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Case Study: SJ9-3 Fork Leg Cycling Production Well of the San Jacinto Tizate Geothermal Field, Nicaragua

Idalia A. Matus Pravia, Lester L. Prado Reyes and Julio A. Guidos Pineda

Polaris Energy Nicaragua, S.A. (PENSA), Km 114 Carretera León-Malpaisillo, Nicaragua

imatus@polarisgeothermal.com

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ABSTRACT

San Jacinto Tizate is a high temperature geothermal field with a total of 24 original legs, 6 sidetracks, and 4 fork wells or multilateral wells (3 production wells and 1 reinjection well). One of the wells that displays cycling behavior is SJ9-3, which is fork-leg well. SJ9-3 is a production well drilled in August 2010 at 1,676 mMD. After drilling the well, was identified to have formation damage due to mud, and an acid treatment applied in July 2011 to remove this damage and to enhance permeability. During the build up test, the slickline broke inside the lubricator tube, and the Kuster K10 tool, two heavy sinker bars and 5500 feet of slickline fell into the well. The well was put into production without any interference from all the parts left inside the well, but from March to September 2012 a decline in production was observed.

In 2013, an enhancement program was carried out with the objectives of recovering the slickline and Kuster tool, deepening the well, perforating a blank section of the 9-5/8” liner and the 13-3/8” production casing, and to fork the well to find additional permeability and to increase production capacity. The SJ9-3 fork leg was put online again in March 2014. From the time it was connected to the power plant, a cycling production behavior was observed, maybe due to some competition between both legs to dominate the production which is affected by the different fluid enthalpies of each feed zone. The original leg behavior showed long cycles that allowed more stable production, and after a remediation program the well showed more frequent cycles which caused instability in its production. Due to the unstable production behavior, PTS logs were used to identify permeable zones, which leg produced, the percentage of contribution and to understand the cycling behavior. Currently, the well continues to show cyclic production behavior for total mass flows between 33 and 72 tph, with an average enthalpy of 1,995.4 kJ/kg and 63.38% of quality. The average power generation is 3.73 MW.

1. INTRODUCTION

The San Jacinto Tizate Geothermal Field is in the northwestern part of Nicaragua in the Marrabios volcanic chain, about 90 km from Managua and approximately 20 km northeast of Leon City (Figure 1). In 2001, the San Jacinto Power Company was awarded with an exploitation license for the San Jacinto-Tizate concession. In 2003, this was transferred to Polaris Energy Nicaragua S.A. (PENSA), which is a Canadian company. A 10 MWe back pressure unit was commissioned in 2005, and an expansion project to replace the backpressure unit for a condensing plant of 72 MWe (2×36 MWe) started in 2009. Phase 1 (36 MWe) was successfully commissioned in January 2012, and Phase 2 (36 MWe) in December 2012.

The first exploration wells were drilled in 1993. From the period of January 1993 to January 2018, six drilling campaigns have been carried out with a total of 24 original legs, 6 sidetracks, and 4 fork/multilateral wells (production and reinjection wells). Currently, 14 production wells and 7 injection wells are in use. The well locations are shown in Figure 2.

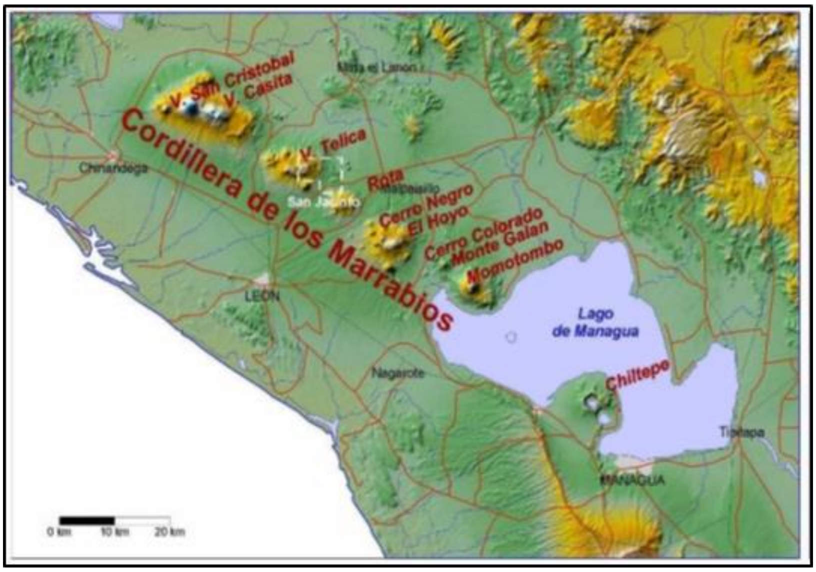

Figure 1: The San Jacinto Tizate Geothermal Field.

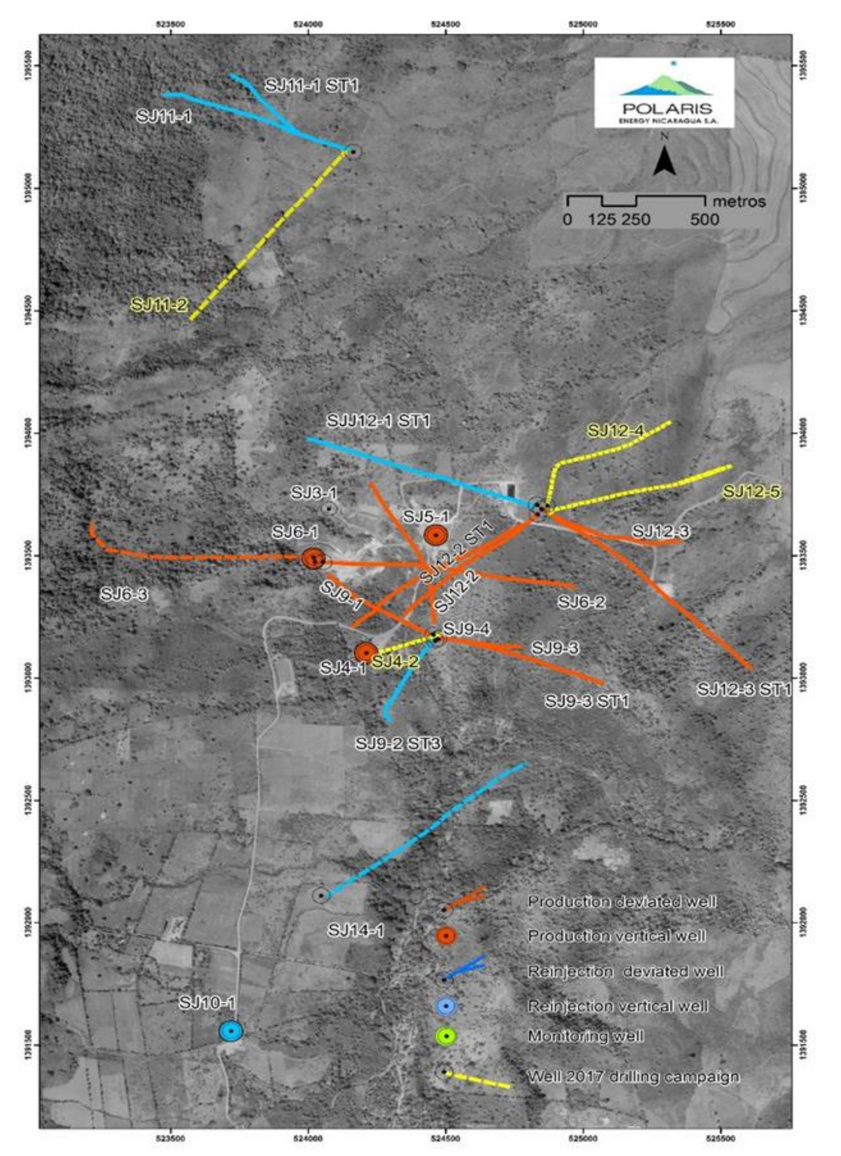

Figure 2: Well locations in the San Jacinto Tizate Geothermal Field.

2. SJ9-3 FORK LEG PRODUCTION WELL

SJ9-3 is a directional production well with a 13-3/8" production casing and a 9-5/8" liner (blank/slotted combination) completed in August 2010. Due to low well productivity, an acid treatment program to remove damage formation was successfully implemented in July 2011. During a build-up test in September 2011, the slickline broke inside the lubricator tube and the Kuster K10 tool plus two sinker bars and 5500 ft of slickline fell into the well. To prove if the well could flow with all of those items inside, the well was stimulated with air to discharge it and it was shown that the well could flow; therefore, a decision was made to leave those items in the well.

However, from March to September 2012, it was observed that steam flow declined from 42 to 36 tph (5.45 to 4.7 MW) at 8.6 barg of wellhead pressure and a 100% open valve. For this reason and to increase productivity, in 2013, a well enhancement program was carried out in well SJ9-3 with the objectives of recovering the slickline and Kuster tool, deepening the well, perforating a blank section of the 9-5/8" liner and the 13-3/8" production casing, and to fork the well to try to achieve additional production capacity.

The first step was to recover the wireline and Kuster tool. A total of six wireline spears were run and recovered 1,337 m of slickline and the remaining 339 m was milled to the bottom of the 9-5/8" liner at 1,666 m. The second step was to deepen the well. The original hole was deepened with an 8-1/2" hole from 1,666 to 1,972 m, and a 7" perforated liner was run to total depth with the top of the liner (TOL) sitting at around 1,653 m. An injectivity test was conducted using 300, 500 and 1,000 gpm pump rates and with a PTS tool at 1,950 m. An II=9 tph/bar was estimated from the downhole pressure and it was slightly higher than the post acid injectivity of around 7.4 tph/bar taken at 1,550m.

The third step was to perforate the casing of the original section of SJ9-3. Three sections were perforated at 1,590-1640 m, 1,163-1,172 m (blank section of the 9-5/8" liner), and 619-640 m (13 3/8" production casing) using Schlumberger wireline equipment and services. The deepest two sections were completed prior to forking the well and the shallowest section was completed after forking the well. An injectivity test was carried out in the two deeper sections and similar a result was obtained with II=8.9 tph/bar. The PFO survey showed a poor permeability thickness (kh=1.54 d-m) with a negative skin factor (s= - 4.3) suggesting an absence of formation damage.

The fourth step was to fork the well. A 13-3/8” casing window was milled using the Pathmaker whipstock system and a 12-1/4” fork hole was drilled from 700 to 1,967 m. Total loss of circulation was encountered at 1,201 m. The hole became tight between 1,824-1,843 m which required additional reaming, but the drilling continued to 1,975 m and then high a torque was encountered, and the fork was terminated. However, the drill pipe became stuck for several days and finally the drill pipe was cut at 1,847 m, and 119 m of fish was left in the hole. The 9-5/8” perforated liner was run and squatted on top of the fill at 1,809m.

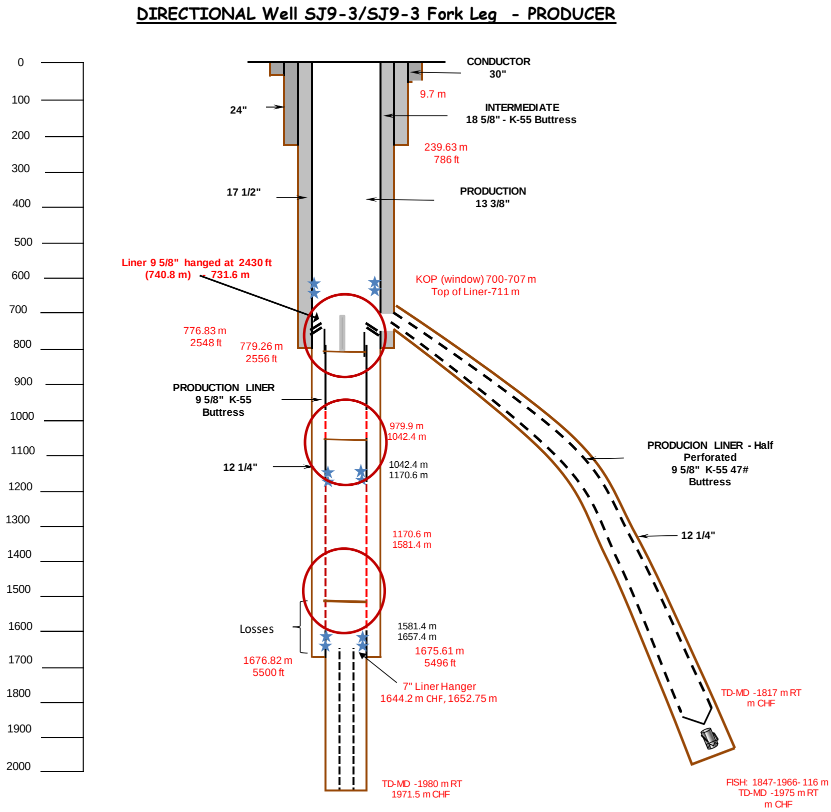

Figure 3: SJ9-3 fork leg well schematic.

After the 9-5/8” liner was run, an injection test was conducted at 500 gpm with the PTS tool at 1,800 m. The temperature profile revealed high permeability at 1,220, 1,600, and 1,700 m. An injectivity index of 9 tph/bar was obtained. Initial discharges and downhole surveys indicated a fixed blockage at 1,524 m within the original leg. In December 2013, a downhole video (DHV) survey was conducted which reconfirmed and showed that the original well was blocked at approximately 1,030 m (see Figure 4). The last workover was carried out in January 2014 to clear the wellbore obstruction. The original leg was cleared to a total depth of 1,980 m, and a sinker bar was run to verify the total depth reached.

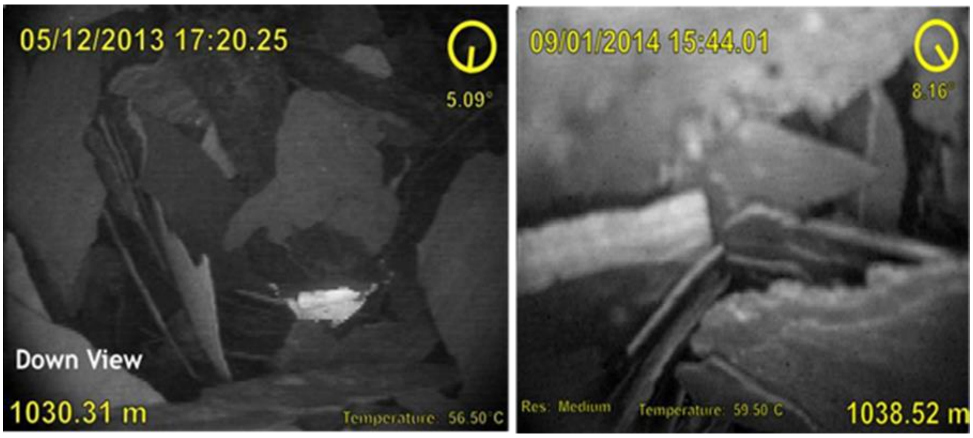

Figure 4: DHV survey showing the obstruction down view of the original leg.

2.1 Well Testing

Once the workover program was finished, a successful horizontal discharge test using the Russel James Method was carried out using 10" and 8" end pipe diameters. The wellhead pressure and lip pressure showed highly variable readings. This behavior could be due to the interplay of multiple feeds from the fork leg, the perforated section and the main leg of the well.

The well continued showing cycling behavior with wellhead pressure (WHP) ranging from ~3.7 barg to ~6.1 barg. The total mass measured was ~90 tph (~55 tph of steam) and 1,750 kJ/kg of discharge enthalpy at lower wellhead pressure and ~160 tph (~78 tph of steam) and 1,450 kJ/kg of discharge enthalpy at higher wellhead pressure.

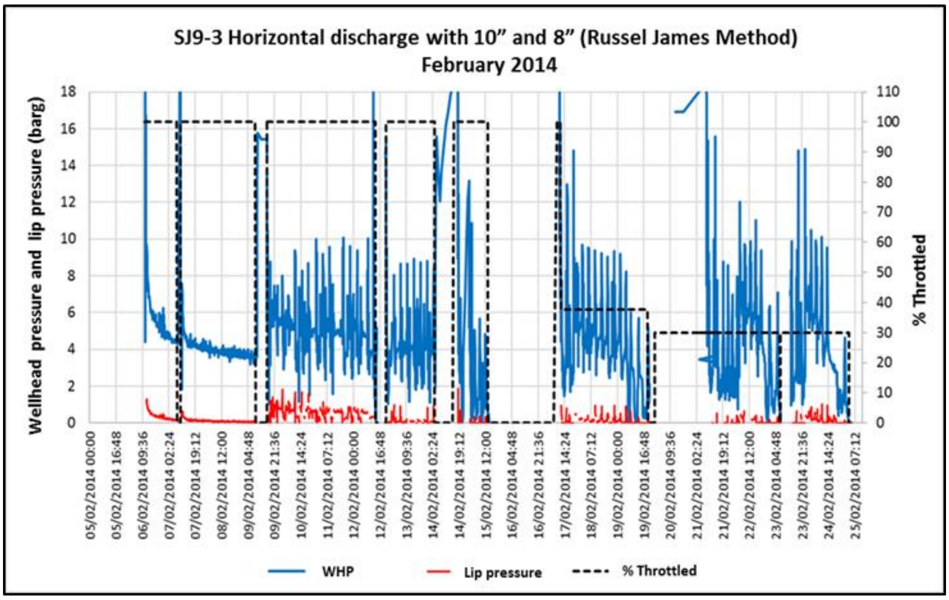

Figure 5: Wellhead pressure and lip pressure during SJ9-3 fork leg discharge.

2.2 Cycling Behavior

The SJ9-3 fork leg was put online in March 2014. From the time it was connected to the power plant, a cycling production behavior was observed, because it is affected by the different fluid enthalpies of the feed zones of each hole.

Figure 6 shows WHP behavior with one leg (2013) and WHP post workover (2014-2015). It can be observed that the original leg had longer cyclic periods that allowed more stable production, and after the remediation program the well showed more frequent cycles which caused instability in its production.

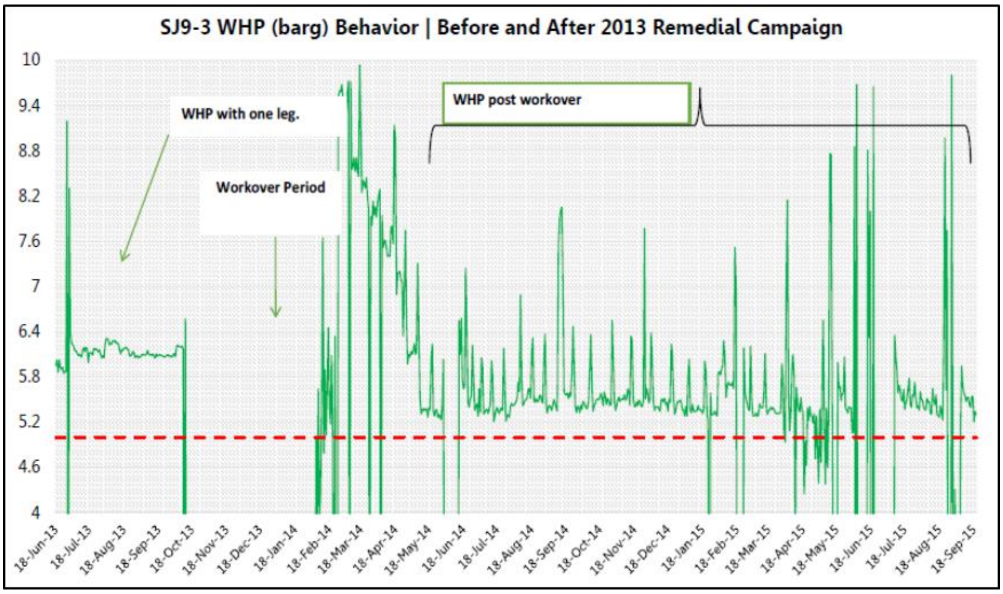

Figure 6: SJ9-3 wellhead pressure behavior before and after the remediation campaign.

Given this behavior, the original leg has been monitored through dynamic logs (PTS) with the aim of determining the reasons for this cycling behavior. Figures 7, 8 and 9 show PTS profiles. The following findings were observed in these logs:

March 2014 spinner log at 100% opened: during down-log at window height (from 700 to the bottom), the tool showed negligible contribution from the original deepened leg, only the fork leg was producing. On the other hand, in the up-log the original leg began to produce.

May 2014 spinner log at 55% opened: in both logs (down and up) there was no contribution from the original leg (below 700m). The steam production was primarily coming from the fork leg.

July 2014 spinner log at 100% opened: spinner response during down and up showed that the steam production was coming from the original leg.

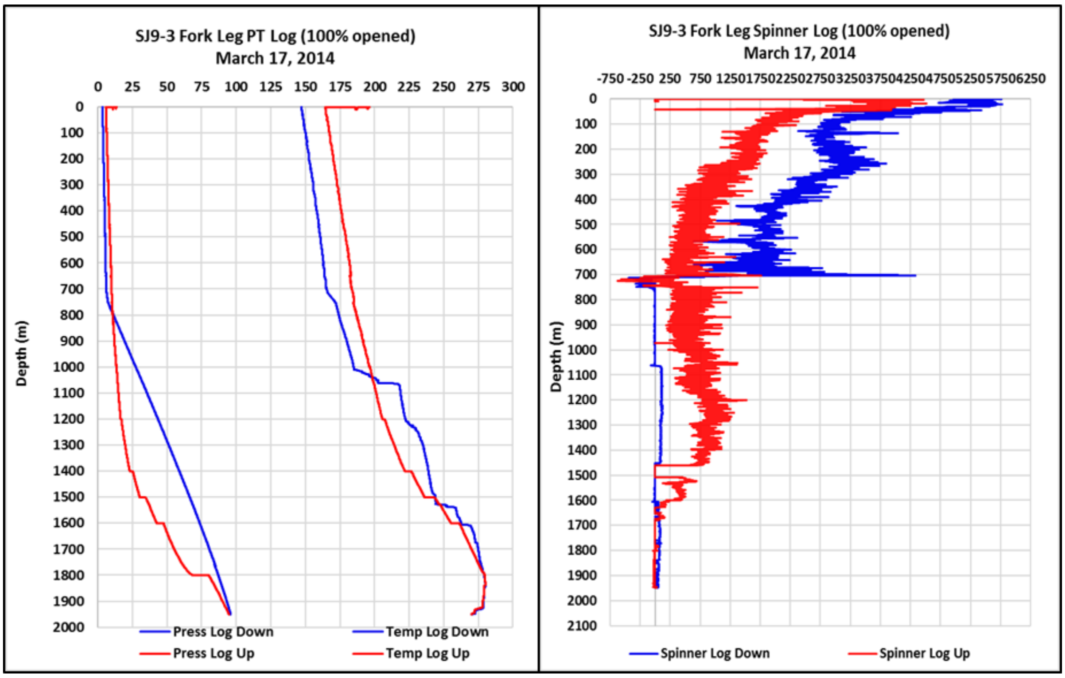

Figure 7: Dynamic log of well SJ9-3 fork leg when it is 100% open (March 2014).

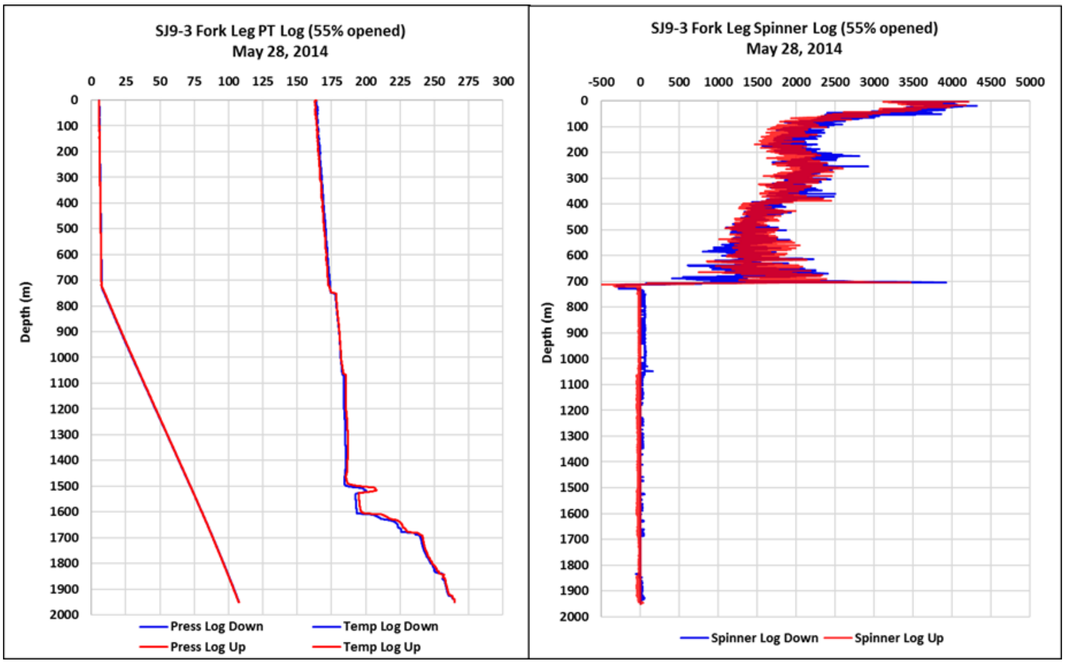

Figure 8: Dynamic log of well SJ9-3 fork leg when it is 55% open (May 2014).

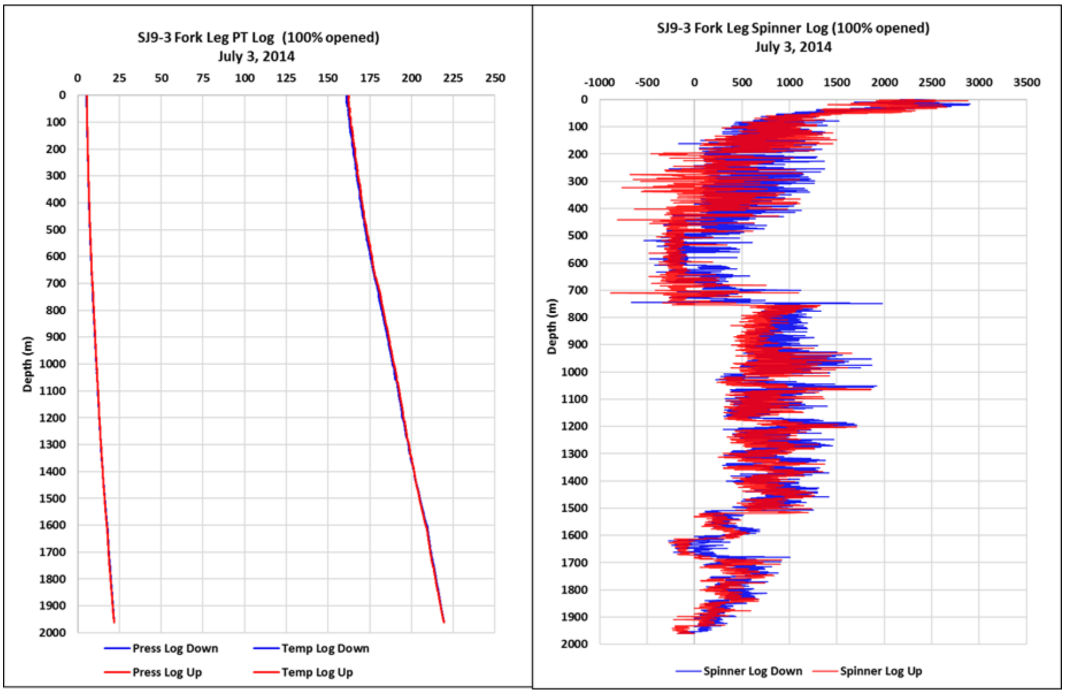

Figure 9: Dynamic log of well SJ9-3 fork leg when it is 100% open (July 2014).

During the year 2015, with the objective to identify which leg allowed stable production, a set of dynamic surveys (PTS) and surface measurements (WHP and mBar) were carried out. Table 1 summarizes all the PTS logs performed. Based on all these measurements, it was determined that the original leg maintains stable production for a longer period. Both legs periodically stop flowing, but, when the original leg is producing, the pressure at the fork is higher than when the fork is producing and it is possible that the original leg is feeding into the fork. Production is being reduced because of interference between the two legs (competition). Maybe having only one of the legs open is likely to result in a more stable flow regime.

Table 1: Summary of SJ9-3 fork leg dynamic logs.

SJ9-3 Fork Leg Dynamic Logs				
Date	% Throttled	Production		Time of production (days)
		Downlog	Uplog	
Sep 17, 2015	100	Fork Leg	Fork Leg	2
Sep 18, 2015	12	Fork Leg	Fork Leg	
Sep 18, 2015	25	Fork Leg	Fork Leg	
Sep 21, 2015	100	Original leg	Original leg	2
Oct 08, 2015	7	Original leg	Dead	5 hours
Oct 09, 2015	100	Original leg	Fork Leg	1
Oct 27, 2015	13	Fork Leg	Fork Leg	1
Oct 28, 2015	10	Original leg	Original leg	2
Oct 29, 2015	100 (at silencer)	Fork Leg	Fork Leg	6 hours
Oct 30, 2015	10	Original leg	Original leg	2
Oct 30, 2015	10	Original leg	Original leg	
Nov 06, 2015	100	Fork Leg	Fork Leg	2
Nov 16, 2015	100	Original leg	Original leg	1
Nov 20, 2015	100	Original leg	Original leg	6
Nov 26, 2015	100	Original leg	Original leg	1
Ene 05, 2016	20	Original leg	Dead	4 hours
Ene 06, 2016	30	Fork Leg	Combine legs	4 hours
Ene 06, 2016	50	Fork Leg	Fork Leg	4 hours
Ene 12, 2016	100	Original leg	Fork Leg	2
Ene 26, 2016	100	Fork Leg	Fork Leg	3
Feb 04, 2016	100	Fork Leg	Fork Leg	1
Feb 11, 2016	100	Original leg	Original leg	

Since 2017, the SJ9-3 fork leg has displayed cyclic behavior with a lower and higher steam production peak of 7 tph (0.9 MW) and 56 tph (7.2 MW) with an enthalpy of 888 kJ/kg and 1,610 kJ/kg, respectively. The higher enthalpy obtained was 2,567 kJ/kg with 90.6 % of quality. The well is operating at 30% open valve. The average power generation in this well is 4.5 MW. Figure 10 shows the mass flow (steam and brine) and differential pressure (mBar) of this well.

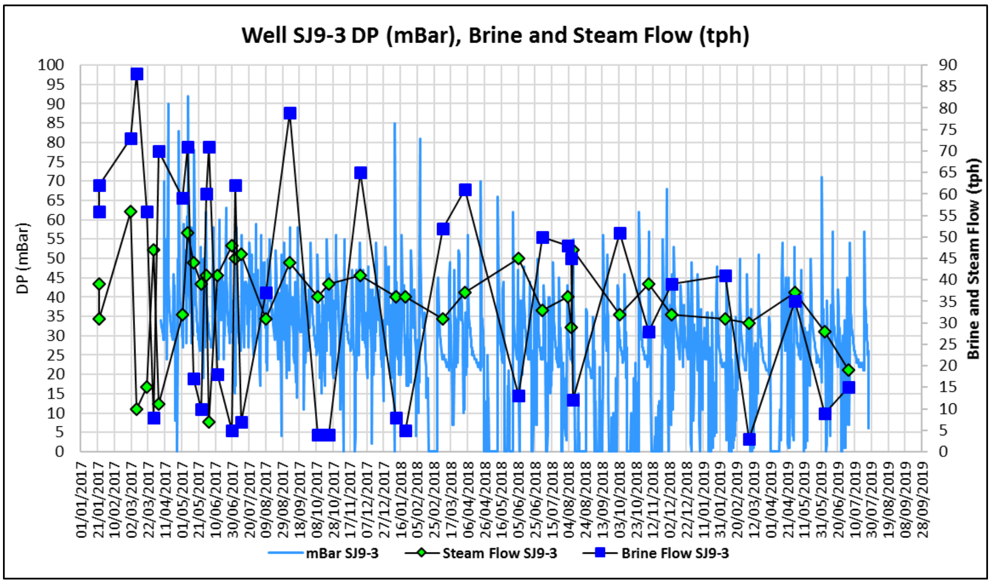

Figure 10: Differential pressure (mBar), brine and steam mass flow of SJ9-3 fork leg.

3. CONCLUSIONS

Drilling of multilateral wells has increased significantly during the past few years, as one of the reservoir development strategies to maximize well productivity. These complex wells represent significant challenges to accessibility for well logging. Effective monitoring of reservoir conditions (temperature, pressure, flow velocity, fluid chemistry) are essential components to identify well evolution, cooling effects, boiling, injection returns, drawdown pressure, feed zones, cycling behaviour, etc.

Pressure, temperature and spinner logs in wells with fork legs are a useful tool for identifying permeable zones, which leg is producing and the percentage of contribution of each leg, and for understanding well cycling behaviour. The disadvantage of this type of well like the SJ9-3 fork leg, is that only the original leg can be surveyed. The SJ9-3 fork leg showed WHP with infrequent cycles and more stable production with only the original leg, and after a remediation program the well showed frequent cycles which caused instability in its production. The cycling behaviour is attributed to different feed zones having different fluid enthalpies.

A set of dynamic surveys carried out in this well, showed that there is a competition between the two legs to dominate the production, and more stable production is achieved when the original leg is being produced. Both legs periodically stop flowing, but when the original leg is producing, the pressure at the fork is higher than when the fork is producing. It is possible that the original leg is feeding into the fork. Perhaps having only one of the legs open is likely to result in a more stable flow regime.

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