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Innovative approach to scale management in Buzios Field: sequential acid job and scale inhibitor squeeze treatments

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Abstract
The sequential acid job and scale inhibitor squeeze treatments in the Buzios field represent an important technical advance in comparisson to conventional treatments and have been applied several times in this field with great success. This work presents the first time a treatment of this type took place in the field, in Well-B. The opportunity for this treatment presented itself with the light workover operation to correct a problem in downhole safety valve and open the sliding sleeve valve. The Buzios field presents extensive oilfield scale issues and carrying out acid jobs followed by scale inhibitor squeezes has a high value for the field management.

Keywords
Buzios; scale; squeeze; acid; inhibitor

Introduction
Buzios is the largest ultra-deepwater field in Petrobras. The reservoir is located between 5,000 and 6,000 meters below sea level, in a seawater depth ranging from 1,500 to 2,200 meters [1]. It is a thick carbonate reservoir formed by the Barra Velha and Itapema formations. The reservoir's properties represent a challenge to its production, requiring design decisions aimed to ensure the success of management actions and flexibility. For this reason, selective and intelligent completions represent the main resources adopted in the field.
The first Floating Production, Storage and Offloading unit (FPSO) started producing in April 2018 and nowadays five FPSOs are in operation, of a total of 11 planned.
To assess the complexity of the reservoir, formation waters were collected from different wells using PVT sampling devices during the drilling campaign. The laboratory analyzes showed high concentrations of ions, such as calcium, strontium, and bicarbonate, for example.
Even before the first FPSO unit came into operation, scale issues were observed in 2016 during an extended well test, in two different intervals of one producer. This behavior was later observed in some other producers, even those that produce with a water cut below 0.5%.
The composition of the formation water, associated with the high pressure & temperature of the reservoir, the presence of a high carbon dioxide content and the rock-fluid interaction result in a medium-high scaling potential or saturation ratio for calcium carbonate from the producer wellbore up to topside facilities.
Various initiatives have been taken to mitigate oilfield scale issues in these producers, such as downhole injection of scale inhibitors, production interval management, cycling intelligent completion valves (ICV), scale inhibitor squeeze treatments among others.
The first squeeze treatment of the Buzios Field took place in well-A in December 2020 and was considered a success [2]. It allowed the evaluation of a patent regarding a combined treatment process for removing and inhibiting scale employing an organophosphonate in acid form, for simultaneous removal and inhibition of scale [3].
This work presents the second squeeze treatment, which took place in October 2021, in well-B, and was designed based on another patent referring to a method of combined application of scale remover and inhibition, ie, conventional formulations of acids and scale inhibitor deployed in a sequential form [4].
This treatment was an added scope to a planned light workover (LWO) operation to install the hold open sleeve in DHSV and open the lower sliding sleeve valve (SSV).

Methodology
Laboratory experiments are crucial to design squeeze treatments. The scale inhibitor must be compatible with the other aqueous fluids involved, efficient in scale inhibition [2,5], compatible with the formation and have an adequate adsorption isotherm.
Buzios represented a challenge for conventional chemistries due to the challenging composition of the produced water and the characteristics of the reservoir. Furthermore, high scale inhibition

efficiency is required due to high well flowrates, which also requires a favorable adsorption isotherm.
As the production scenario and scale inhibitor selected for well-B do not differ from well-A, the results presented in a previous work [2] cover this. To avoid potential operational problems during the LWO and best ensure the expected inhibition performance, a set of experiments were designed to define a set of constraints to ensure that the scale inhibitor would not precipitate in the formation during the expected shut-in period, which was estimated in ten days or more.

Experimental Procedure

To represent the mixing zone between the spearhead acid job and the posterior scale inhibitor squeeze, two solutions were mixed. The first consisted of a solution representing a spent 15% hydrochloric acid, ie, around 90,000 mg/l of calcium. For the second, four different solutions were used consisting of 2, 5, 10 and 20% scale inhibitor solutions. The mixture proportions evaluated were: 10(inhibitor solution): 90(spent acid), 50: 50 and 90: 10 in %volume.
The pH of each mixture was adjusted to 4.0 using sodium hydroxide to mimic the equilibrium pH at the formation after total expenditure of the acid/inhibitor acidity. This value of 4.0 was obtained via thermodynamic simulation in Multiscale 8.3 [3] considering the total expenditure of a hydrochloric acid 15%.

Results and Discussion

Figure 1 shows a brief history of inorganic scale problems in the Buzios field until 2023. In fact, 70% of wells showed signs of inorganic scale problems, observed by well production history or restrictions in well columns highlighted during LWO operations (DHSV failures and other integrity safety procedures).

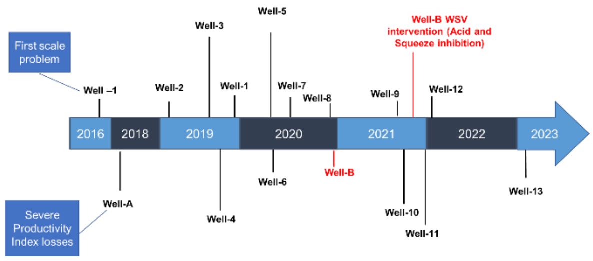

Figure 1. Buzios wells inorganic scale problems observed until 2023.

Multiscale thermodynamic simulator [6] was used to evaluate the severity of scale potential. The ranges of pressure and temperature and the flowrate and water cut considered in the simulations are presented in Tab. 3.

The results obtained in the Multiscale simulator are shown in Fig. 2 at different points in the production system. It is possible to observe a medium-high scale potential for calcium carbonate in the well [7]

Table 3. Pressure, temperature and flowrate used in Multiscale simulation.

Properties	Value
Pressure (kgf/cm²)	570 - 600
Temperature (℃)	89-93
Flowrate (m³/d)	8000-8300

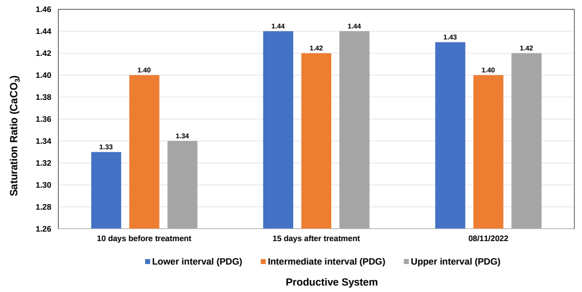

Figure 2. Calcium carbonate saturation ratio before and after acidizing and squeeze inhibition.

The producer chosen to be a pilot has ICVs in three production zones. Additionally, the well has there permanent downhole gauges (PDG) in the annulus of the three zones, as well as another PDG in the tubing near the upper production zone.
To eliminate scaling problems in the tubing, two chemical injection mandrels (CIM) were installed for continuous dosing of scale inhibitor (annulus and production tubing) of the lower and intermediate production zones. Unfortunately, no CIM was installed in lower zone. Figure 3 shows the schematic drawing of the completion of Well-B.

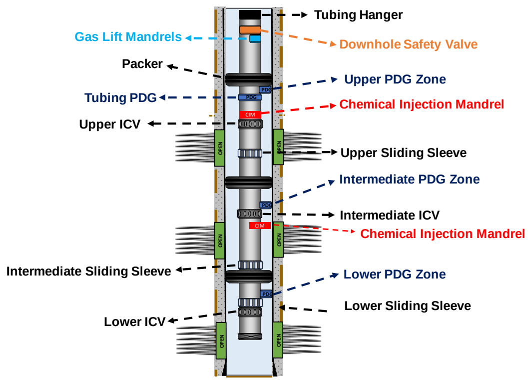

Figure 3. Schematic drawing of the completion of Well-B.

In September 2021, a LWO operation was carried out due the spurious closing of the DHSV and issues related to well integrity. It was necessary to open the lower SSV and install the hold open sleeve on the DHSV.

Figure 4 shows the rig and the Well Service and Stimulation Vessel (WSSV) used in the operation.

Figure 4. Rig and WSSV used in the operation.

During the operation, the impression block run by slickline showed a restriction in 5,559 meters or 40 meters above intermediate SSV. Based in the succeeded previous operations [2], a removal/inhibition operation was designed using a preflush containing organic solvents followed by hydrochloric acid and then squeeze inhibitor.
Due to operational uncertainties, studies have been conducted to ensure no reservoir damage for shut-in periods longer than 48 hours.
Table 4 shows the scale inhibitor concentration and the maximum shut-in time in the reservoir. It is worth mentioning that the mixtures tend to fail for the ratio 10(inhibitor solution): 90(spent acid). Therefore, in this scenario, the region with excess of calcium is the critical one.

Table 4. Scale inhibitor concentration and maximum time permitted.

Concentration (%)	Time limit (days)
2	≥ 20
5	16
10	5
20	2

A scale inhibitor concentration of 5% was chosen for this treatment, although a higher concentration, probably even 10%, could be used for the partition between the bulk and the rock surface should be enough to reduce the amount of inhibitor in the bulk by a significant margin.
Acid was only pumped in the lower interval due to volumetric restrictions in WSSV and the impossibility of continuous scale inhibitor injection.
The operational and well return to production sequence is shown in Fig. 5.

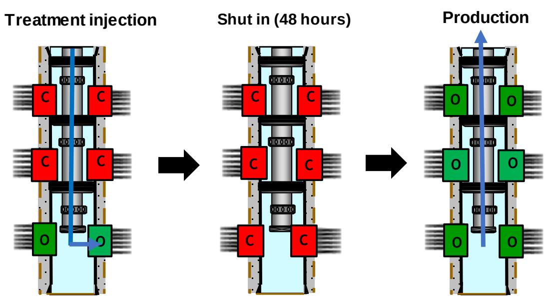

Figure 5. Sequential chemical treatment and well return to production.

The chemical treatment is detailed in Tab. 5.

Table 5. Chemical treatment performed in Well-B.

Fluid	Volume
Mixture of solvents (Diesel, butyl glycol and xylene)	100 bbl
Hydrochloric acid 10%	50 bbl
Scale inhibitor 5%	314 bbl
Potassium chloride 2%	157 bbl
Diesel	710 bbl

The Production Index (PI) before and after chemical treatment is shown in Fig. 6.

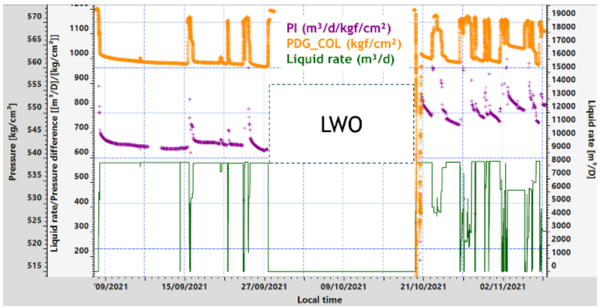

Figure 6. Productivity index before and after chemical treatment.

The sensors showed a 15% increase in PI after the chemical treatment. This can be mainly attributed to the treatment itself and the opening of an the lower SSV. In fact, the high productivity of these wells makes it difficult to analyze small scale amounts deposited in tubing.
The squeeze treatment simulations showed a lifetime of approximately 400 days based on a production of 8,200 m³/d (0.3% water cut) and a minimal inhibitor concentration of 137 ppm, with PI stability until October 2023.

Conclusions

The sequential treatment represents an important technical advance in comparison with traditional treatments and has been applied in Buzios field with high success.
Indeed, the economy involved in the process, compared with traditional treatments, is very substantial.

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