DOI: 10.24996/ijs.2024.65.8.20

ISSN: 0067-2904

Utilising Injection Logging Tool: A Case Study of a Well in An Iraqi Oil Field

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Received: 12/4/2023 Accepted: 10/7/2023 Published: 30/8/2024

Abstract

Injection logging tools (ILT) have long been used in the industry to evaluate well performance and make strategic decisions. This case study validates the application of ILT in diagnosing anomalies and evaluating well-injection performance. An injector in Iraq's southern oil fields has three perforations, each in a different zone (commingled injection). Throughout the ILT job interpretation, at the flow pass analysis, according to the spinner recording, the first zone perforation takes all the injected water confirmed by the temperature sensor. While in the shut-in pass, the temperature sensor detects an anomaly, a cooling effect, on the entire first zone, not just in front of the injection perforation; there is also a cooling effect across the last perforation that is supposed to take nothing based on the spinner record at the flowing pass. Considering the interpretation, the whole first zone was connected vertically, with good rock quality, which made it cold by the effect of injected water. Also, a small amount of injected water goes to the other perforation, less than the value the spinner can detect. The downhole profile confirmed the perforations contribution.

Keywords: Injection Logging Tool; Temperature Sensor; Well Profile; Flow meter

أستخدام مجسات الحقن: دراسة حالة لبئر في حقل نفطي عراقي

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الخلاصة

لطالما استخدمت أدوات مجسات الحقن في الصناعة النفطية لتقييم اداء الابار واتخاذ القرارات الإستراتيجية بخصوص تطويرها. تتحقق هذه الدراسه من استخدام تطبيقات هذه المجسات وكذلك في تشخيص الحالات الشاذة وتقييم أداء حقن الآبار .يوجد بئر حقن في أحد حقول النفط بجنوب العراق مثقب بثلاث مناطق (ثلاث طبقات) ، كل ثقب في طبقة مختلفة (حقن مختلط). خلال تفسير بيانات مجسات الحقن ,اثناء الحقن (التدفق) ، ووفقًا لتسجيل بيانات عداد التدفق تبين ان الثقب الاول فقط يأخذ كل الماء المحقون الذي تم تاكيده من خلال قراءة مستشعر الحراره. بينما التحليل اثناء فترة الاغلاق، يكتشف مستشعر درجة الحرارة تأثير التبريد على المنطقة الأولى بأكملها ، وليس فقط أمام الثقب الاول كما هوه الطبيعي وكذلك ايظا هناك تأثير تبريد

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عبر الثقب الثالث الأخير التي من المفترض الا يوجد ماء حقن داخل بناءً على سجل عداد التدفق الدوار اثناء عملية الحقن. وبالنظر إلى التفسير الكلي فان المنطقة الأولى متصله فيما بأكملها رأسياً ، بسبب جودة الصخور ، مما جعلها باردة بتأثير الماء المحقون. وكذلك أيضًا ، تذهب كمية صغيرة من الماء المحقون إلى الثقب الثالث الاخير وهي أقل من القيمة التي يمكن أن يكتشفها العداد وميزت بمستشعر درجة الحراره. أكد التمثيل المفسر لثقوب البئر مساهمة كل الثقوب.

Introduction

Injection logging tools (ILT) have been widely accepted as quantitative and qualitative tools to evaluate a zonal injection profile[1], [2]. These tools include a gamma ray, caliper, spinner, temperature, and pressure sensors. Commingling injection in a well is a common practice to maximise the total water injection while increasing reservoir pressure[3], [4]. Commingled injection demands a tool capable of measuring downhole zonal contributions to understand the zonal injectivity of a well, understand injection profile changes, detect crossflowing, and select candidates for workover and completion. This case study presents ILT interpretation in well G by analysing the temperature behaviour and the spinner records processing.

Field and Well Background

Field X is located in the south of Iraq. The producing reservoir is composed of sandstone with a staggered shale layer as cap rocks separate between the reservoir formations. The field is under water flood. Well G is a deviated S-shaped water injector, shown in the Figure1, injecting in three commingled pay zones A, B, and C, since 2022-Aug. For the injection history of the G well, the cumulative amount of water that has been injected was about 3.36 million BW, with an average daily rate of 21 000-barrel water per day (BWPD).

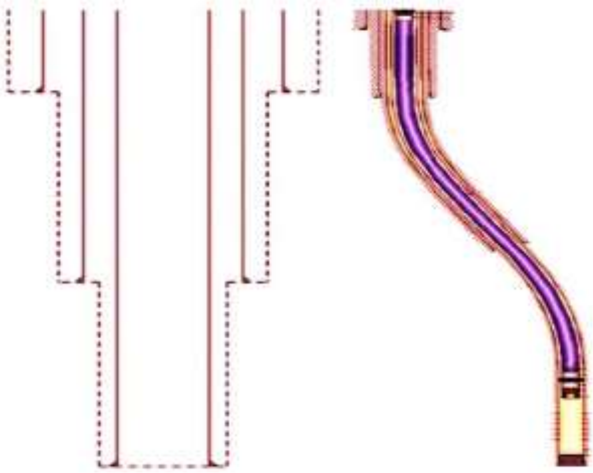

Figure. 1: well schematic (unpublished field well report).[5]

Geological view

The reservoir under study comprises three zones separated by shale and poor reservoir rock quality. The three zones are interpreted from the open-hole logs: the low gamma ray and photoelectric factor indicate sandstone formation; each zone is separated from another by a shale layer as indicated by high GR above and beneath it. The zones are swept with water, as shown by the low resistivity log reading. Neutron-density logs confirm the good quality of sandstone rock, as indicated by the separation of their curves. The three zones have high porosity and permeability [6]– [8]. Figure 2 shows the open hole logs data and their interpretation, perforation and petrophysical properties. Table 1 describes the reservoir column flow capacity for each perforation. A channel is expected to occur in zone-A within the area approximately 500m in width, which was suggested by reservoir geology through studying the surrounding area from the offset wells. Zone-A is highlighted as a high risk of low-pressure, depleted formation. The oil production from this depleted area exceeds injection by 50 000 BOPD. Zones B and C were also depleted but not severely like zone-A.

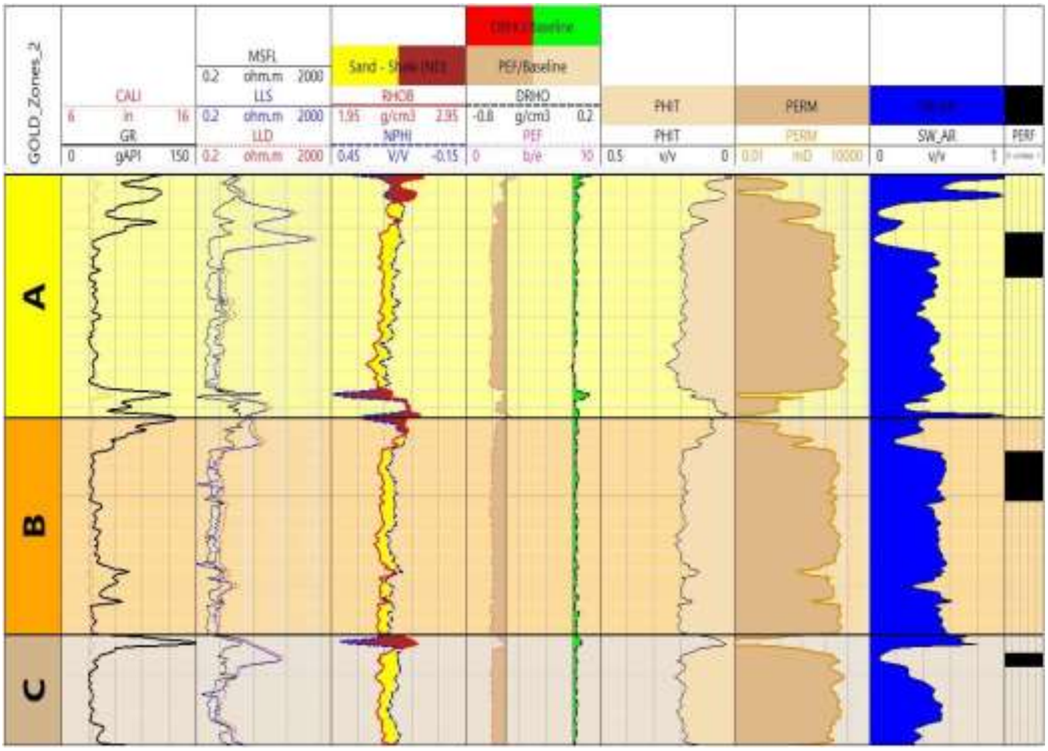

Figure 2: Open hole logs data and their interpretation.

Table 1: Petrophysical properties and flow capacity of the zones.

Zone	Rock Quality	AVG K (md)	Gross (m)	NET Sand (m)	Net To Gross
A	Good Sand	325.5	27.3	20.6	0.8
B	Good Sand	268	24.2	22	0.9
C	Good Sand	298	12.4	11	0.9

Zonal isolation and well integrity

Hydraulic zonal isolation is essential to maintain a well as a long-term producer/injector [9], [10], and the cement placement over the reservoir must meet specific requirements. Production losses in a well may occur if the hydraulic isolation is insufficient. This injector deals with high pressures and high flow rates (maximum pressure of 5200 psi, maximum historical pick injection rate of 27000 BWPD), increasing the possibility of generating sustained crossflow behind the casing, so preventing flow between reservoir units is necessary. For G well, the data quality is satisfactory to the analysis of the production section. The annulus in the area of interest (production section) is completely covered with cement, a circumferential signature; therefore, there is no scenario for a flow connection between the zones behind the casing, as shown in Figure 3.

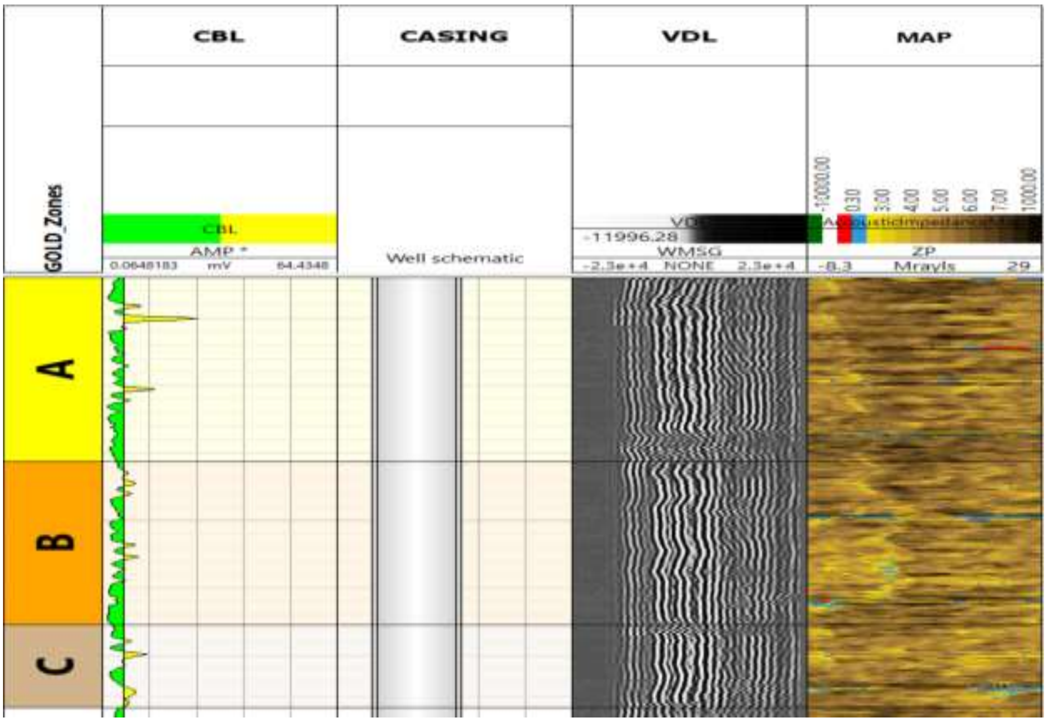

Figure. 3: Cement logs and Their Interpretation.

Discussion and Results of the Injection Logging Execution

Flowing condition passes:

The ILT was run during injection conditions with ten different pass speeds, five up and five down, to get representative data for the downhole contribution across each perforation interval, besides getting a good spinner calibration. The raw data includes temperature, pressure, line speed, spinner, Gama Ray, casing-collar locator (CCL), Caliper, and perforation, as illustrated in Figure 4.

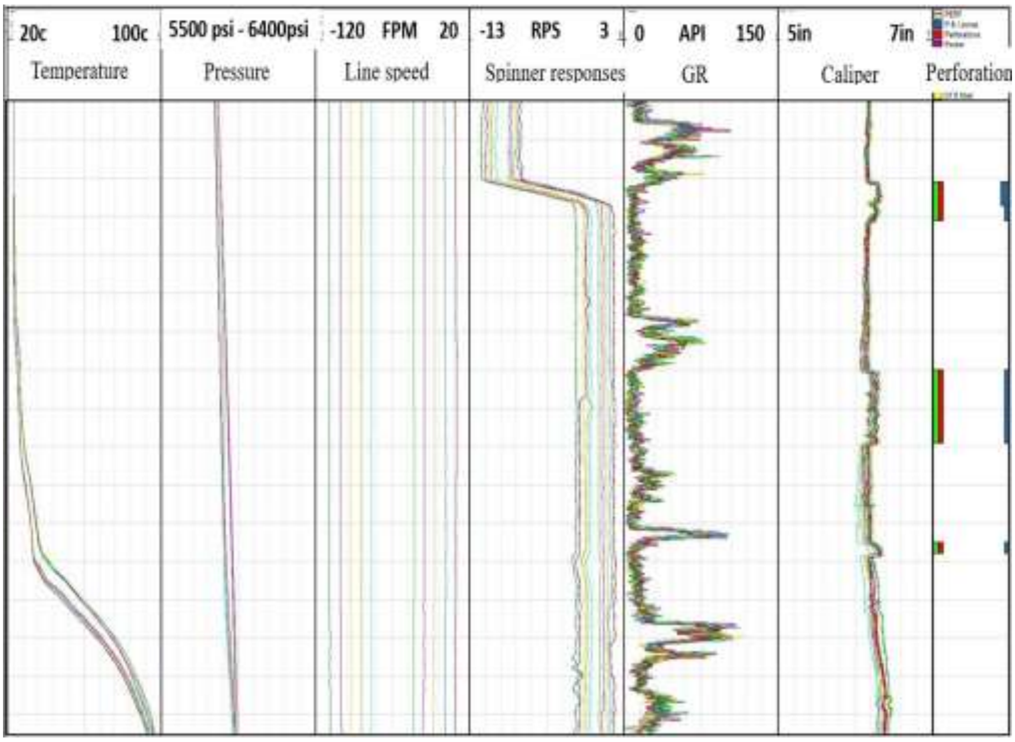

Figure 4: Raw Data of ILT (flowing).

The first look at the raw data shows that the well appears with a stable condition based on the pressure responses (in track 2), as the pressure difference among all the up and down passes is within 30psi, which is considered a very good logging condition for an injection well. The tool, or line speed, looks smooth across the logged interval, as shown in tack 3, which indicates a clean interval without restrictions due to scale, or any integrity casing, which reduces the chances of getting anomaly behaviour on the other sensors.

Caliper and GR have confirmed the data depth with the perforation intervals and no wireline shifting or stretching across the logged interval, which is lined with the Line-Speed behaviour (smooth recording curves). Figure 5 shows the curves of the GR for all the passes and the caliper responding with the perforation intervals. The lengths of the perforations were indicated by the caliper, which matched with the well data, as listed in the Table 2.

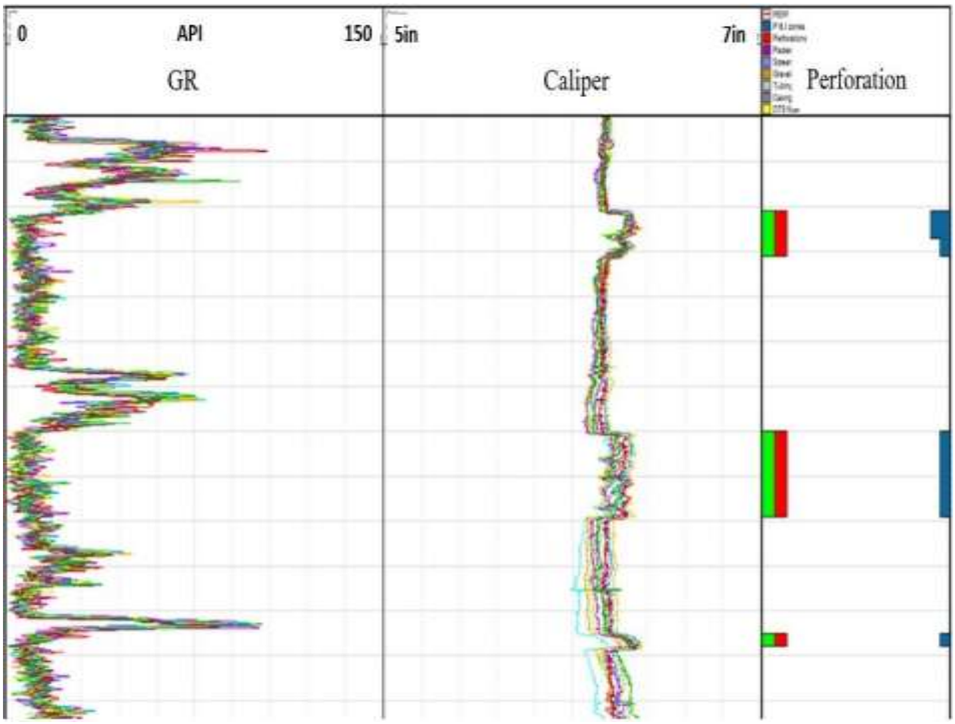

Figure 5: GR-Caliper and perforations, respectively.

Table 2: The Perforations length within their Zones.

Unit Name	Perforation length (m)	Gross (m)
A	5	27.3
B	9.5	24.2
C	1.5	12.4

The temperature sensor is mostly used for qualitative interpretation and can confirm or refute conclusions drawn from other measurements. The anomalies in the temperature log are the key to interpretation [11]. The majority of anomalies are due to fluids entering or exiting the borehole, and any fluid movement behind the casing may indicate another anomaly. Over the perforated intervals, the temperature log responds well. All of the perforated zones experience a drop in temperature in front of them, indicating that water is injected into them, regardless of the amount. Below the last perforation, the temperature returns to the normal geothermal gradient, as shown in Figure 6.

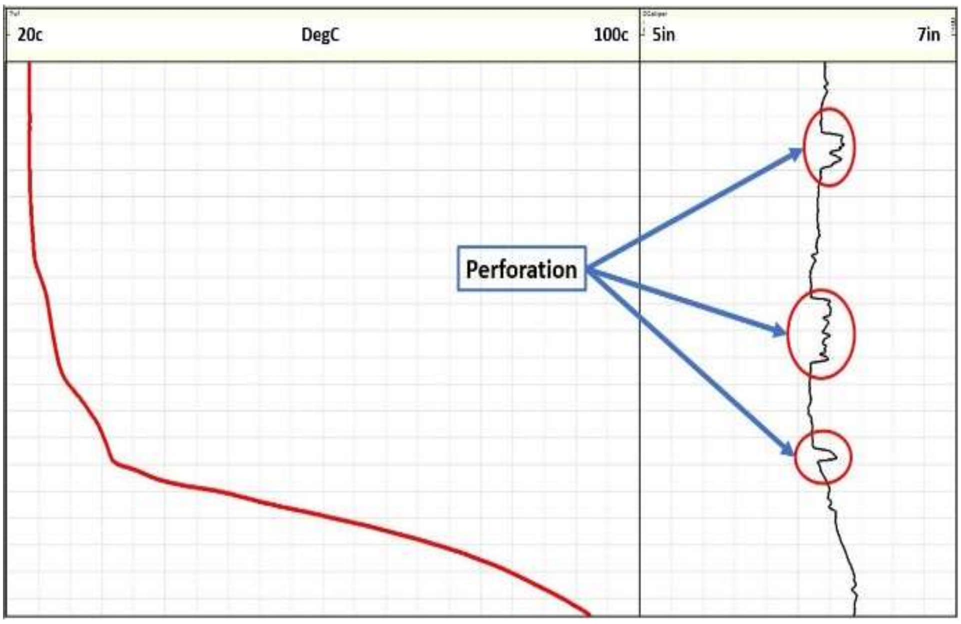

Figure 6: Temperature behaviour in flowing pass (First track).

The flow meter or spinner, with each pass, has displayed convenient repeatability, strongly responding in front of the perforations for both up and down passes. Spinner calibration is the main key for the injection logging tool to represent the downhole profile and calculate the apparent velocity and spinner threshold[11]. Figure 7_left, depicts the calibration and data quality. A comparison of the observed and computed values at particular depths can be seen in the cross plots on the left. The red line and red dots show the calculated values, while the blue dots reflect the raw data. All of the flowmeter data is shown in a cross plot to the right. Each pass is displayed using a constant, predetermined colour. The cable speed is adjusted for the apparent fluid velocities to enable comparability of all the data. The spinner threshold, calculated apparent velocity, and spinner records for the passes (five passes up and five passes down) across the logged interval are shown in Figure 7_right.

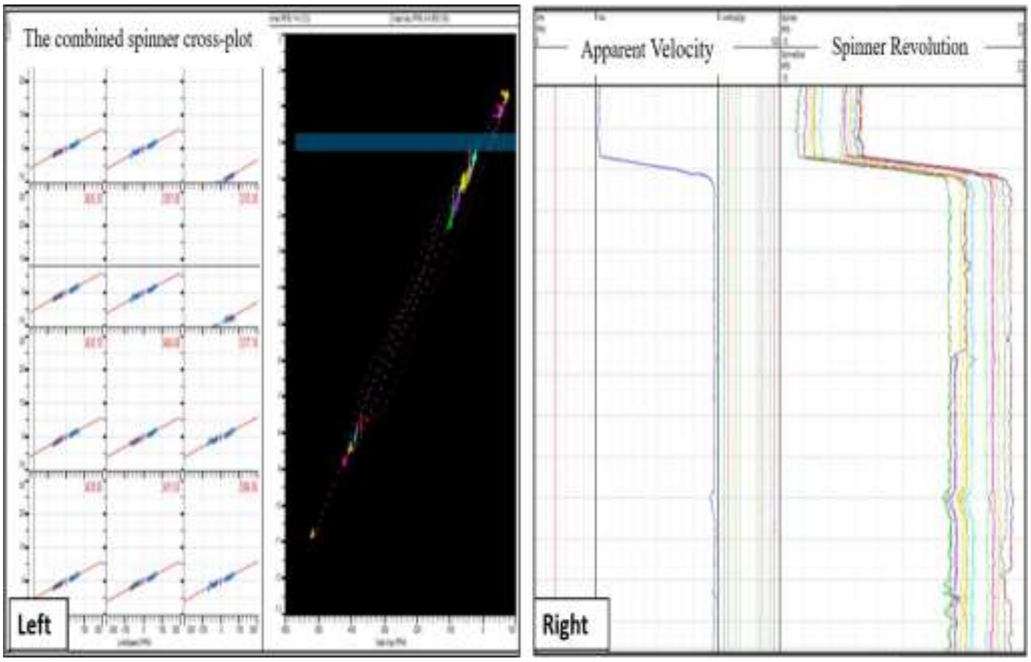

Figure 7: Left: Apparent Velocity Quality Plot; Right: Apparent Velocity.

The spinner shows that all of the water goes to the first perforation (zone-A), where the calculated downhole injection flow rate by the spinner was 21650 WBPD.

The threshold is defined as the minimum fluid velocity required to start rotating the spinner [1]. Because of the high injection rate, a cage spinner, Figure 8, was used. This type of spinner has a slightly higher threshold value than the full-pore regular spinner. The threshold velocity within the case is 6.688 ft/min, which is equivalent to about 350 BWPD, so any injection values less than this are uncountable because they're below the threshold value.

Figure 8**:** Cage spinner(turbine).

The station where the ILT is placed is located between the perforations. The record of the station indicates there is no water flow going to the last two perforations. Figure 9 shows the spinner record cross-plot between revolutions versus time for both stations.

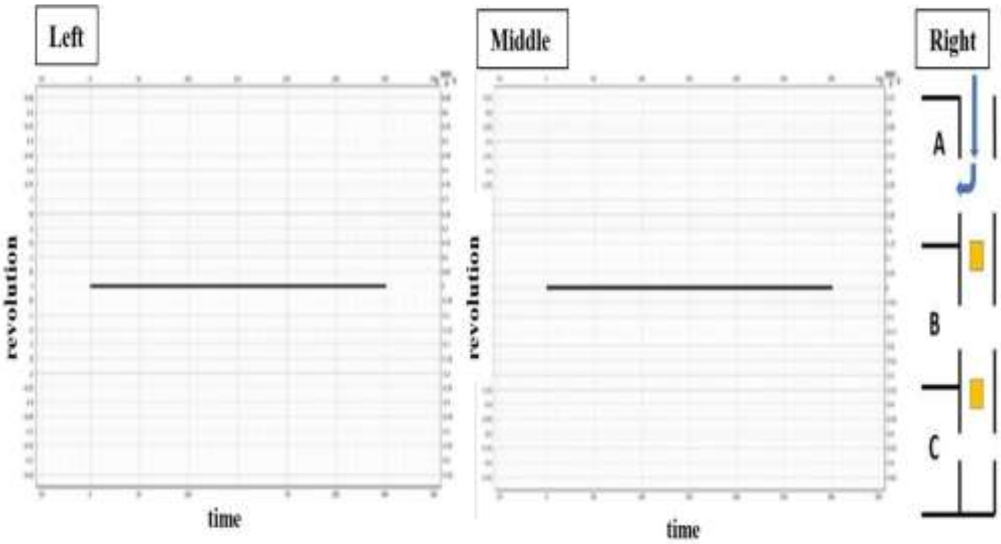

Figure 9: Left: Station between the A and B perforation; Middle: Station between the B and C perforation; Right: Station positions between the perforations (Yellow boxes).

The surface injection flow rate test was approximately 21256 STB/d, which closely matches the interpretation of the injection flow rate of the ILT Shown in Figure 10.

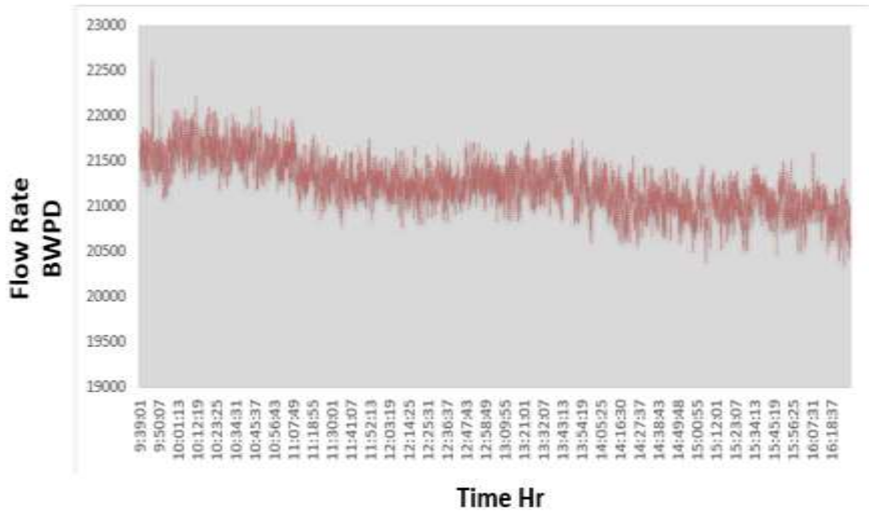

Figure 10: Surface rate measurement (well flow testing).

Shut-in condition passes:

When a well is turned off, the wellbore warms back up to the geothermal temperature. Zones that have taken in a lot of cool injection fluid take a longer time to warm back up [12]. Before the shut-in condition pass, the well was shut down for 24 hours. No crossflowing has been detected as per spinner readings during the passes. There were anomalies seen during the shut-in pass. The temperature sensor in area A still displays the cooling effect, but not just in front of the perforation; the cooling effect actually covers the entire zone, and B-zone showed a slight cooling, which indicates this perforation may take a very small amount of water. The C-Zone, which has 1.5 meters of perforation, also showed a cooling effect, indicating that this perforation takes injection water, but only very little compared to the first perforation but more than the B-Perf. Finally, the temperatures go back to the geothermal gradient below the perforations. Figure11 illustrates the raw data of the shut-in pass.

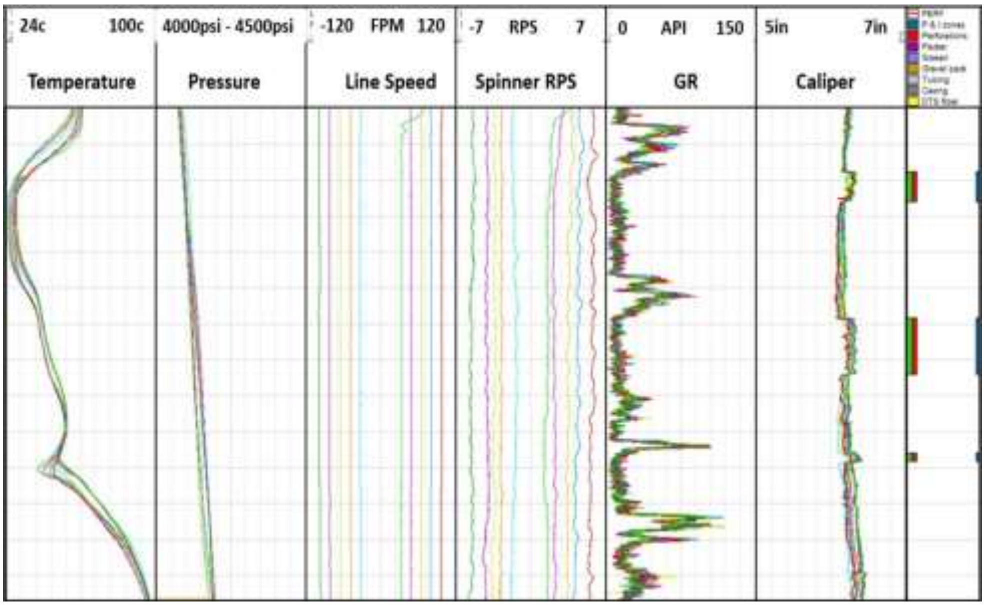

Figure 11: Raw Data of ILT (shut in).

Initiating an integrated plot for the two conditions (Flowing & Shut-in) to analyse the temperature behaviour shown in Figure 12. The temperature response shows cooling along the A-Zone, which means the injected water through the flowing condition goes into all of it. A slight temperature change in front of and below the second perforation at B-Zone has been observed at the same depth through the Shut-in condition, which means it was taking a few water. The cooling behaviour across the third perforation at the flowing condition means there is injection going into this perforation which the cooling phenomena have confirmed at the Shut-in condition, even if it is not detected by the flow meter of the flowing condition passes and the stations due to spinner threshold limitation.

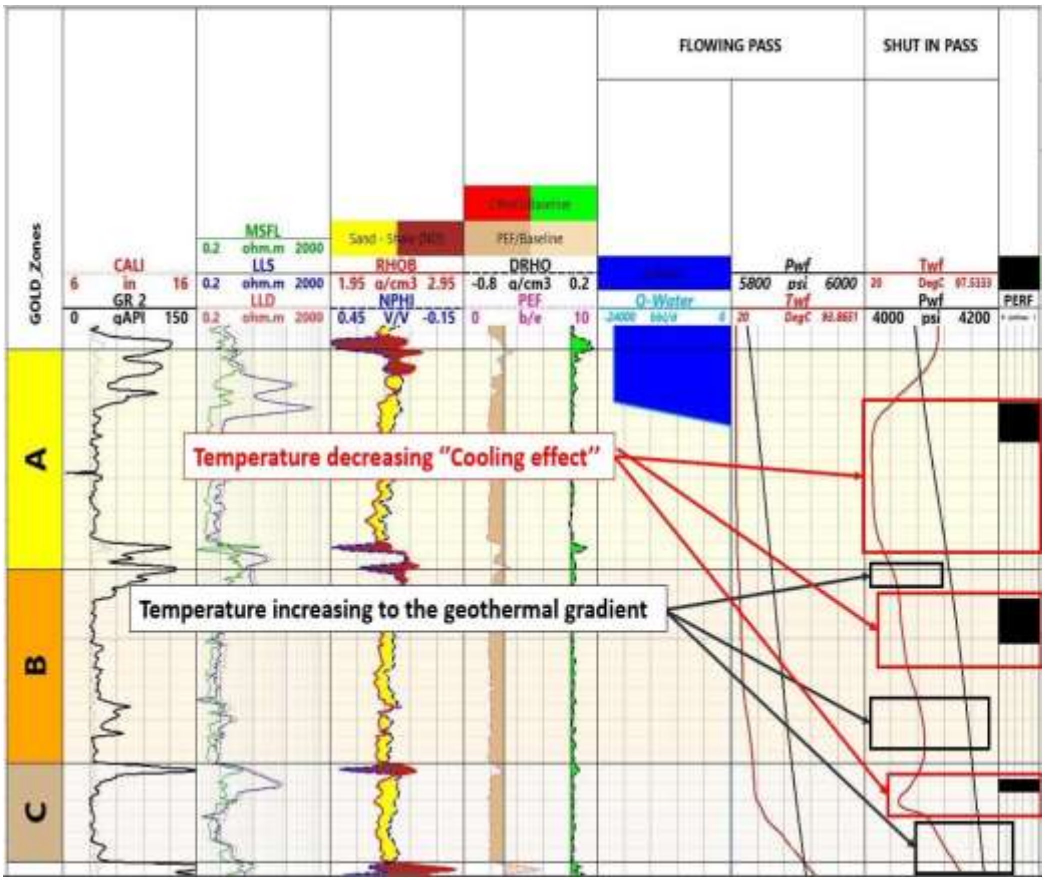

Figure 12: Integrated plot for Flowing and Shut-in passes.

Table 3 displays the results of the final injection profile analysis and interpretation, taking into account the results obtained from the interpretation of the threshold and its value.

Table 3: Final Injection Profile Results

Unit Name	Perforation length (m)	Profile	Injection flow rate (WBPD)
A	5	Inject	-21357
B	9.5	Inject	Less than the threshold barrels value
C	1.5	Inject	Fewer threshold barrels value, but Taking water more than B-Perf
			Total Injection Rate About -21630

Conclusions

- The discussed case shows that using injection logging tools is extremely important in understanding well and reservoir behaviors.
- The qualitative value from the temperature sensor is very important to detect any fluid movement inside the well bore; it captures the anomalies for the flowing and shut-in passes.
- The anomaly that the temperature sensor captured led to more investigation to understand the quality of the reservoir.
- Homogeneous reservoir with vertical connectivity is the reason of why the cooling effects are present for the entire zone and not just in front of the perforation.
- The large amount of injecting water for long periods of time also makes the cooling effects spread out the perforation intervals.
- Another confluence is a 24-hour shut-in period that is insufficient time to get the well temperature worm back to the geothermal gradient for thermal equilibrium with the reservoir temperature.
- Temperature sensor shows that there was injected water going to other zones that the spinner did not detect.
- The calibration of the flow meter (spinner), the threshold value, as an additional important task, ensures the accuracy of the flow computation and also informs of the potential number of water barrels that may be injected undetectably into other zones.

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