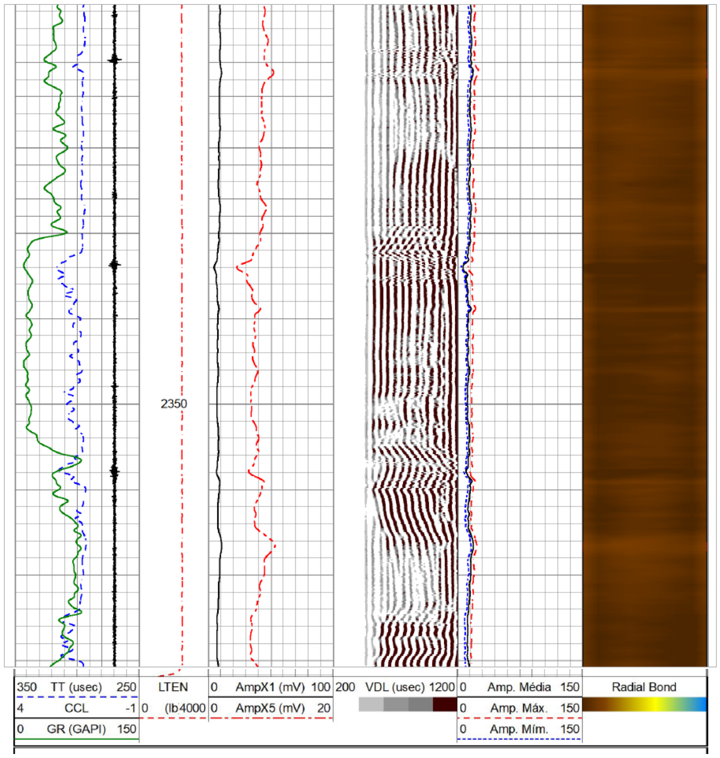

Fig. 2 – Radial cement bond log in the perforating interval

Simulations were performed with penetration charge software to assess the in-situ charge downhole performance, identifying the effective perforation penetration and the entry hole diameters (EHD). Actual penetration depth in downhole conditions differs from the traditional API 19B standard outcomes because of differing conditions, such us overburden gradient, unconfined compressive strength (UCS), temperature, and pressure.

Perforation depth of penetration and the EHD are essential simulation inputs to assess the propellant efficiency. Various gun systems were compared, ranging from 5 to 12 shots per foot (SPF), resulting in tradeoff decision.

With 5 SPF guns, a higher penetration could be achieved because it is possible to use larger charges. Conversely, 12 SPF guns have a faster propellant burn rate, achieving higher pressure and, consequently, better microfracturing results. Figures 3 and 4 illustrate the charge performance of both systems; Table 1 compares data from both systems. The 5 SPF system was selected with Premium HMX charges for a formation penetration of 14.26 in.

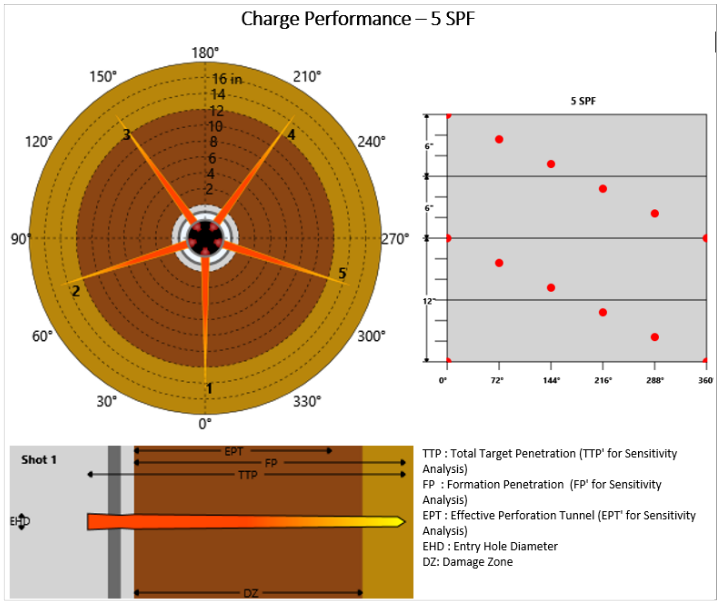

Fig. 3 – Premium charge HMX 5 SPF

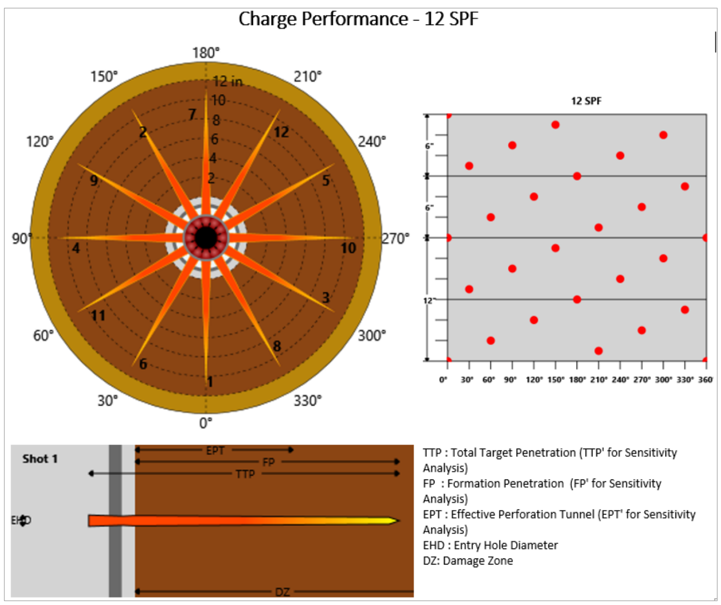

Fig. 4 – Premium charge HMX 12 SPF

Table 1 - Premium Charge HMX 5 SPF vs. 12 SPF

Property	Measurement (in.)	
	5 SPF	12 SPF
Effective perforation tunnel	10.38	6.22
Formation penetration	14.26	10.39
Total target penetration	15.37	11.5
Average exit hole final casing	0.424 in	0.297

Several simulations were performed with specific software to verify the propellant efficiency results and to ensure the creation of micro-fractures. The job set was adjusted to achieve the desired fracture lengths, primarily using the following parameters:

- Underbalance level
- Confined volume in the production zone below the packer
- Volume of propellant to use

With respect to the confined volume, simulations indicated that the space between packer and plug in the well was large, resulting in a dissipation of the propellant energy. Consequently, a bridge plug was placed after the rigless cement bond log (CBL), reducing the rat hole to 20 m. In addition, the simulation software was used to simulate the shock waves generated during the detonation and propellant burning to ensure the integrity of the DST/TCP toolstring (Fig. 5 and Fig. 6).

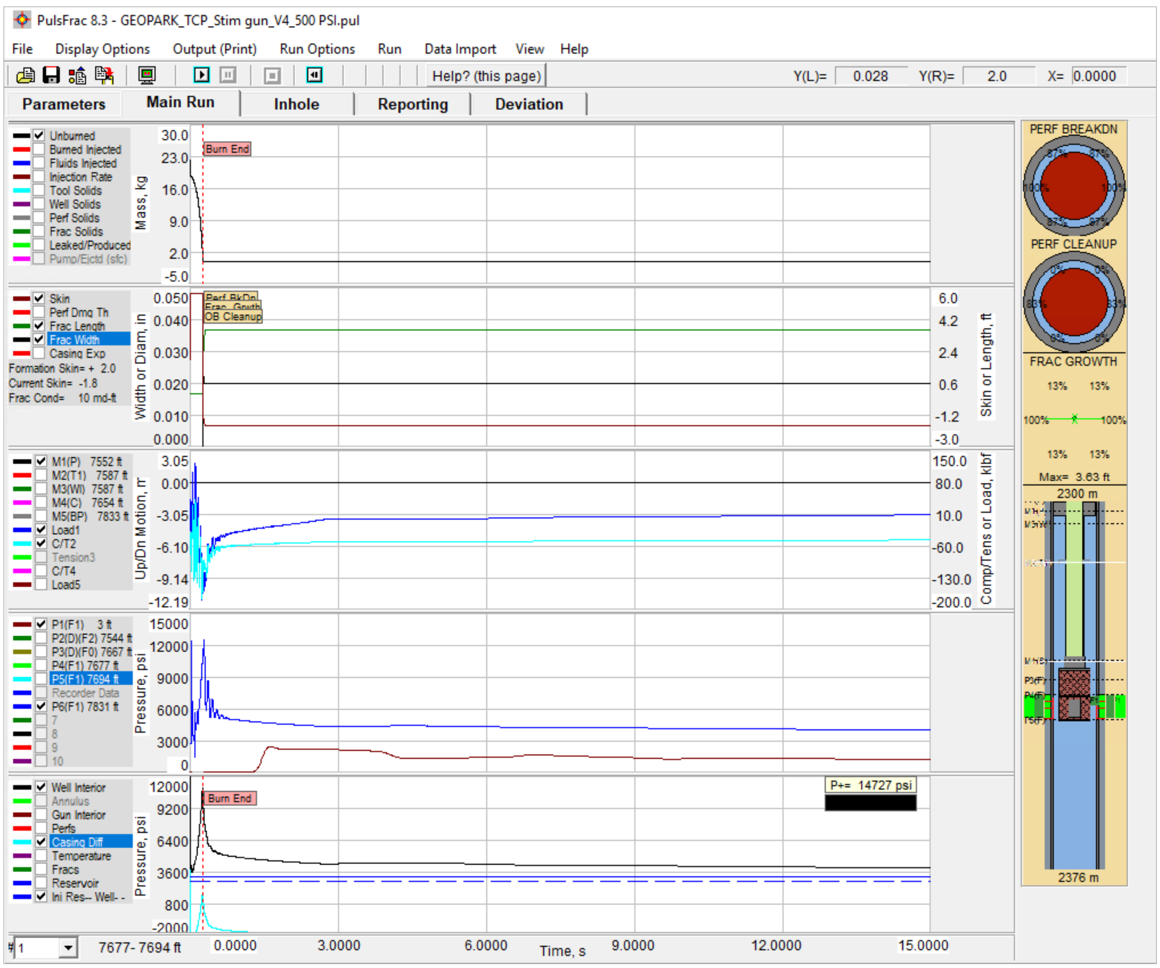

Fig. 5 – Microfracture and shock simulation (15 sec)

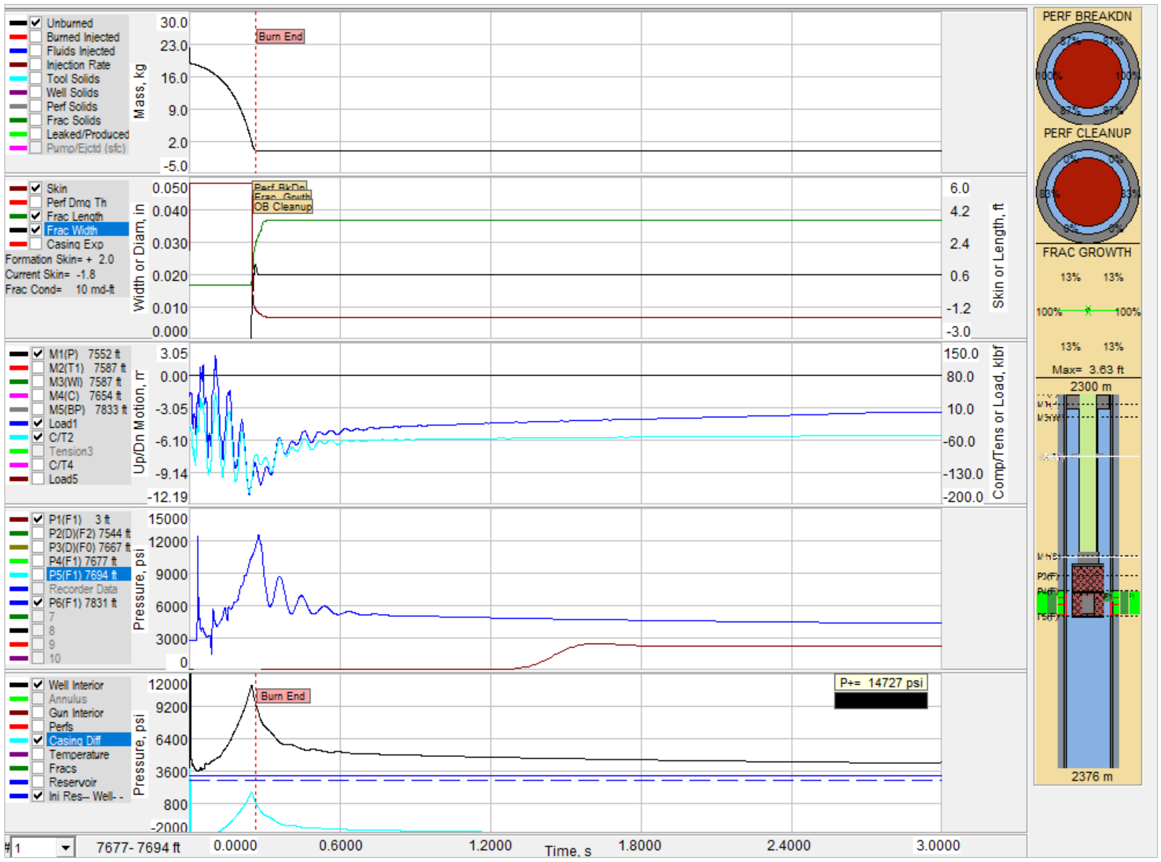

Fig. 6 – Microfracture and shock simulation (3 sec)

The first chart in Fig. 6 shows that the propellant is completely burned at approximately 250 msec (burn end flag). Some mseconds before, a pressure of approximately 11 kpsi is generated with sufficient strength to break the horizontal stress, generating the desired microfractures. The perforation breakdown achieved is 100% in the maximum horizontal stress, whereas it is 87% in the other phases. The perforation clean-up of the tunnel is 83%.

The second chart in Fig. 6 represents the damage in the formation zone, before and after the near-wellbore stimulation (NWS). The initial skin value was +2, and the final value was -1.8. The fracture length was 3.63 ft, and the fracture conductivity was 10 md-ft.

The third chart in Fig. 6 presents the evolution of the tension and compression loads in different elements of the DST-TCP string, particularly on the packer assembly testing. All devices are in compliance with their ratings, indicating good operational safety.

The Fourth chart in Fig 6 describes the behavior of the wellbore pressure in selected points. With this tool is it possible to assess differential pressures, as well as, absolute pressures. At surface (3 ft depth), we can observe a final wellhead pressure of 1100 psi, confirming enough micro fractures length to effectively connect the virgin zone with the wellbore in order to allow flowing the well.

Finally, the fifth chart in Fig. 6 shows the well interior pressure in the perforating interval, which represents the static underbalance effect.

Results

After the gun detonation, the well produced naturally with no artificial lift. Various flow tests were performed with different chokes. Fig. 7 shows the results of the build-up/drop-down flow tests.

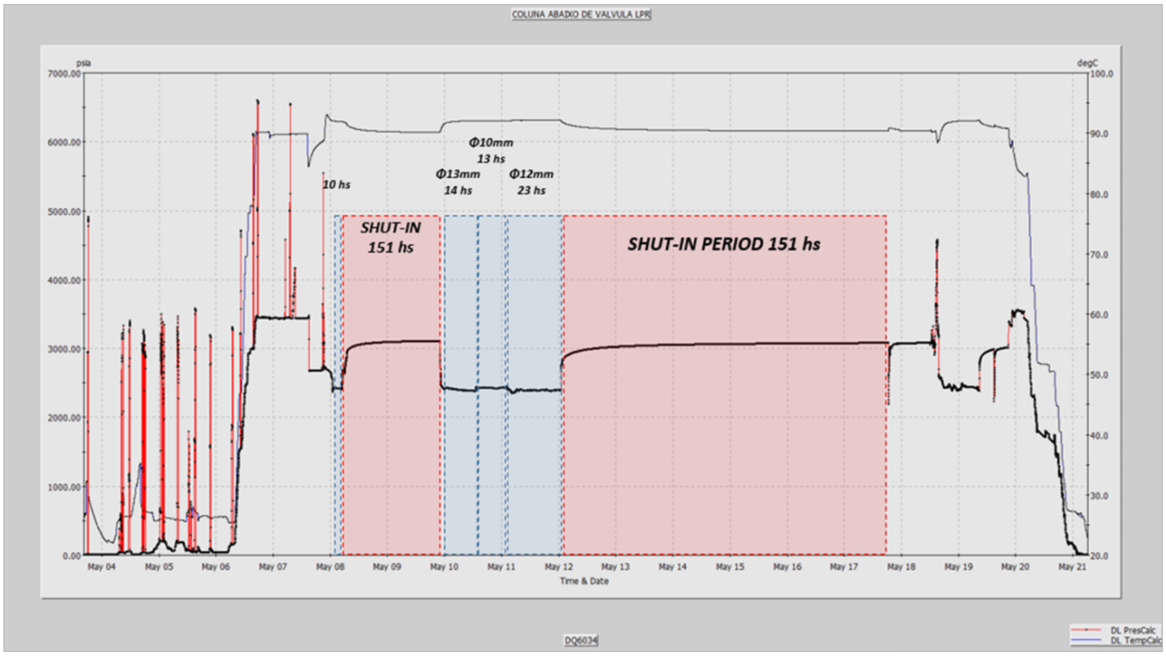

Fig. 7 – Build-up/drop-down flow tests

Analyses of the DST data (Fig. 8) revealed that the propellant stimulation and static underbalance achieved the desired negative skin results (Fig. 9).

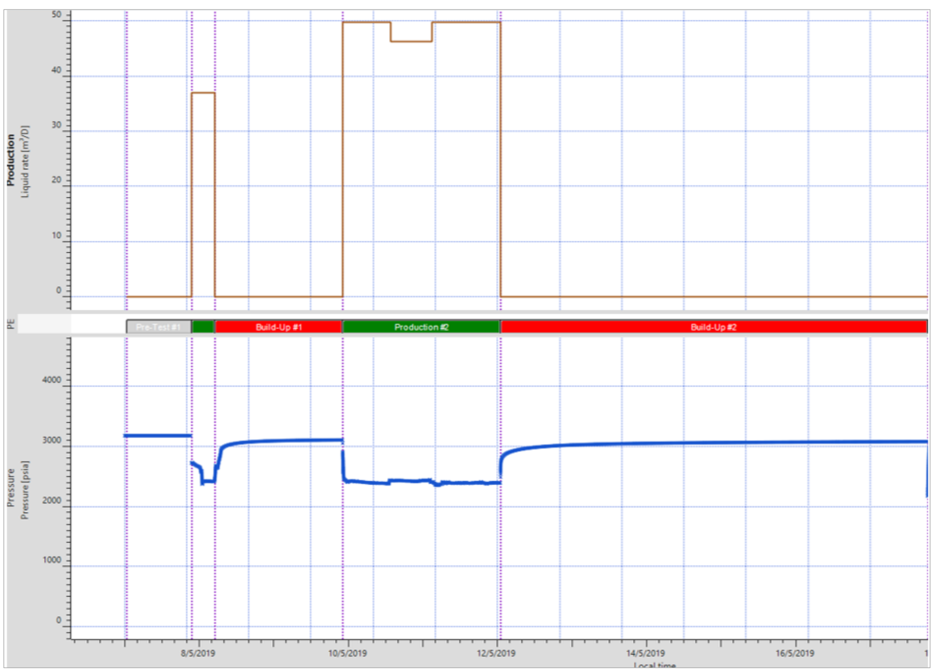

Fig. 8 – Pressure and production data used

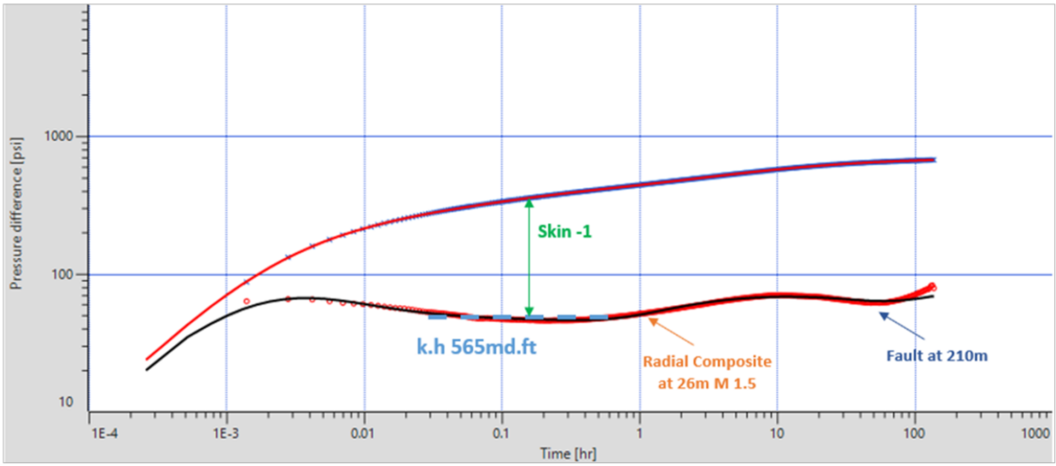

Fig. 9 – Interpretation of pressure transient during buildup

During the test, the water percentage was near-zero, indicating that the microfractures did not reach the oil/water contact.

Conclusions

The proper analysis of the issue and performance of a good planning operation between the operator and service company made it possible to achieve the critical success factors using a near-wellbore stimulation technique. These efforts resulted in the following:

- Skin reduction, improving the well production
- Cost and time reduction by avoiding workover operations, such as matrix acidification.
- Better well performance by preventing potential water production by avoiding a close water/oil contact with a hydraulic fracture.

About the Authors

Ariel Omar Sedlacek holds an MBA degree in financial management from Fundação Getulio Vargas (FGV), Rio de Janeiro, Brazil, and a degree in electronic engineering from National University of Rosario, Rosario, Argentina. Sedlacek works at Halliburton as a senior technical sales advisor and is based in Brazil. He began his professional career in 2004 as an electronic engineer in Grupo Television Litoral, Rosario, Argentina. He later worked for Underwriters Laboratories, Inc. as a project engineer in Buenos Aires, Argentina. Sedlacek began working at Halliburton in 2007 as a wireline field engineer in Argentina. Since moving to Brazil, he has held several frontline supervision roles within Halliburton, including field service manager, area resource coordinator, field service quality coordinator, and performance development coordinator in the onshore and offshore market. Since 2017, Sedlacek has worked in the marketing and sales domain as a technical sales advisor for the wireline product line. His certifications include Regional Latin America Internal Integrated Auditor in standards API-Q2 (certified by API) and ISO 9001/ 29001-OSHAS 18001- ISO 14001 (certified by DNV). Sedlacek is a member of SPE.

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