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Crossflow Detection to Allocate Production by using Spinner, Spectral Noise and Temperature Modelling in Malay Basin

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Abstract*— Crossflow exists when there are zones with dissimilar pressure properties allowed to communicate during production. Reservoir fluid from a high-pressure zone will flows preferentially to a low- pressure zone except if the production parameters are well controlled. A poor cement bonding often creates unwanted conduits behind casing that leads to crossflow between multi-layer of producing reservoirs. A conventional Memory Production Logging Tool (MPLT) that consists of mechanical spinners routinely run to perform quantitative assessment of each sand's contribution for production allocation in Malay basin fields. Detecting and quantifying crossflow behind casing is impossible using the conventional PLT as the tool is deployed inside the casing. Thus, advanced additions to the conventional production logging tools using High Precision Temperature (HPT) and Spectral Noise Logging (SNL) which aim to address the issues. This research aims to study the detection of behind casing crossflow and reservoir allocation by using spectral noise and temperature modelling in Malay basin. The research specifically based on a dual completion well of which Z-01L string was completed as an oil producer, flowing gas lifted from Z-35L sand, while Z-01S string completed as oil producer, flowing gas lifted from Z-35U sand. This research is based on secondary data obtained from an oil and gas industry in Malaysia. The data was analyzed and interpreted to investigate the communication between sand Z-35U and Z-35L crossflow behind casing. The research suggested that combination of HPT-SNL-PLT logging is crucial in investigating the crossflow behind casing. The results of the study also suggested that a holistic data acquisition program by combining conventional and advanced tools is vital for the quantifying the true zonal production allocation. It is hope that the study can contribute to the improvement of a field-wide scale reservoir allocation and long-term production strategy in Malay basin.

***Index Terms*—Crossflow, production allocation, spectral noise, temperature modelling.**

I. INTRODUCTION

A conventional Memory Production Logging Tool (MPLT) is a tool comprises of mechanical spinners that is routinely used to perform a quantitative assessment of each sand's contribution for production allocation in Malay basin fields. Because the tool is deployed inside the casing, detecting and quantifying crossflow behind the casing is impossible. Thus, advanced additions to the conventional production logging tools using High Precision Temperature (HPT) and Spectral Noise Logging (SNL) are aimed to address the issues. The innovative logging technology presented in this study is to track fluid movement within the formation through casing or tubing.

Temperature is measured during down passes at low speed. Noise data are acquired at multiple stations enabling data stacking and extraction of correlated noise from the prevailing uncorrelated noise. The key element of the high-precision temperature logging tool is a high-sensitivity fast-response temperature sensor with a response time of less than 1 second that can pick up the smallest perturbations of wellbore-fluid temperature through multiple barriers with a resolution of 0.003-degree Celsius.

The SNL tool represents a new generation of noise logging tools. Its key component is the new high-sensitivity hydrophone detecting noise in a wide frequency range. The tool captures 100– 60,000 Hz noise in the wellbore, casing annulus, faults, fractures, and rock matrix. The resulting digitized acoustic wave sample consists of 1024-time bins. About 50 noise samples are stacked at each station, filtered of uncorrelated noise, and processed into 512 frequency channels in the form of a color spectrum. The frequency range can be adjusted as required. Conventional noise tools normally measure noise power in only three to six narrow frequency bands and fail to detect noise beyond these frequencies. The spectral noise tool determines the frequency and amplitude of noise as two independent parameters where the noise amplitude depends on differential pressure, flow velocity and type of fluid (gas or liquid), and the frequency is a function of conductive channel aperture size.

The study aims to demonstrate that the combination of PLT-HPT-SNL logging is critical in investigating crossflow behind casing. The study's intention is that a comprehensive data acquisition programme combining conventional and advanced tools is critical for quantifying true zonal production allocation. It is hoped that the research will help to improve a field-wide scale reservoir allocation and long-term production strategy in the Malay basin.

II. CROSSFLOW BEHIND CASING OVERVIEW

A study [1] pointed out that the induced pressure differential and gradient begin to dissipate as soon as injection stops (that is, at well shutdown). First, the pressure gradient within the monolayer induces fluid flow from the near wellbore towards the far field. However, pressure dissipation through the well also occurs. This is because during shut-in, the inflow into more permeable formations reduces the pressure of the well, and the pressure in the more permeable formations can quickly become lower than the pressure in other formations. A layer with a higher pressure than the wellbore then produces fluid that flows through the wellbore into a layer with a lower pressure. This pressure equalization phenomenon is known as crossflow.

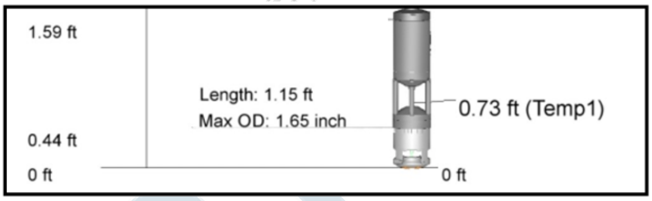
Natural crossflow occurs when all layers are in hydrostatic equilibrium with each other in the absence of flow. Forced crossflow is formed when the injected layer is not in pressure equilibrium due to the injection/production activity. The pressure difference between layers is the main driving force for forced crossflow. Crossflow can cause sand production into the wellbore, and this particulate matter can also be carried into the low-pressure formation. This will alter the well's injection response and may lead to perforation plugging (sand accumulation in the well) or it may plug or damage downhole equipment that controls zonal injection. In exceptional cases, crossflow can reach initial rate of thousands of barrels per day, which can even affect reservoir behaviour beyond the immediate wellbore region [2]. These issues are most important in highly porous sandstone reservoirs. For example, [3] presented a field case from the Norwegian Sea. There, crossflow, and associated sand formation during shut- in condition led to massive injectability loss and complete blockage of the borehole due to liquefaction of the sand layer.

Study [4] supported by [5] and [6] analysing well test data in a multi-layer well is a difficult problem due to the complexity of interlayer flow. These issues are caused in part by a lack of data on individual layer flow into the wellbore, and in part by the mathematical consequences of commingled inflow, particularly when different layers have different skin values. Furthermore, during the shut-in period, these types of tests are frequently unable to be interpreted. Crossflow between layers has a negative impact on data quality in conventional build-up tests from layered reservoirs, especially when the permeability contrast between layers is high. And, even when good quality data is obtained, conventional draw down and build-up tests typically reveal only the overall system behavior [7] and [8]. Different reservoirs are depleted to different degrees (Jongkittinarukorn et al., 2021).

Sand production from shallower and more productive zones can cause wellbore plugging and obstruction in some cases. This would result in a lengthy and costly well intervention and/or reserve loss. While fluid compatibility issues, which could result in wellbore scaling, should also be considered [3]. In a multi-layer well, there is most likely bypassed hydrocarbon [9] and [10]. As a result, the recovery factors of each reservoir are not maximized.

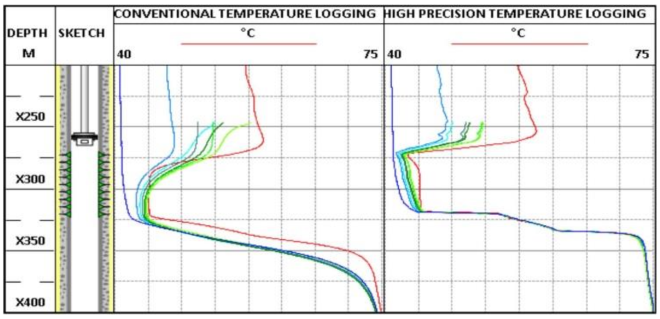
III. HIGH PRECISION TEMPERATURE COMPONENTS

According to [7] the temperature sensor is a platinum-wire thermistor. The sensor resistance varies with temperature, and the sensor's changing output voltage is fed into the input of an analogue-digital converter. The temperature is then calculated using a calibration procedure [8]. Figure below depicts an HPT tool diagram.



The HPT is a specially designed wireline tool that differs from the standard temperature tool that is typically used with PLT. The main issue in temperature logging today is sensor response time and depth correlation, not sensor sensitivity. The response time indicates how quickly the sensor responds to changes in fluid temperature, though tool manufacturers do not always publish this parameter. Furthermore, because the sensor's housing is not completely transparent to fluid flow, the tool's response is typically longer than the sensor's specified time response. This lengthens the time required to achieve a temperature balance between the sensor or tool and borehole fluid. As a result, the best temperature tools are designed with maximum temperature sensor exposure [6].

Figure below depicts the differences between the low-resolution conventional temperature log and the high-precision temperature log [9]. In comparison to HPT logs, which correlate perfectly with the top and bottom of the perforated interval, the low-resolution temperature log records are blurry. Low-quality records may depend on the tool location inside the hole and cannot even be reproduced under identical temperature conditions due to longer response times. This appears to explain why the flowing and transient temperatures in figure below (left panel) differed from the static log (red color), which can be misinterpreted as behind-casing channeling beneath the perforations. In fact, there is no evidence of channeling in the HPT logs shown in the right panel. In the left panel, transient logs that occasionally intersect each other and the static log demonstrate the instability of low-resolution logging. The HPT logs, on the other hand, are in strict chronological order.



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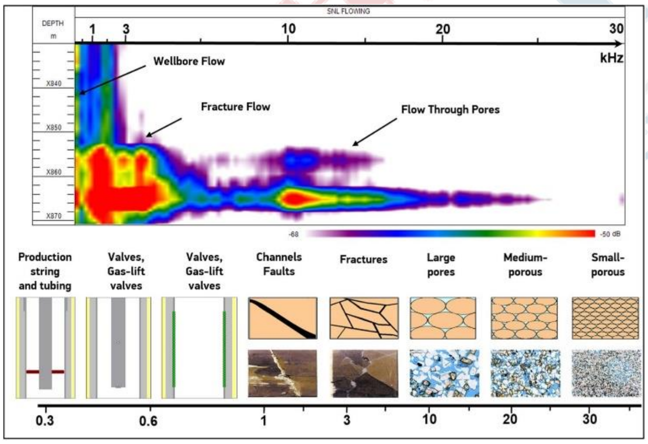
IV. SPECTRAL NOISE LOGGING COMPONENTS

According to [10], the spectral noise logging tool is intended to record sound across a broad frequency range. A highly sensitive hydrophone, which is a piezo crystal sensor placed in an oil-filled chamber, is the key component of the SNL tool. Oil reduces the density difference between the wellbore fluid and the sensor's environment, minimizing acoustic wave reflection from the interface and increasing sensor sensitivity [4]. Using high- frequency analogue-to-digital converters, the recorded time-domain data is written to the tool's internal memory. After reading the data from the tool, further analysis of SNL data is performed.

The recorded noise logging data span a wide frequency range in the spectral domain, from 8 Hz to 58.5 kHz. The tool's battery pack can power all its electronic components for 48 hours straight. Figure below show SNL tool diagram.

The tool can be used in both vertical and horizontal wells and operates in memory mode on slickline, wireline, tractor, or coiled tubing. The tool's components are all made of high-strength materials, and its electronic circuits are built with high-temperature components. As a result, the SNL tool can survey wells at temperatures as high as 150 °C and pressures as high as 60 MPa.

Figure below depicts the SNL panel's noise volume distribution from less than 300 Hz (left side of the panel) to 30 kHz (right side of the panel). The color palette begins with red for the highest noise volumes and progresses to yellow, green, and blue for lower noise volumes, with white denoting noise below the tool sensitivity threshold, and the spectra clearly show matrix flow as a noise peak (Services, 2017).



V. METHODOLOGY

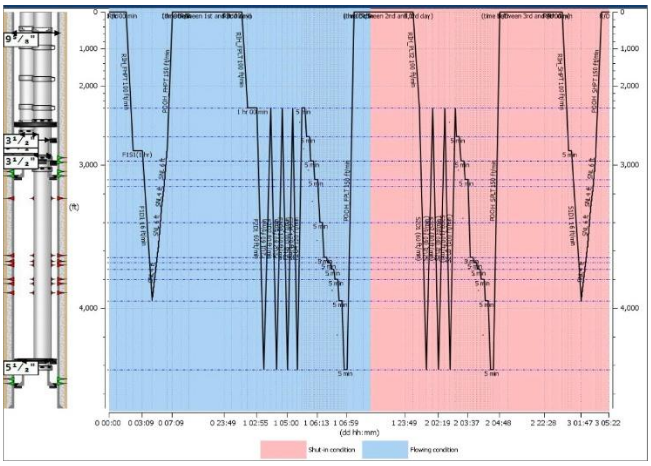
The methodology is divided into four phases: (1) literature review and development of research problem statement and research objectives, (2) data collection of the research from established technical journals and consultation from industrial experts for the analysis of a well, field, and production data. The third phase (3) consists of software data analysis and interpretation, followed by (4) interpretation results and data validation. Finally, the research's conclusion and recommendations.

A thorough review of the literature on previous technical papers pertaining to the technologies under consideration was carried out. As discussed in Chapter 2, the analysis from the literature review aids in the development of research objectives, problem statements, and the identification of gaps for the study, as well as the investigation of the effectiveness of PLT-HPT- SNL logging tools in detecting crossflow behind casing.

For the purposes of this thesis, an industrial data from a Malaysian oil and gas company in one of Malaysia's offshore areas was chosen. Well XX is an oil producer that was completed on January 24, 1991, as a dual completion strings, maximum deviation of 29.9 degree with gas lifted on the short string produced from the P-26 reservoirs and the long string currently producing from the Y-27, Y-45/65/67, and Z-25 reservoirs. The long string was idle since 2002. The LRLC zones Y9/Y10/Y12 additional perforation was done in December 2014 and the well flowed with instantaneous oil gain of 50 BOPD. However, the well could not flow after the well shut-in and was idle until the second phase of LRLC additional perforation was done in August 2015. The well flowed with 250 BOPD post LRLC second phase perforation. Currently, the well is flowing at 100 BOPD with 69% of water cut and gas rate at 0.45 MMscf/d. The reservoirs are all perforated behind tubing and producing through SSD.

The salinity of the water in the Y and Z reservoirs ranges from 13,000 to 22,000 ppm, with current reservoir pressures ranging from 913 to 1495 psia and temperatures ranging from 161 to 198 degrees Fahrenheit (dF).

The survey of the PLT-HPT-SNL logging programme was conducted in both flowing and static modes. On the 19th and 25th of January 2017, a slickline survey was conducted from the surface to 2234.7m into the well bore below sea water level. A dummy run was performed on January 19, 2017, and the hold-up depth (HUD) was determined to be 2230.0 mTHF. Figure and table below depict the logging programme and flow regimes.



Run	Tool string	Operation conditions	Surveyed interval (ft-DFE)
1	HPT-SNL	Flowing	Surface – 4007.9
2	HPT-SNL-PLT	Flowing	Surface – 4400.4
3	HPT-SNL-PLT	Shut-in	Surface – 4380.6
4	HPT-SNL	Shut-in	Surface – 4020.4

The well test data for gas fluid was collected during Run #1 of the HPT-SNL survey in flowing condition with the gas rate of 0.175 MMscf/d that was intended to be used as the temperature modelling input. Another well test data for gas fluid taken during Run#2 in flowing condition PLT survey shows a gas rate of 0.226 MMscf/d.

PLT raw log data must be processed in three mode passes: shut-in, flowing, and stationary. Kappa's EMERAUDE software is used to process raw PLT data on the processing platform. All production data should be pre-quality checked easily by respective service providers. A quality check plot will be provided along with the raw data to verify any anomalies found in the raw data. Surface measurement should be used to validate computed PLT total flow rates. However, surface measurement should not be considered absolute. Hold up probes data should always include a log quality check.

Based on the selected passes, a single apparent velocity will be computed and used as an input into the solver. PVT data is primarily used in dual and three phase systems to accurately simulate downhole density for hold-up matching and phase identification. The software generates a simulated response of the velocity, density, and hold-up data based on the hold-up and PVT data. The total flowrate is calculated in conjunction with the simulated data response. Once the measured data and simulated data response match, the zonal contribution can be calculated. The zonal contribution should be allocated only to the zones that are producing based on the spinner, density, temperature, and hold-up sensor responses.

The TECHLOG software application is used for PLT-HPT-SNL data pre-processing QAQC. The survey is divided into four runs, with Runs #1 and #2 during the flowing condition and Runs #3 and #4 during the shut-in condition. To begin, the repeatability data in flowing conditions must be validated by plotting the data curves in TECHLOG, as shown in Figure 25. To ensure on-depth measurement with the PLT-HPT-SNL log data, the measured depth of the reservoir target, petrophysical open hole log, and completion strings schematics must be plotted. To test the log correlation, the gamma ray of the PLT-HPT-SNL log data in Run#1 and Run#2 is plotted alongside the gamma ray of the open hole log data. To check on-depth measurement, the casing collar locator (CCL) of the PLT-HPT-SNL log data is plotted on top of the CCL from the open hole logs, and the log signatures are tallied with the completion strings accessories in the completion schematic.

Temperature simulation using THERMOSIM is used to quantify and comprehend reservoir performance. The information from acquired temperature data under shut-in and flowing conditions, as well as input parameters provided by the client, is used in the modelling. The identified active reservoir units from SNL-HD data are used as reservoir thickness input in the hydrodynamic model.

The final surface rate computed after sensor matching should be compared to the reported surface rate. If the computed surface rates do not match, make sure the PVT data is entered correctly. To convert computed downhole flowrates into surface flowrate figures, reliable and accurate PVT data is required. When reported surface rates are reliable, the computed figures should be within 10% of the reported surface flowrates. As a result, the accuracy of the interpretation will be determined by the reported surface rates. It is best to measure surface production rates with a calibrated surface flowmeter. If, after several iterations and checking with PVT properties, the computed surface rates do not match the reported figures, the computed PLT may be correct, but the surface rate reading is incorrect.

VI. RESULTS AND DISCUSSION

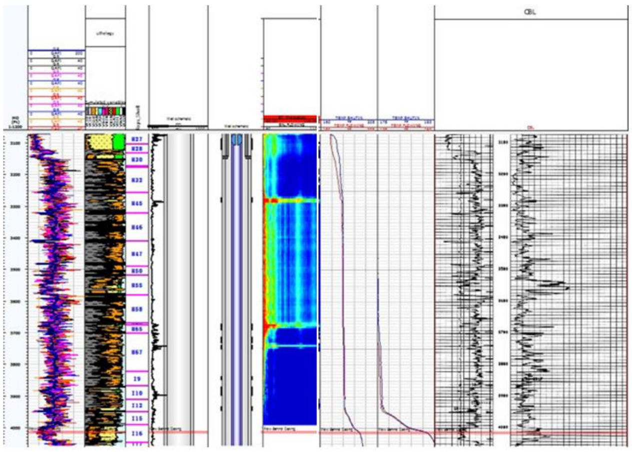
Following a thorough literature review in Chapter Two, the effectiveness of PLT-HPT-SNL logging tools in detecting crossflow behind casing was discovered to be high. PLT-HPT-SNL logging instruments are said to be highly sensitive and accurate at detecting crossflow behind casing. Several studies have used these methods to identify crossflow behind casing in various reservoirs with success. Overall, the literature review supports the use of PLT-HPT-SNL logging instruments in reservoirs for detecting crossflow behind casing.

According to the SNL plot below, no matrix noise was identified opposite perforation inflow interval at deeper reservoirs unit, zones I9 - I16 from 3820.8 ft to 4007.6 ft measured depth. As shown in Table 19, SNL indicates very low noise readings of less than 76 dB and frequency readings of less than 0.4 kHz. According to the established SNL noise volume matrix distribution, the interval can be interpreted within the proximity of wellbore flow under production string flow interval based on the frequency range of below 10 kHz, but the amplitude of the matrix noise is out of range and the tool is unable to detect which is below the tool threshold of approximately below 76 decibels. Based on SNL signals, deep reservoirs are regarded as having insignificant movement of liquid input during HPT-SNL logging. The SNL interpretation of this occasion is confirmed by HPT temperature data, which show no significant influx between the intervals given with a temperature measurement of 190 degrees Fahrenheit on average.

SNL data revealed matrix noise opposite perforation inflow intervals for reservoir unit zones H45-H67 with observed depths ranging from 3267.1 ft to 3751.6 ft. The SNL indicates exceptionally high noise readings of 76 dB to 117 dB and frequency readings of 22 - 62 kHz. The interval can be understood as medium to small pores and flow through pores based on the SNL noise volume matrix distribution. The reservoirs are active reservoirs with substantial input liquid in advance of the perforation intervals, according on SNL log signatures. The SNL interpretation of this interval is supported by HPT temperature data that show temperature anomalies with lower temperature readings opposite the perforation interval with the highest noise reading, indicating a cooler liquid flow into the wellbore with an average temperature of 185 dF - 190 dF.

SNL data revealed matrix noise opposing perforation inflow intervals for reservoir unit zones H27-H30 with observed depths ranging from 3073.4 ft to 3148.8 ft. The SNL indicates a loud noise level of 76 - 91 dB and a frequency reading of 22 - 31 kHz. The interval can be understood as wellbore flow with channels/fault based on the SNL noise volume matrix distribution. The reservoirs are active reservoirs with inflow liquid in front of the perforation intervals, according on SNL log signatures. This interpretation is confirmed by HPT temperature data, which show temperature anomalies with lower temperature readings opposite the perforation interval, indicating a cooler liquid flow into the wellbore with an average temperature of 183 dF - 185 dF.

SNL data revealed noise anomalies across the un-perforated interval in reservoir unit zones H46 - H58 at depths ranging from 3300 ft to 3668 ft. The SNL indicates a noise range of 76-80 dB and a frequency range of 46-50 kHz. According to the SNL noise volume matrix distribution, the interval can be interpreted as flow through pores with the existence of big pores; nevertheless, due to the absence of a perforation interval across the interval, this noise implies probable flow behind 3-1/2" tubing due to crossflow behind casing. Across the interval, the HPT temperature reads 185 - 187-degree Fahrenheits. According to cement bond log plot data, there is cement behind the casing with an average cement bond quality index of amplitude reading of 9 - 50 mV from a depth interval of 3200 - 3700 ft. It is feasible to add the presence of channel behind casing in the cement based on the cement amplitude reading.



According to PLT CFS spinner data in Table 20, there is minimal spinner reaction found opposite perforation interval inflow interval at deeper reservoirs unit, zone I9-I16 from 3820.8 ft to 4007.6 ft measure depth. The down line (- line) and up line (+ line) logging speeds were -72 and +68 feet per minute, respectively. The down pass CFS (- CFS) and up pass CFS (+CFS) were recorded at -5 to -10 and +4 to +8 rev/s, respectively. Across the interval, this spinner reaction implies relatively minimal inflow activity in front of the perforation. The interval recorded at 98% capacitance and 13,500 ppm salinity, indicating the formation water values, based on capacitance and salinity readings. This is corroborated by the salinity data from the field studies' well test data in Chapter 3. According to the SNL plot, no matrix noise was identified opposite perforation inflow interval at deeper reservoirs unit, zones I9 - I16 from 3820.8 ft to 4007.6 ft measured depth. The SNL indicates very low noise readings of less than 76 dB and frequency readings of less than 0.4 kHz. According to the established SNL noise volume matrix distribution, the interval can be interpreted within the proximity of wellbore flow under production string flow interval based on the frequency range of below 10 kHz, but the amplitude of the matrix noise is out of range and the tool is unable to detect which is below the tool threshold of approximately below 76 dB. Based on SNL signals, deep reservoirs are regarded as having little liquid inflow movement during HPT-SNL logging. The SNL interpretation of this time is confirmed by HPT temperature data, which show no significant influx between the intervals given with an average temperature of 190 degrees Fahrenheit.

Based on PLT CFS spinner data, a substantial spinner response opposing perforation interval inflow interval was found at reservoirs unit, zone H45-H67 from 3267.1 ft to 3751.6 ft. The down line (- line) and up line (+ line) logging speeds were -72 and +68 feet per minute, respectively. The spinner rotation of the down pass CFS (-CFS) and up pass CFS (+CFS) was recorded at -15 to +36 rev/s and +5 to +54 rev/s, respectively. Across the interval, this spinning reaction suggests very high inflow activity in front of the perforation. According to capacitance and salinity readings, the interval is 96% average capacitance and 10,500 - 12,300 ppm salinity, indicating a mixture of formation water and hydrocarbon values. SNL data revealed matrix noise opposite perforation inflow intervals for reservoir unit zones H45-H67 with observed depths ranging from 3267.1 ft to 3751.6 ft. The SNL indicates exceptionally high noise readings of 76 dB to 117 dB and frequency readings of 22 - 62 kHz. The interval can be understood as medium to tiny holes and flow through pores based on the SNL noise volume matrix distribution. The reservoirs are active reservoirs with substantial input liquid in advance of the perforation intervals, according on SNL log signatures. The SNL interpretation of this interval is supported by HPT temperature data that show temperature anomalies with lower temperature readings opposite the perforation interval with the highest noise reading, indicating a cooler liquid flow into the wellbore with an average temperature of 185 dF - 190 dF.

According to PLT CFS spinner data shown in figure below, there is a substantial spinner response found opposite perforation interval inflow interval at reservoirs unit, zone H27-H30 from 3073.4 ft to 3148.8 feet of measured depth. The down line (- line) and up line (+ line) logging speeds were -72 and +68 feet per minute, respectively. The spinner

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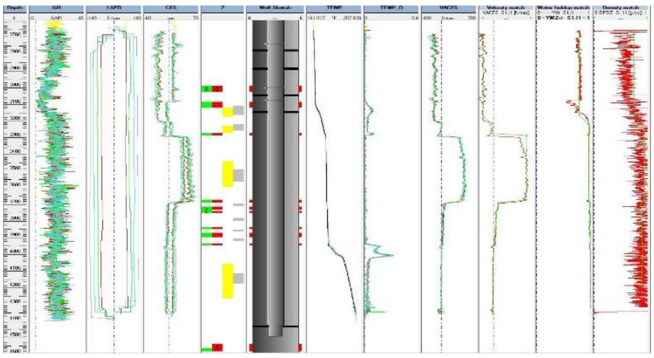
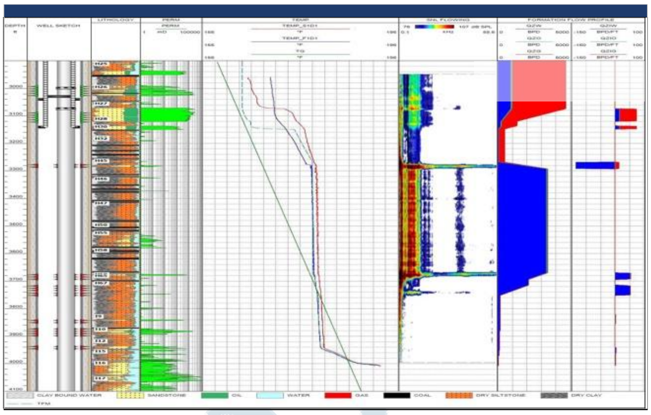
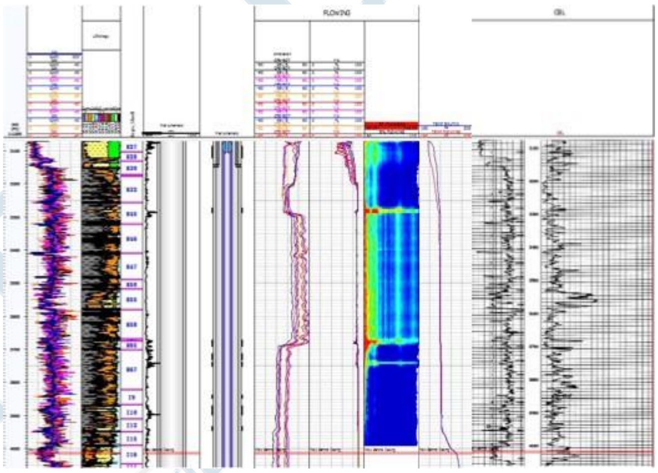
rotation of the down pass CFS (-CFS) and up pass CFS (+CFS) was recorded at -30 to -38 rev/s and -9 to -10 rev/s, respectively. As the spinner speed drops dramatically in front of the perforation due to water recirculation and vacuum effect as the fluid loss across this interval, this anomaly suggests outflow of activities in front of the perforation throughout the interval, likely thief zone in H45 reservoir. Based on capacitance and salinity measurements, the interval was 77% average capacitance and 5,000 - 5,300 ppm salinity, indicating mild hydrocarbon levels. SNL data revealed matrix noise opposing perforation inflow intervals for reservoir unit zones H27- H30 with observed depths ranging from 3073.4 ft to 3148.8 ft. The SNL indicates a loud noise level of 76 - 91 dB and a frequency reading of 22 - 31 kHz. The interval can be understood as wellbore flow with channels/fault based on the SNL noise volume matrix distribution. The reservoirs are active reservoirs with inflow liquid in front of the perforation intervals, according on SNL log signatures. This interpretation is confirmed by HPT temperature data, which show temperature anomalies with lower temperature readings opposite the perforation interval, indicating a cooler liquid flow into the wellbore with an average temperature of 161 dF - 172 dF.

As the spinner drop after the perforation interval of H45 zone, PLT data showed spinner abnormalities across the un-perforated interval between H45 - H27/30 at depth 3150 ft - 3180 ft. SNL data revealed noise anomalies across the un-perforated interval in reservoir unit zones H46 - H58 at depths ranging from 3300 ft to 3668 ft. The capacitance and salinity PLT data indicate irregular readings above the H30 zone interval, presumably due to recirculation effects in the tubing. The SNL indicates a noise range of 76-80 dB and a frequency range of 46-50 kHz. According to the SNL noise volume matrix distribution, the interval can be interpreted as flow via pores with the existence of big pores; nevertheless, due to the absence of a perforation interval across the interval, this noise implies the possibility of inflow behind 3-1/2" tubing due to crossflow behind casing. Across the span, the HPT temperature reads 185 - 187 dF. According to cement bond log plot data, there is cement behind the casing with an average cement bond quality of amplitude reading of 9 - 50 mV from a depth interval of 3200 - 3700 ft. It is feasible to add the presence of channel behind casing in the cement based on the cement amplitude reading.







Temperature simulation using HPT-SNL data is used to assess and comprehend reservoir performance. The modelling incorporates input from obtained temperature data during shut-in and flowing mode settings, as well as field report characteristics. The identified active reservoir units from SNL data are used as reservoir thickness input in the hydrodynamic model, which is supported by open hole well correlation. The temperature modelling profile's phase distribution was created using multiphase sensors and the real percentage of hydrocarbon that could be affected due to stratified flow in 3-1/2" tubing and the presence of water recirculation effect in the deviated well of about 26 degrees in the zone of interest. Due to the multiphase flow and recirculation effect, a full hydrodynamic simulation including shut-in and flowing temperature could not be performed. The geothermal profile's reference temperature was changed from 161 degrees Fahrenheit as provided in the PVT data to 158 degrees Fahrenheit based on the current temperature reading data as measured by the tool at the top of the H25 reservoir unit.

Based on temperature modelling simulation analysis in figure below, the main gas inflow and oil inflow are coming from H27-28, with current gas production of 2648 bpd/mscf/d and 40 bpd, respectively, and current water production of 683 bpd, which accounts for approximately 76% of total liquid production. Major gas and oil inflows are also arriving from H60-65 and H67, which have current gas production of about 37-20 bpd/mscf/d and 20-30 bpd, respectively, and current water production of 1273-1895 bpd, which accounts for about 2-3% of total liquid production. A significant water outflow (thief zone) is discovered from H45, resulting in a reduction of current water production of 3339 bpd. Based on temperature simulation studies, H45 reveals gas and oil inflows of 343 bpd/mscf/d and 5 bpd, respectively, covering about 1% of total current percentage of liquid. There is no gas or oil inflow from the I9-16 reservoir unit, as shown by temperature modelling. There is a little water input from I9- 16, with current water production ranging from 7 to 125 bpd.

The PLT-HPT-SNL data interpretation result of zonal quantification allocation is compared to surface production data as depicted in table below. The temperature modelling profile's phase distribution was generated by multiphase sensors, and the actual percentage of hydrocarbon may differ due to stratified flow in 3-1/2" tubing. Temperature modelling was based on well test data collected during Run#1 (HPT-SNL) of the flowing mode survey. During the survey, the well test data for gas fluid showed 0.175 mscf/d. The units are incorrectly applied based on past well test results, and the current unit should be in mmscf/day. As a result, the gas value of 0.175 mmscf was chosen for temperature modelling.

The PLT-HPT-SNL data quantified that the gas and oil production for reservoir unit H27-H28 are 2648 BPD/mscf/d and 40 bpd, respectively, whereas the surface production data for gas and oil are 121 bpd/mscf/d and 36 bpd, respectively, based on previous well test results. PLT-HPT-SNL and production surface rate are both measured at 683 bpd for water production.

The PLT-HPT-SNL data for reservoir unit H45 quantified gas and oil production at 343 bpd/mscf/d and 5 bpd, respectively, but surface production figures based on earlier well test results for gas and oil are 16 bpd/mscf/d and 4 bpd, respectively. PLT-HPT-SNL and production surface rate are both measured at -3339 bpd for water production.

The PLT-HPT-SNL data quantified gas and oil production for reservoir unit H60-65 as 37 bpd/mscf/d and 20 bpd, respectively, but surface production statistics based on earlier well test results for gas and oil are 4 bpd/mscf/d and 28 bpd, respectively. PLT-HPT-SNL and production surface rate are both measured at 1273 bpd for water production.

The PLT-HPT-SNL data quantified that the gas and oil production for reservoir unit H67 are 20 bpd/mscf/d and 30 bpd, respectively, but the surface production data for gas and oil based on earlier well test results are 4 bpd/mscf/d and 28 bpd, respectively. PLT-HPT-SNL and production surface rate are both measured at 1895 bpd for water production.

The PLT-HPT-SNL data and production surface rate quantified for reservoir unit I9-16 that gas and oil output are 0 bpd/mscf/d and 0 bpd, respectively, while water production ranges between 7 and 125 bpd for both PLT-HPT-SNL and surface production data.

Zonal Quantification PLT-HPT-SNL					Surface Production Data			
Unit	Gas production (BPD/mscf/d)	Oil production (BPD)	Water production (BPD)	Liquid (%)	Gas production (BPD/mscf/d)	Oil production (BPD)	Water production (BPD)	Liquid (%)
H27-28	2648	40	683	75	121	36	683	-
H30	674	10	174	19	31	9	174	-
H45	343	5	-3339	1	16	4	-3339	-
H60-65	37	20	1273	2	4	28	1273	-
H67	20	30	1895	3	4	28	1895	-
I9	0	0	17	-	0	0	17	-
I10	0	0	7	-	0	0	7	-
I12-16	0	0	125	-	0	0	125	-
Total	3720	105	835	100	176	105	835	100

VII. CONCLUSION

Based on the logging data analyses for the HPT-SNL single run and the PLT-HPT-SNL tandem run, it is possible to infer that both logging methodologies are capable of detecting crossflow identification behind tubing using noise anomalies and temperature data analysis. Because the tool is run inside the tubing, the crossflow is not directly detected by the spinner behind tubing. However, based on the spinner anomalies, it can detect water recirculation effects in the unperforated interval, which can be due to possible crossflow behind casing that flow into the tubing through leaks or any opening conduits in the well completion. This discovery of potential crossflow from PLT spinner data can be corroborated by other tool sensors, such the SNL and HPT.

1) According to the studies, HPT-SNL can quantify zonal allocation for each reservoir in a single run using temperature modelling analysis backed by SNL noise data. The temperature modelling is merely a theoretical interpretation supported by surface production rates based on dynamic modelling input. Mechanical measurements are required for zonal allocation quantification to have a confirmed zonal allocation rate. The zonal quantification based on the PLT-HPT-SNL tandem run data is not possible due to the existence of water recirculation, which influences the spinner data. As a result, only temperature modelling is employed to calculate zonal allocation.
2) The HPT-SNL instrument can detect noise anomalies across the interval for leak identification, however the data cannot reveal leak position in the well completion due to noise from the crossflow behind tubing. Based on PLT spinner data and other tool sensors, the PLT-HPT-SNL tool can identify leaks and offer leak points.
3) The data quality for HPT-SNL data is satisfactory in terms of repeatability and consistency over the logging interval, and the data can be utilized to comprehend zonal allocation quantification. The spinning, capacitance, and hold-up statistics for the PLT-HPT- SNL tool is unpredictable in shallow reservoir intervals because of water recirculation, hence the data from PLT cannot be utilized to measure zonal allocation. In terms of logging operation hours,

HPT-SNL and PLT-HPT-SNL logging were completed in about 10 hours for both flowing and shut-in modes, for a total of 20 hours logging operation. Table 31 below shows the summary of the comparison between HPT-SNL versus PLT-HPT-SNL interpretation results based on the data in this study.

VIII. ACKNOWLEDGEMENT

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Nomenclature

BPD	: Barrels per day
CFS	: Continous fullbore spinner
Hz	: Hertz
Mscf	: Thousand standard cubic feet
PVT	: Pressure-volume-temperature
QAQC	: Quality assurance – quality check

REFERENCES

[1] Jalali, M., Embry, J.-M., Sanfilippo, F., Santarelli, F. J., & Dusseault, M. B. (2016). Cross-flow analysis of injection wells in a multilayered reservoir. *Petroleum*, *2*(3), 273-281
[2] Bellarby, J. (2009). Sand Control. *Developments in Petroleum Science*, *56*, 129-239.Santarelli et al. (2000)
[3] Jongkittinarukorn, K., Last, N., & Chaianansutcharit, T. (2021). The Dynamics of Commingled Production. *Engineering Journal*, *25*(8), 1-10
[4] Larsen, L. (1981). Wells producing commingled zones with unequal initial pressures and reservoir properties. SPE annual technical conference and exhibition Kucuk et al. (1986)
[5] Eskandari Niya, M., Hashemi, A., & Zareiforoush, A. (2012). Challenges in Well Testing Data from Multi-Layered Reservoirs; a Field Case. *Int. J Sci. Emerging Tech Vol*, *4*(6), 208. (Luo et al., 2014)
[6] Antariksa, Z. N., Ultra, D., Malau, A., & Sukotrihadiyono, T. (2014). Reviving Brown field oil potential: case study of multilayer reservoir. International Petroleum Technology Conference (Craig & Odegard, 2008).
[7] Zeinalabideen, M. J., Al-Hilali, M. M., & Savinkov, A. (2021). State of the art of advanced spectral noise and high-precision temperature logging technology utilization in Iraqi oil fields: an integration approach to diagnose wells performance complications. *Journal of Petroleum Exploration and Production*, *11*(4), 1597-1607
[8] Aslanyan, A., Wilson, M., Al-Shammakhy, A., & Aristov, S. (2013). Evaluating injection performance with high-precision temperature logging and numerical temperature modelling. SPE Reservoir Characterization and Simulation Conference and Exhibition (Sarsekov et al., 2017).
[9] Maslennikova, Y. S., Bochkarev, V., Savinkov, A., & Davydov, D. (2012). Spectral noise logging data processing technology. SPE Russian Oil and Gas Exploration and Production Technical Conference and Exhibition
[10] Services, T. O. (2017). Spectral Noise Logging SNL-HD.