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Evaluating Well Performance using Production Logging: Case Analysis of an Oil Field in Libya.

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Abstract
Well performance evaluation is crucial for enhancing hydrocarbon recovery, particularly in mature and geologically complex reservoirs. This study applies Stingray Production Logging Tool (PLTs) to evaluate zonal inflow contributions and identify flow anomalies in a producing well from the Messla Field, located in the Sirt Basin, southwestern Libya. The well, completed in a shaly sandstone reservoir with variable porosity and water saturation and was logged using a suite of PLTs including spinner, temperature, pressure, and fluid identification sensors. Interpretation of the PLT data revealed that approximately 60% of the total oil and gas production of 2650 STB/D and 1189 Mscf/D originated from the second perforations (8761' - 8770'), while the other intervals contributed 40 % despite favorable petrophysical characteristics with no water cut. Temperature and spinner profiles also indicated no cross flow in, behind casing, or from plug. During shut in and flowing regime, spinner data indicated that there is not cross flow observed between intervals. The integrated analysis provided actionable insights for zonal shutoff recommendations and optimization of well productivity. These findings demonstrate the practical value of PLT-based diagnostics in identifying hidden production inefficiencies and guiding reservoir management decisions in the Messla Field

Keywords: Capacitance sensors, Gradiomanometer, Pressure Sensors, Spinner Flowmeter, Temperature Log Production logging tool.

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تقييم أداء الآبار باستخدام التسجيل الإنتاجي: دراسة حالة لحقل نفطي في ليبيا

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الملخّص

يُعدّ تقييم أداء الآبار أمرًا بالغ الأهمية لتعزيز استخلاص الهيدروكربونات، خاصة في المكامن الناضجة والمعقدة جيولوجيًا. تطبّق هذه الدراسة أدوات التسجيل الإنتاجي (PLTs)لتقييم مساهمة التدفق من الطبقات المختلفة وتحديد الشذوذات في التدفق داخل أحد الآبار المنتجة في حقل مسلة الواقع في حوض سرت جنوب–غرب ليبيا. أُنجز التسجيل الإنتاجي للبئر المكمل في مكمن من الحجر الرملي الطفلي ذي المسامية المتغيرة والتشبع المائي المتباين، باستخدام مجموعة من أدوات PLT تشمل الفرارة، وقياس الحرارة، والضغط، ومستشعرات تمييز الموائع.

أظهرت تفسير بيانات التسجيل الإنتاجي أن حوالي 60% من إجمالي إنتاج النفط والغاز البالغ 2650برميل نفط/اليوم و1189 ألف قدم مكعب قياسي/اليوم مصدره الفتحات الثانية ('8761 – '8770)، بينما ساهمت الفتحات الأخرى بنسبة 40% فقط رغم تمتعها بخصائص بتروفيزيائية جيدة ومن دون أي نسبة مياه منتجة. كما بيّنت ملفات الحرارة والفرارة عدم وجود أي تدفق متقاطع داخل أو خلف الغلاف أو من السدادة. وخلال حالتي الإغلاق وتدفق البئر، أشارت بيانات الفرارة إلى عدم ملاحظة أي تدفق متقاطع بين الطبقات.

قدمت هذه الدراسة المدمجة تحليلاً ذا قيمة عملية مكّن من اقتراح إغلاق مناطق محددة وتحسين إنتاجية البئر. وتبرهن النتائج على الأهمية العملية لتقنيات التسجيل الإنتاجي في كشف أوجه القصور الخفية في الإنتاج ودعم قرارات إدارة المكامن في حقل مسلة.

الكلمات المفتاحية :حساسات السعة؛ مقياس تدرج الضغط؛ حساسات الضغط؛ عدّاد تدفق دوار؛ أداة تسجيل الإنتاج لقياس درجة الحرارة.

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1. Introduction

Optimizing hydrocarbon production from oil wells requires a detailed understanding of reservoir behavior and wellbore flow dynamics. In mature and geologically complex fields, conventional monitoring methods are often insufficient to identify zonal contributions, detect production anomalies, or diagnose water or gas break through. Production logging used to establish a diagnostic technique, provides a reliable method for evaluating well performance by measuring flow rates, fluid types, and temperature and pressure profiles along the wellbore. These insights are crucial for designing targeted interventions, such as recompletions, selective stimulations, or water shut-off operations [1].
Libya, with its vast oil reserves and diverse reservoir settings, presents both opportunities and challenges for production optimization. Fields located in oil Libyan Basin often exhibit reservoir heterogeneity, multi-layered sandstone formations, and varying fluid saturations. In such environments, production logging becomes particularly valuable, enabling engineers to assess which zones contribute effectively to oil production and which zones may be underperforming or producing unwanted fluids [2].
This study focuses on the evaluation of a producing well from the Messla Field, which is located in the southeastern part of the Sirte Basin, one of Libya's most prolific hydrocarbon provinces. Geologically, the field is predominated by a sequence of Mesozoic to Cenozoic sedimentary formations, with hydrocarbon production primarily associated with Cretaceous clastic reservoirs.
The dominant reservoir units in Messla consist of interbedded sandstone and shale, deposited in fluvial to shallow marine environments. These sandstones typically exhibit moderate to good porosity and variable permeability, reflecting changes in depositional energy and digenetic overprinting. Shale interbeds contribute to reservoir heterogeneity and vertical compartmentalization.
Structurally, the Messla Field lies within an area influenced by extensional tectonics typical of the Sirt Basin. Normal faulting has created tilted fault blocks and structural traps, which play a major role in hydrocarbon entrapment. Many producing wells target downthrown fault blocks where effective sealing rock made by overlying shale units.

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The reservoir fluids are generally under saturated oils associated with solution gas, and water saturation varies significantly from zone to zone due to the complex layering and capillary behavior of the sandstone-shale system.

The objective is to identify contributing and non-contributing zones, quantify flow rates from individual reservoir layers, and detect any behind-casing communication or cross flow. Tools such as spinner flow meters, temperature and pressure sensors, and fluid identification logs employed to acquire dynamic down-hole data.
The output of this study offers valuable insights for improving well productivity and reservoir management in similar Libyan fields. By demonstrating how production logging data can guide operational decisions, this case study underscores the importance of integrating dynamic well diagnostics into field development and surveillance workflows [3].

2. Literature Review

Production logging tool is a key technique in well performance appraisal, particularly in complex or mature oil and gas fields where zonal productivity and fluid behavior vary significantly along the wellbore. Over the last few years, innovations in production logging tools and interpretation techniques have facilitated better accurate identification of productive zones, water and gas influx and behind-casing flow [4].

2.1 Basics of Production Logging

According to Makerji PA. (2013) [5], production-logging tools (PLTs) provide dynamic down hole measurements under flowing conditions, enabling the evaluation of multiphase flow profiles along the wellbore. Core tools include spinner flow meters, temperature and pressure sensors and fluid identification tools. These tools ran under both single-phase and multiphase flow conditions to determine the inflow or outflow profile, identify cross flow, and locate fluid entries.
Precise interpretation of production logging data is comprehensively dependent on tool calibration, flow regime, and wellbore geometry. Furthermore, interpretation becomes more

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complicated in horizontal or highly deviated wells, where flow segregation and phase slippage affect measurement reliability.

2.2 Data Integration with Petrophysical Results

Previous studies stress the need to integrate PLT data with open-hole logs, core data, and geological models for accurate interpretation. Several studies have highlighted that petrophysical parameters such as porosity, permeability, and water saturation should be considered when interpreting zonal contributions, particularly in heterogeneous sandstone formations. In Libyan oil fields especially in oil Libyan basins reservoirs, which exhibit layering, compartmentalization, and variations in wettability, making production logging integration essential for reliable decision-making.

2.3 Implementation within Libyan Contexts

While global literature on production logging is extensive, studies focusing specifically on Libyan oil fields remain limited. However, several regional investigations highlight the value of PLTs in evaluating well performance under complex geological conditions.

A Study conducted by Suleimanov & Abbasov (2024) [6] in oil Libyan Basin and demonstrated the use of temperature and pressure profiles to detect water breakthrough and improve recompletion strategies. Moreover, used spinner and other measurements to analyze production anomalies in oil Libyan Basin, recommending selective shut offs to improve overall well efficiency.

3. Case Study and Methodology

This study involves a field-based approach to evaluate well performance using production-logging techniques in a selected oil well located in Libyan Sirt Basin, Messla Field. The methodology involves the acquisition, processing, and interpretation of dynamic wellbore data collected during production logging operations, as shown in Figure (1). The approach integrates both quantitative and qualitative analyses to identify productive intervals, fluid entries, and possible production anomalies. The overall process is divided into five main stages: field selection, data acquisition, tool deployment, data processing, and interpretation.

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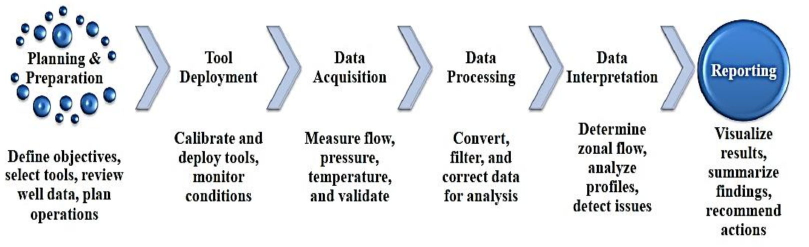

Figure 1. Workflow for PLT processing and interpretation

3.1 Field Selection and Well Profile

The vertical selected well is located in a mature shaly sandstone oil reservoir in Libyan Sirt Basin, Messla Field which characterized by moderate porosity (10–19%). The reservoir consists of multilayered formations with differing flow capacities and petrophysical properties. The selected well has a history of fluctuating oil rates and high amount of stagnant water holdup, making it a suitable candidate for production logging evaluation.

3.2 Data Acquisition and Tool Selection

Production logging was carried out under stabilized flow and shut-in conditions using a combination of wire line conveyed tools. The following tools were employed:

• Spinner Flowmeter: to measure fluid velocity and estimate zonal flow contributions.

• Temperature Log: to identify inflow points, thermal anomalies, and possible cross flows.

• Pressure Sensors: to record down hole pressure profiles along the wellbore.

• Gradio-manometer Measurement: his tool determines the fluid density inside tubing and casing pipes.

• Capacitance sensors: exploit the fact that gas and liquid phases have very different dielectric constants

All data were acquired during multiple passes in shut-in and flowing conditions. A calibration run was conducted prior to the main survey to ensure tool accuracy.

3.3 Data Handling and Processing

Raw log data were processed using industry standard software Emeraude (KAPPA Engineering) and cross-referenced with well completion details and production history.

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The software was used to calibrate the spinner response, depth-match the logs, and integrate pressure, temperature, and capacitance data to construct a dynamic inflow profile for the Messla Field well. Figure (2) shows the shut-in logs survey, which well correlated with the station points for data validity.

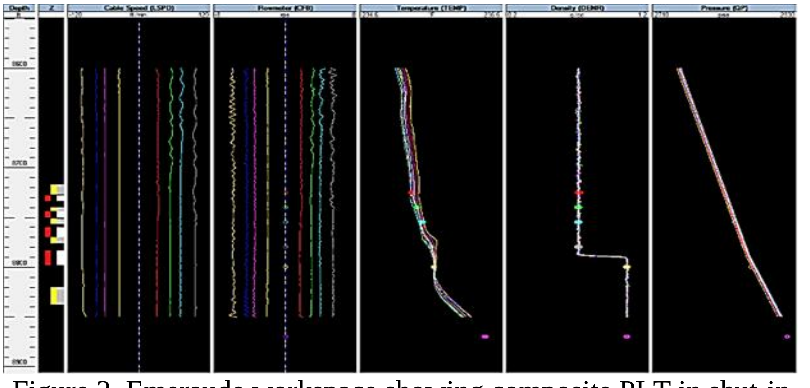

Figure 2. Emeraude workspace showing composite PLT in shut-in survey display from left to right with cable speed, spinner, temperature, density and pressure curves.

Next Figure (3) shows a tool calibration window from production logging software (Emeraude). It displays the calibration of the spinner (flow meter) specifically the relationship between rotations per second (rps) and flow velocity (ft/min) for Zone 5 (8820–8838 ft).

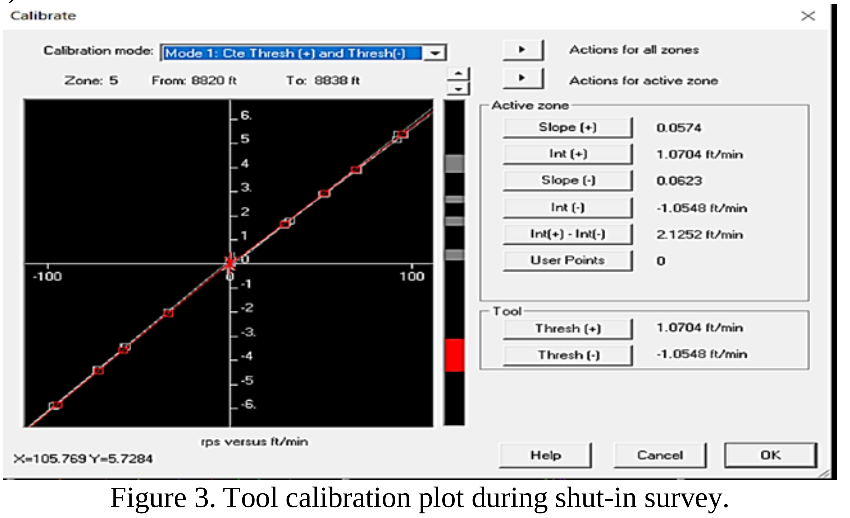

Figure 3. Tool calibration plot during shut-in survey.

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- The calibration shows good symmetry between positive and negative flow.
- Slopes are nearly identical, indicating consistent spinner response.
- Intercept differences are small and within expected limits — the tool is properly calibrated.

During the flowing survey as in Figure (4) showing, several measurements acquired during the flowing well survey. It visually integrates multiple logging sensors to analyze wellbore flow behavior and formation contributions.

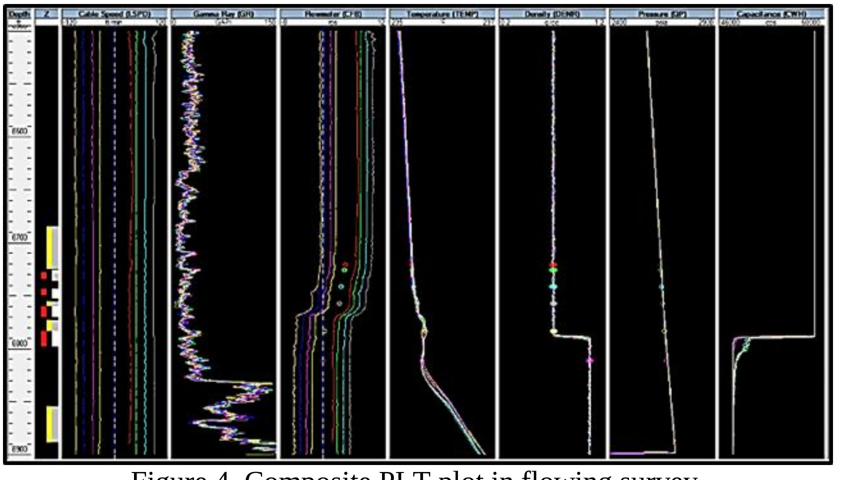

Figure 4. Composite PLT plot in flowing survey.

Track descriptions (from left to right)
Depth Track (ft)
Displays the measured depth reference for all logs, typically in feet.
Zonal Indicators (Colored Bars)
The colored segments beside the depth column represent completion zones, including perforated intervals (red), calibration locations (yellow), inflow zones (grey) and calculation zones (white).
Cable Speed (LSPD, ft/min)
Indicates the logging speed during the run (up and down passes). Multiple colored lines show the tool movement for various passes, ensuring data repeatability.

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Gamma Ray (GR)
Measures natural radioactivity to distinguish lithology.
The higher GR readings correspond to shaly or non-reservoir zones, while lower readings suggest clean sand or reservoir intervals.
Flow meter (CFB, rps)
Displays spinner response (rotations per second), directly related to fluid velocity inside the wellbore.
Variations indicate entry or exit points, showing where fluid enters or leaves the well.
Temperature (TEMP, °F)
Temperature profile helps identify fluid movement and inflow zones by detecting temperature anomalies.
A deviation from the normal geothermal gradient may indicate active flow zones.
Density (DENR, g/cc)
Used to identify fluid type (oil, water, gas).
Changes in density may correspond to fluid segregation or zonal contributions.
Pressure (QP, psia)
Shows the pressure gradient along the wellbore.
Pressure changes can correlate with entry or restriction points.
Capacitance (CWH, cps)
Indicates fluid phase typically used to distinguish oil and water holdup.
A sharp change in capacitance suggests fluid interface movement.

Figure (5) Graph (Left Panel)
X-axis: Flow velocity (ft/min)
Y-axis: Spinner speed (rps)
Red squares: Calibration data points for Zone 4.
Diagonal red line: The best-fit linear regression for spinner calibration, showing a strong linear correlation between rps and flow velocity.
The near-symmetry of the lines about the origin indicates accurate and balanced tool response in both flow directions.

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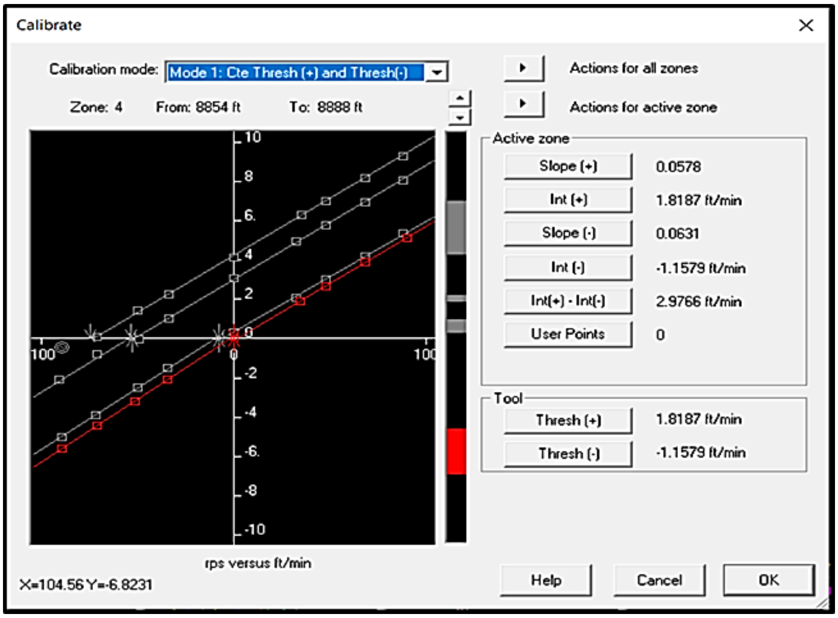

Figure 5. Tool calibration plot during flowing survey.

Table 1. Active zone calibration parameters (Right Panel)

Parameter	Meaning	Value
Slope (+)	**Slope of calibration line (upward flow)**	**0.0578**
Int (+)	**Intercept for positive flow**	**1.8187 ft/min**
Slope (–)	**Slope of calibration line (downward flow)**	**0.0631**
Int (–)	**Intercept for negative flow**	**–1.1579 ft/min**
Int(+)-Int(–)	**Difference between intercepts (sensitivity offset)**	**2.9766 ft/min**

These parameters (table 1) define how raw spinner rotations (rps) are converted to linear flow velocity for this specific interval.

Tool Thresholds

- Thresh (+): 1.8187 ft/min
- Thresh (–): –1.1579 ft/min

These are the minimum flow velocities required for the spinner to begin registering consistent rotations in each direction representing the tool's detection limit.
The slopes for positive and negative directions are very close (0.0578 vs. 0.0631), indicating good calibration consistency.

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The small difference between intercepts suggests a minor offset, acceptable in typical PLT calibration results.
The calibration curve demonstrates a linear and reliable spinner response, confirming that the tool is properly calibrated and ready for accurate flow measurements in Zone 4 (Rat Zone).

The key processing steps included:
• Depth matching using open-hole and cased-hole Gamma ray and Caliper logs.
• Correction of spinner data for tool eccentricity and fluid slippage.
• Conversion of spinner velocity readings to volumetric flow rates.
• Identification zones of inflow and outflow using spinner flow meter readings.
• Capacitance for water and hydrocarbon distinction.
After measuring spinner velocity (vs) in revolutions per second (or ft/min), corrections are applied:
• Correct for tool speed and calibration.
• Apply a profile correction factor, commonly ~0.83, to estimate average fluid velocity:

$$Vi = 0.83 \times Vs \quad (1)$$

Then compute interval flow rate using (for vertical wells):

$$Qi = 1.4 \times Vi \times (ID)^2 \quad (2)$$

Where:
Qi = flow rate in barrels/day (bbl/d)
Vi = average velocity (ft/min)
vs = spinner velocity in revolutions per second (rps)
ID = wellbore inner diameter (inches)
Water Hold up (Yw %) from capacitance:
Yw = (Die (measured) - Die (100% H.C) / Die (100% H2O) - Die (100% H.C)) (3)

Where:
Die (measured) = Dielectrical Measurement from log Count Per Second (cps)
Die (100% H.C) = Dielectrical for Hydrocarbon
Die (100% H2O) = Dielectrical for water [7].

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3.4 Data Interpretation

The interpretation has been done by a zone-by-zone analysis method. Flow contributions were calculated by comparing total surface rates with cumulative zone inflows. Fluid types were identified based on dielectric and capacitance readings, with cross validation from temperature log data. The following key parameters were interpreted:

- Correlations with open-hole logs for depth matching and radioactive scale buildup.
- Zonal contribution (oil, gas and water percentage)
- Detection of thief or cross flow zones, if there is any!
- Identification of no contributing or shut in layers (inactive perforation).

These interpretations were used to evaluate the performance of each reservoir layer, detect mechanical or flow related issues, and propose optimization strategies.

3.5 Well details

- Vertical well
- Logging Interval: From 8510' to 8880' kb
- PBTD-8977' kb.
- Perforation Intervals: 8720' - 8714' kb, 8741' - 8752' kb, 8761' - 8770' kb and 8780' - 8796' kb.

3.6 Problem statement

- Assessing if there is any flow in casing from plug or cross flow throughout the well intervals.
- Investigating active and inactive perforation zones.
- Estimation of flow rates for each perforation zone.

3.7 PVT data inputs

Figure (6) shows a PVT definition main window

Fluid Type

Hydrocarbons is selected (not Water).

The subtype chosen is Saturated Oil (bubble point fluid), meaning the reservoir fluid is an oil that contains dissolved gas up to its bubble point pressure.

Other options (not selected) are Dry Gas and Condensate (dew point fluid).

This configuration defines a saturated oil PVT model with:

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Rs = 449 cf/bbl, T = 212°F, Pmin = 14.7 psia, Pmax = 10,014.7 psia and ΔP = 50 psia.

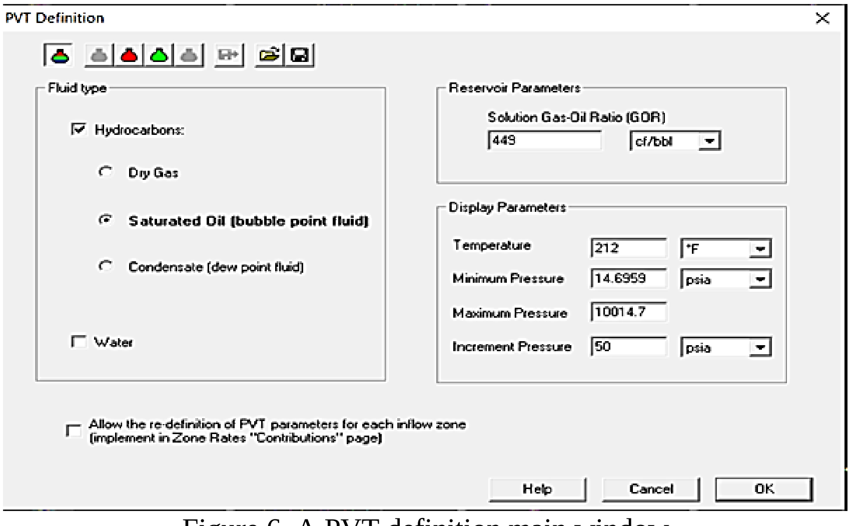

Figure 6. A PVT definition main window

Figure (7) shows a PVT definition of oil parameters window Gravity.

Value: 36.7 °API

Correlations:

These empirical correlations (table 2) are used to estimate PVT properties based on field or lab data.

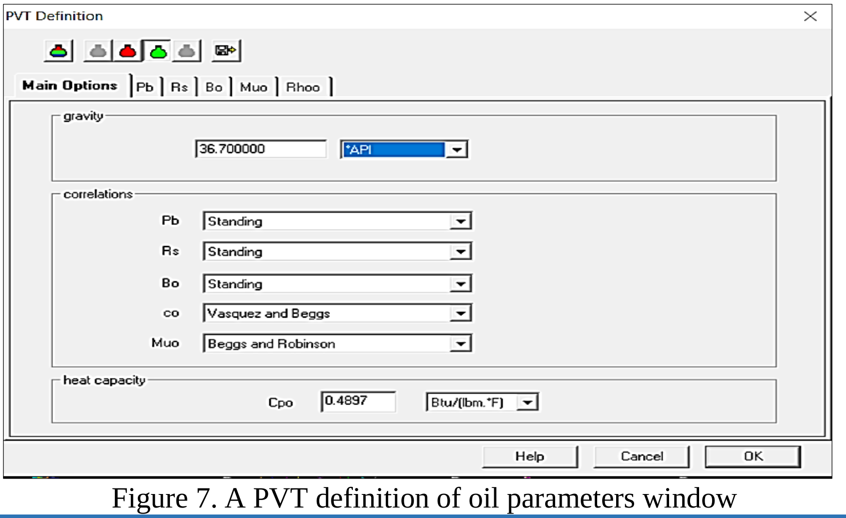

Figure 7. A PVT definition of oil parameters window

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Table 2. Used property for correlation model

Property	Correlation	Purpose
Pb (Bubble Point Pressure)	Standing	Calculates the pressure at which gas starts to come out of solution.
Rs (Solution GOR)	Standing	Determines the gas dissolved in oil at a given pressure and temperature.
Bo (Oil Formation Volume Factor)	Standing	Relates the volume of oil at reservoir conditions to its surface volume.
Co (Oil Compressibility)	Vasquez and Beggs	Estimates oil compressibility as a function of pressure and Rs.
Mu_o (Oil Viscosity)	Beggs and Robinson	Calculates oil viscosity over different pressures and temperatures.

3.8 Production Logging Tool findings and discussion

- Table (3) shows the perforation intervals contributions by phase
- Table (4-5) the total rate and production percentage for each interval
- Most of the Oil is being produced from perforation (8761' - 8770').
- Temperature log does not show any significant flow in, behind casing or from plug.
- During shut in and flowing regime, spinner data indicated that there is not cross flow observed between intervals.
- Zone 8728.0'-8729.2' contributed by 10.70% of total flow
- Zone 8744.0'-8752.6' contributed by 19.04% of total flow
- Zone 8760.0'-8Z770.0' contributed by 60.45% of total flow
- Zone 8783.0'-8798.0' contributed by 9.8% of total flow

Table 3. Perforation intervals contributions by phase

Zones ft	Water Rate Barrel/Day	Oil Rate Barrel/Day	Gas Rate Barrel/Day	W O G
8728.0-8729.2	0.00	365.29	0.00	
8744.0-8752.6	0.00	649.88	0.00	
8760.0-8770.0	0.00	2063.22	0.00	
8783.0-8798.0	0.00	334.56	0.00	

Table 4. Total rate and production percentage for each interval

Zones ft	Water STB/D	Oil STB/D	Gas Mscf/D
8728.0-8729.2	0.00	283.59	127.33
8744.0-8752.6	0.00	504.58	226.56
8760.0-8770.0	0.00	1602.04	719.32
8783.0-8798.0	0.00	259.78	116.64
Total	0.00	2650.00	1189.85

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Table 5. Total oil and gas surface rates STB/D

Zones ft	Total Rate Barrel/Day	Production %
8728.0-8729.2	365.29	10.70
8744.0-8752.6	649.88	19.04
8760.0-8770.0	2063.22	60.45
8783.0-8798.0	334.56	9.80

Figure (8) is a composite PLT plot and reflects the following:

1- Cable speed was constant and consistent for most of the passes. Since cable speed was reliable, you can confidently use this dataset for quantitative flow profiling or inflow diagnostics.
2- X-Y Caliper behavior suggests small eccentralization, which did not affect the measurement.
3- Spinner measurements were consistent at different cable speed and clearly indicated to fluid entry zones so high confidence inflow profile derived from spinner data.
4- Capacitance clearly indicate the water hold up below the bottom perforation (stagnant water).
5- Consistent temperature anomalies confirm spinner readings, temperature measurements were very consistent and repeated and clearly indicated to fluid entry zones at all perforations.
6- Stable well pressure during logging increases confidence in data interpretation. Pressure data was consistent and indicated that the well was stable during PLT logging.
7- Density log indicates exactly the oil phase at the bottom perforation upwards.
8- Excellent log validation across dynamic (spinner) and static (station) measurements indicates excellent match between the station Points (colored Dotes) and the rest of the data especially with the spinner Readings.

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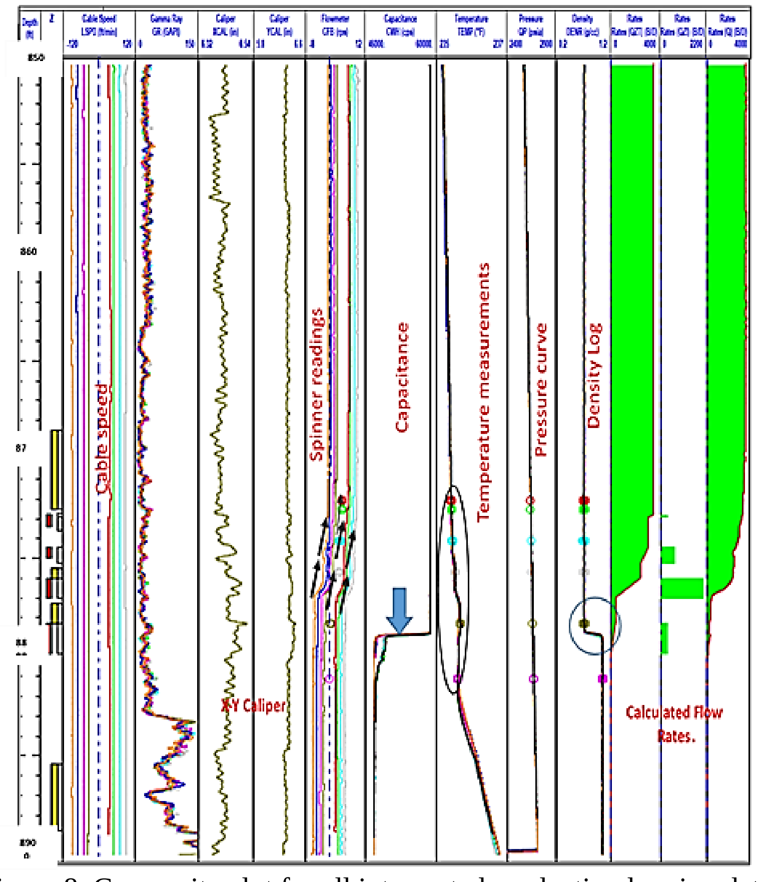

Figure 8. Composite plot for all interpreted production logging data

4. Recommendations:

- ✓ The presence of water below the bottom perforation suggests:
  - o No water coning yet, but water is approaching the zone.
  - o Monitor closely in future PLTs or consider running a water saturation log RST.
  - o If water production begins to increase, consider zonal isolation, chemical water shutoff, or mechanical plugs.
- ✓ Fluid entry
  - o Reperforation above these zones is not necessary at this stage.
  - o Consider stimulating the low contributing zones (acidizing or fracturing) for well improvement productivity.
- ✓ Stable well pressure

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- Utilize the pressure data to validate your nodal analysis and inflow performance relationship (IPR) models.
- If planning artificial lift upgrades, this pressure stability provides a reliable starting point.

✓ Density and Capacitance

- Avoid water producing zones below, if any, based on water cut trends or future density and water holdup measurements.

✓ Excellent log validation across dynamic (spinner) and static (station) measurements. You can confidently proceed to:

- Run a wellbore flow simulation to optimize choke settings or evaluate skin factor.

✓ Last but not least: Update or calibrate your well/reservoir model with spinner confirmed flow zones.

5. Conclusion

Production logging tool is accurately identifies the contribution of oil, gas, and water along different intervals of the well and helps determine the producing and non-producing zones, water or gas breakthrough, and cross flow, in addition can detects casing leaks, channeling behind casing,

In the Messla Field well, production-logging tools (PLTs) precisely quantified zonal contributions, revealing that the shaly sandstone reservoir has a surface productivity 2650 STB/D of oil and 1189 Mscf/D of gas with no water flowing from the well.

The production logging survey successfully evaluated the vertical well between 8510' and 8880' kb, including all perforation intervals down to the total depth at 8977' kb. Analysis of the PLT data indicates the following:

The primary oil contribution comes from the perforation interval 8761'–8770', accounting for approximately 60% of total production. Other perforations contributed smaller portions, with 8744'–8752.6' at 19%, 8728'–8729.2' at 10.7%, and 8783'–8798' at 9.8%. No significant flow was observed in or behind the casing, nor through plugs, during either shut-in or flowing conditions. No cross flow was detected between perforation intervals.

Temperature, spinner, capacitance, density, and pressure logs were consistent and reliable, confirming the identified fluid entry zones and supporting a high-confidence inflow profile. Minor wellbore eccentricity did not affect measurements, and stable well pressures

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ensured accurate logging conditions. Capacitance data indicated the existence of stagnant water below the lowest perforation, while density logs indicated the oil phase distribution from the bottom perforation upwards.

Overall, the PLT survey provided a robust assessment of inflow contributions, confirming the active perforation zones and quantifying flow rates without evidence of cross flow or casing leaks. These results can be confidently used for reservoir management and production optimization [8].

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