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-TOPIC -

Memory Production Logging Tool (MPLT) in a Cross Flow

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DEDICATION

I dedicate this thesis to the unwavering support system that carried me through:

- **To my parents, who instilled in me the value of education and the courage to pursue my goals.**
- **To my siblings, for their unwavering belief in me and the laughter that kept me going.**
- **To my wife, my rock and partner in crime. Your endless patience, encouragement, and sacrifices fueled my determination to finish.**
- **And to my children, whose innocent love and occasional interruptions reminded me of the world I was striving to build a better future for.**

BELOUAD BILAL

DEDICATION

I dedicate my dissertation work to my family and many friends.A special feeling of gratitude to my loving parent and sisters and my brother whose push for tenacity ring in my ears.

I also dedicate this dissertation to my many friends and family who havesupported me throughout the process.

I will always appreciate all they have done.

Houssam Eddine

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I dedicate this modest work above all to:

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May they be thanked with this all
It is a moment of pleasure to dedicate
To my dear brother and sisters,
To all the members of my family.

I also dedicate this work to all my dear friends.

To all the teachers of hydrocarbons.

Finally, I warmly dedicate this thesis to my trinomial group.

BASSA Houssam and BELOUAD Bilal

Aymen

Résumé

Le présent travail a pour but de détecter le phénomène de cross-flow. Trois puits du champ de Rhourd-nouss ont été sélectionnés L'interprétation des MPLT a été faite par le logiciel Emeraude. L'interprétation du MPLT réalisé le 31/09/2023 pour le puits **RN-111** a montré qu'il y a un cross flow entre **le réservoir A2 et TAGI**. Par ailleurs l'interprétation du MPLT réalisé le 09/10/2023 pour le puits **RNA-8**montre qu'il n'y a pasde production d'eau et il y a une différence entre le débit de surface mesure par MPLT et celle mesure par Well Test. L'interprétation de MPLT réalisé (juin2023-oct2023) sur le puits **RNSE-68** a montré qu'il n'existe pas de changement de débit totale de well Test et pas de production d'eau. Cette étude a permis de différencier entre les eaux et leurs impacts, de collecter plusieurs données et informations sur le réservoir, et de déterminer l'importance de MPLT dans la détection de Cross-flow.

Mots clés: MPLT, Cross-flow, logiciel Emeraude, WT.

The objective of this study is to investigate the cross-flow phenomenon in three wells in the Rhourd-Nouss field. The interpretation of the Multi-Phase Logging Tool (MPLT) data was performed using the Emeraude software.

The interpretation of the MPLT conducted on September 31, 2023, for well RN-111 revealed cross-flow between reservoir A2 and TAGI. Additionally, the interpretation of the MPLT conducted on October 9, 2023, for well RNA-8 indicated no water production and a discrepancy between the surface flow rate measured by MPLT and that measured by the well test. The interpretation of the MPLT conducted between June and October 2023 on well RNSE-68 showed no change in total well test flow rate and no water production.

This study successfully differentiated between waters and their impacts, collected various data and information about the reservoir, and demonstrated the significance of MPLT in cross-flow detection.

Key words: MPLT, Cross-flow, logiciel Emeraude, WT.

الغرض من هذا العمل هو الكشف ودراسة ظاهرة التدفق المتقاطع. تم اختيار ثلاث آبار من حقل غرد النص، وتم إجراء تفسير لبيانات MPLT باستخدام برنامج Emeraude. أظهر تفسير بيانات MPLT الذي تم إجراؤه على البئر RN-111 بتاريخ 31/09/2023 وجود تدفق متقاطع بين الخزان A2 و TAGI. بالإضافة إلى ذلك ، أشار تفسير بيانات MPLT الذي تم إجراؤه على البئر RNA-8 بتاريخ 09/10/2023 إلى أنه لا يوجد إنتاج للمياه وهناك فرق بين معدل تدفق السطح بواسطة MPLT و WT. وأظهر تفسير بيانات MPLT الذي تم إجراؤه (من يونيو 2023 إلى أكتوبر 2023) على البئر RNSE-68 أنه لا يوجد تغيير في معدل تدفق WT الكلي ولا يوجد إنتاج للمياه. وقد أتاحت هذه الدراسة التفريق بين أنواع مختلفة من المياه وتأثيراتها ، وجمع العديد من البيانات والمعلومات حول الخزان ، وتحديد أهمية MPLT في اكتشاف التدفق المتقاطع.

الكلمات المفتاحية:MPLT،ظاهرة التدفق المتقاطع، برنامج Emeraude،WT

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Chapter III: *Overview of Cross Flow*

IV : Case Study

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List of Abbreviation and Symbol

Bo: formation volume factor.

C: compressibility.

CCL: Casing Collar Locator.

CFB: Caged Full Bore.

CFS: Continuous Flowmeter Spinner.

CPF: Central Processing Facility.

Csc: Compression Separation Center.

CWH: Enhanced Capacitance Water Hold-Up.

d: density.

FDR: Fluid Density – Radioactive.

FID: Fluid Identification.

GCL: Gamma CCL TOOL.

GHT: Gas Hold-up Tool.

GR: Gamma Ray.

HMD: Hassi Messaoud.

ILS: In-Line Spinner.

K: permeability

LPG: Liquefied Petroleum Gas.

LVDT: Linear variable differential transformer.

LWD: Logging While Drilling.

MBS004: Memory Battery Sub.

MLT002: Memory logging tool.

MPLT: Memory Production Logging Tool.

Mu: viscosity.

MWD: Measurements While Drilling.

P:pressure.

PFD:down Hole pressure.

Phi: porosity.

PL: Production Logging.

PRT: Platinum Resistance Thermometer.

Qg: Gaz flow.

Qo: Oil flow.

QPS: Quartz Pressure Sensor.

Qt: total flow.

Qw: water flow.

SWD: Seismic While Drilling.

T: température

TAGI: Lower Argilo-Gresous Triassic.

v: speed.

WT: well test.

GENERALE INTRODUCTION

The most important system in oil exploitation is reservoir study, as it provides a comprehensive image of hydrocarbon deposits. Studying the reservoir involves employing behavior analysis techniques to better acquire data for reservoir modeling, optimizing the field, and establishing a development project for hydrocarbon recovery.

Production logging and well testing are diagnostic and interpretation tools used to determine the type and model of the studied reservoir, as well as changes occurring during well life and factors influencing their exploitation and development over time, such as effluent rates (Qo, Qw, Qg), useful thickness of the oil-producing layer (hu), pressure (P), and especially what interests us most and is the focus of our study: cross flow phenomena, their origins, and the resulting consequences.

This study is conducted using computer software: Emeraude, which includes Spinner, density, capacitance, temperature, and pressure curves, all introduced under the term MPLT.

The Rhourd_noss field reservoir faces productivity or injectivity issues. Some of these problems are related to water influx. In this work, we are particularly interested in locating water influxes through the interpretation of MPLT production logs in the Rhourd_noss reservoir. Hence, it is crucial to detect water influxes, their origins, nature, and contribution by interpreting the MPLT logs.

Research Problem:

The Rhourd_noss field reservoir presents several issues affecting well productivity and injectivity. The impact of water influx leads to a decrease in productivity and/or injectivity indices and causes various phenomena such as salt deposits, $BaSO_4$ deposits, corrosion, asphaltic blockages, perforation plugging, etc.

This work aims to better understand the interpretation of MPLT logs and well tests conducted on wells to decide whether or not to implement cross flow or proceed with other solutions.

This thesis is structured into 4 chapters as follows:

- Chapter I: Presentation of the study region.

- Chapter II: Generalities on MPLT production logging.

- Chapter III: Generalities on cross flow.

- Chapter IV: Case study and we finished our work with a conclusion.

CHAPTER I:
Description of the Rhourde Nouss Area

Introduction

The Rhourde-Nouss Regional Directorate is an operational unit of the National Company SONATRACH, Upstream Activity. During its development phase, the Rhourde Nouss field was attached to the HMD region until January 1984. Then its activities were transferred to the Gassi-Touil region.

In 1987, this field became an independent region and was classified as the country's second gas region.

Production at Rhourde-Nouss only began in 1988 after the installation of a treatment center.

The hydrocarbon accumulations are located in Triassic, Silurian, and Ordovician reservoirs. The encountered fluids are gas, condensate gas, and oil.

I.1. Geographical situation

The Rhourde-Nouss region is located in the Illizi province**(Figure I.1)**, 280 kilometers southeast of Hassi Messaoud, and approximately 1000 kilometers from Algiers. It lies between parallels 29°16' and 30° and meridians 06°24' and 07°.

It is bordered to the north by the Gassi-Touil region and to the south by the Hamra and Tin-Fouye Tabankort regions.

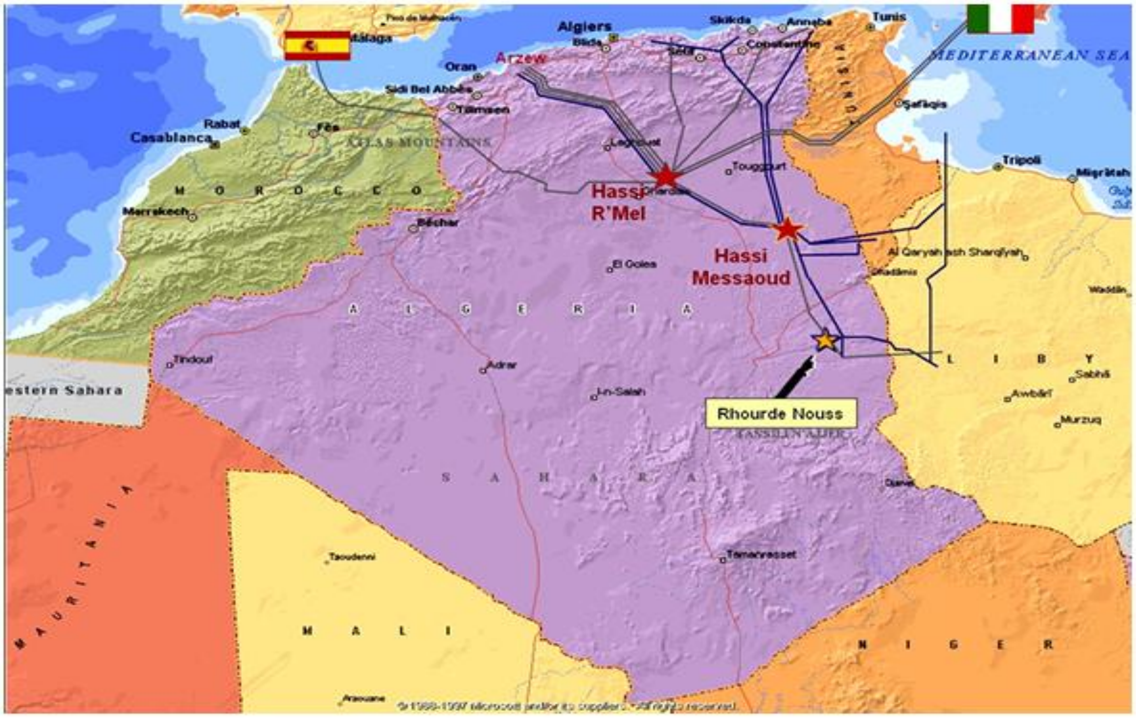


Figure I.1: Geographical location of the Rhourde Nouss region.**[1]**

I.2. The development stages of the Rhourde Nouss field[1]

Date	**stages**
1956	The first discovery of a gas well at Rhourde Nouss.
1966	The first discovery of an oil well at Rhourde Nouss.
1988	Start-up of Phase A plant. (Four (04) trains each with a capacity of 10 million SM3/d of raw gas).
1989	Commissioning of Rhourde Adra.
1992	Commissioning of Rhourde Chouf and Rhourde Hamra.
1995	Start-up of the Hamra plant.
1996	First shipment of Liquefied Petroleum Gas (LPG) from Hamra.

2000	Start-up of the Liquefied Petroleum Gas (LPG) plant (Phase B) with a processing capacity of 48 million cubic meters per day.
2005/2010	Preparation of the Development Plan for CTH and QHA.
2012	The start-up of the Separation and Compression Center (CSC) with a processing capacity of 1000 cubic meters per day of crude.
2014	The commissioning of the Central Processing Facility (CPF) plant (the 6th gas processing train).

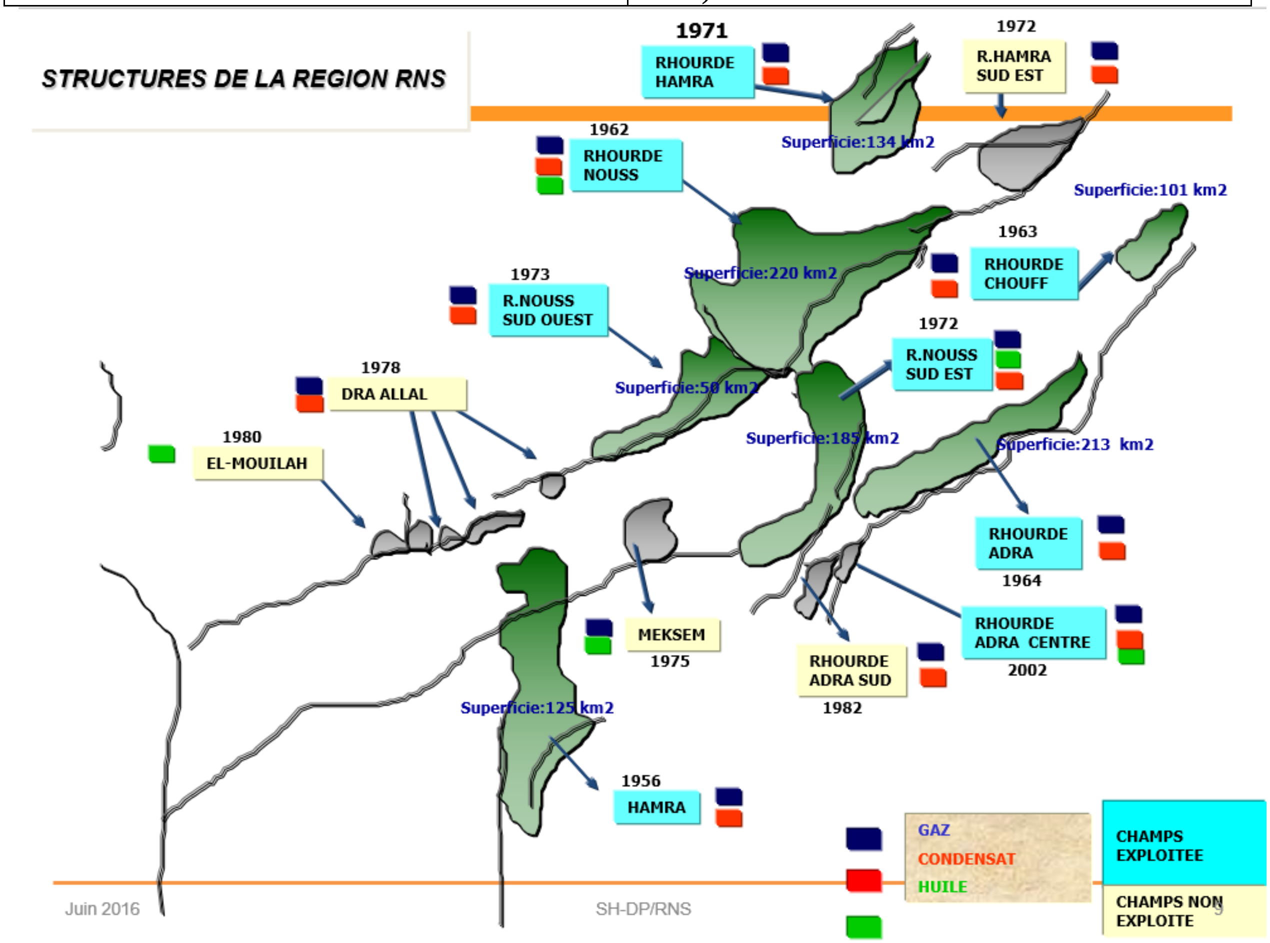


Figure I.2: Structures of the RNS Region.**[2]**

I.3 The main fields

The Rhourde Nouss region is composed of several fields**(Figure I.2)** (deposits) within a radius of 100 km from the regional headquarters located in the Rhourde Nouss Center field. The main fields in operation are:

- Rhourde Nouss Field.
- Rhourde Adra Field.
- Rhourde Chouf Field.
- Rhourde Hamra Field.
- Hamra Field.

Other fields of lesser importance have been discovered and will be developed in the future. These include:

- Rhourde Hamra Southeast Field.
- Rhourde Nouss 3 Field.
- Mouilah Field.
- Meksem Field.
- Draa Allal Field.
- Elketaia Field.
- Rhourde Adra Southeast Field.**[1]**

I.4 Stratigraphic aspect

The sedimentary series in the region is represented by Cenozoic, Mesozoic, and Paleozoic formations with a total thickness exceeding 4000 meters**(Figure I.3)**.

a) Cenozoic:

It is represented by the Mio-Pliocene, with a thickness ranging from 150 to 370 meters.

b) Mesozoic:

It includes the Cretaceous, Jurassic, and Triassic formations with a total thickness of 2621 meters.

- **Cretaceous:**

It consists of Senonian, Turonian, Cenomanian, Albian, and Neocomian formations, totaling 1273 meters.

- **Jurassic:**

It comprises Dogger and Lias formations with a total thickness of 1012 meters.

- **Triassic:**

Considered one of the drilling targets, it includes TAGS, Intermediate Triassic II, Middle Triassic, Intermediate Triassic I, and Lower Triassic formations, with a total thickness of 389 meters.

c) Paleozoic:

The first Paleozoic horizon, beneath the Hercynian unconformity, includes the Clayey-Sandy Silurian, Devonian, and Carboniferous formations, which are eroded. Additionally, all Ordovician and Silurian formations are present, except for level B2, which is eroded.**[1]**

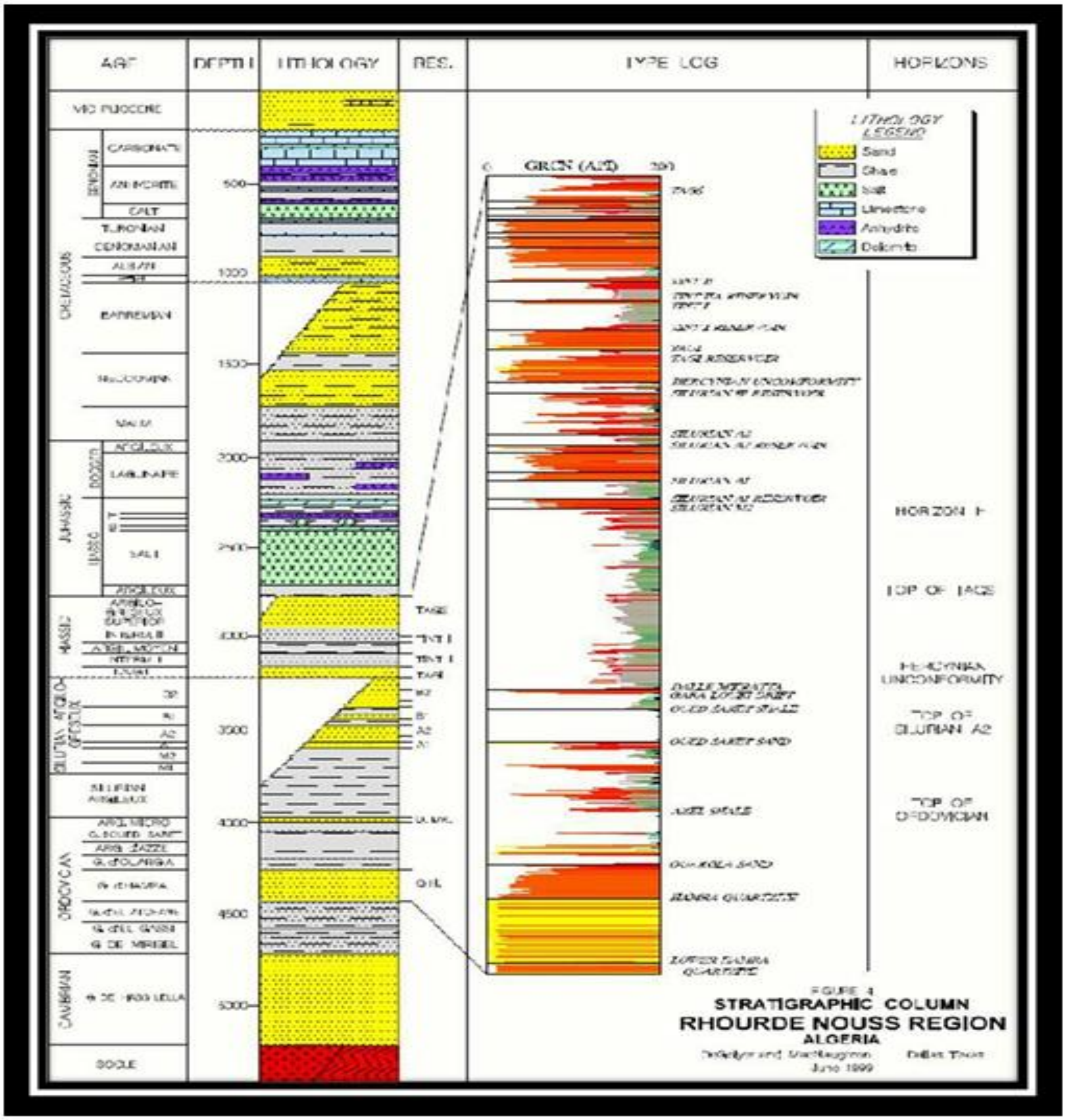


Figure I.3: The stratigraphic column of the Rhourde Nouss region.**[1]**

I.5.The various formations in the region

The Rhourde Nouss region is primarily dedicated to gas production. It is equipped with:

- Two plants for processing wet gas:
    - Phase A: Processing 51 million standard cubic meters per day (Sm3/d) of gas to recover condensate.

- Phase B: Processing 48.3 million Sm3/d to recover Liquefied Petroleum Gas (LPG) and traces of condensate.

- An oil treatment center with a capacity of 1000 cubic meters per day.
- A power plant generating 21 megawatts of clean energy for the region.
- A processing center for 35 million Sm3/d of unconventional gas to remove carbon dioxide.

I.6. The overall production capacity of Rhourde Nouss: [1]

The overall production capacity is presented in the following table:

Raw Gas	51 millions Sm^3/j.
Reinjection	Approximately 75%, which is 32 million standard cubic meters per day of dry gas.
Commercialization	20 millions Sm^3/j.
LPG	3986 T/d.
Condensate	5000 T/d.
Crude oil	500T/d.

I.7 Organization of the HR department of RHOURDE NOUSS: [1]

The Regional Direction RHOURDE NOUSS is composed of the following structures and units**(Figure I.4)**:

1st Part:

- HAMRA Directorate.
- Assistant DR Cell.
- Internal Security Cell.
- IT & Operations Service.
- Regional Direction Secretariat.

2nd Part:

- MN Division: Maintenance Division.
- EP Division: Engineering & Production Division.
- XP Division: Exploitation Division.
- SE Division: Security Division.
- AT Division: Procurement & Transport Division.
- REAL Division: Realization Division.
- PE Division: Personnel Division.
- FI Division: Finance Division.
- IT Division: Intendance Division.

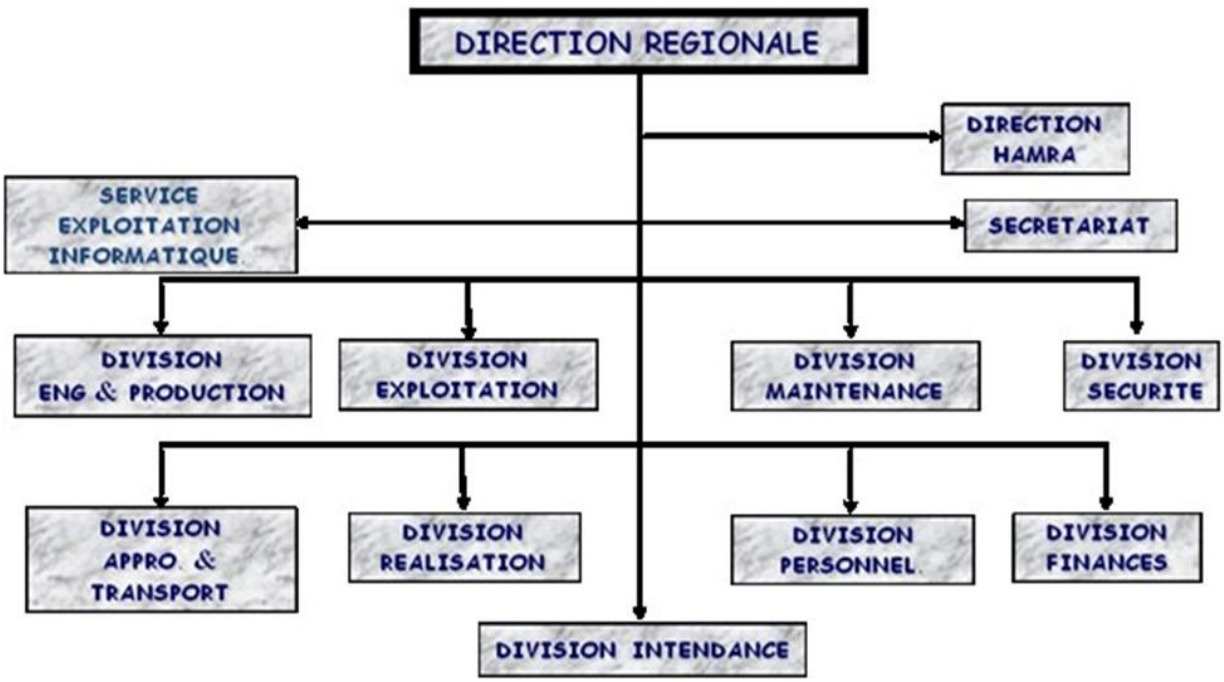


Figure I.4: Organization of the Rhourde Nouss regional directorate.**[1]**

Chapter II:
General Overview of Production Logging and MPLT

II.1. General Overview of Production Logging
II.2. Introduction

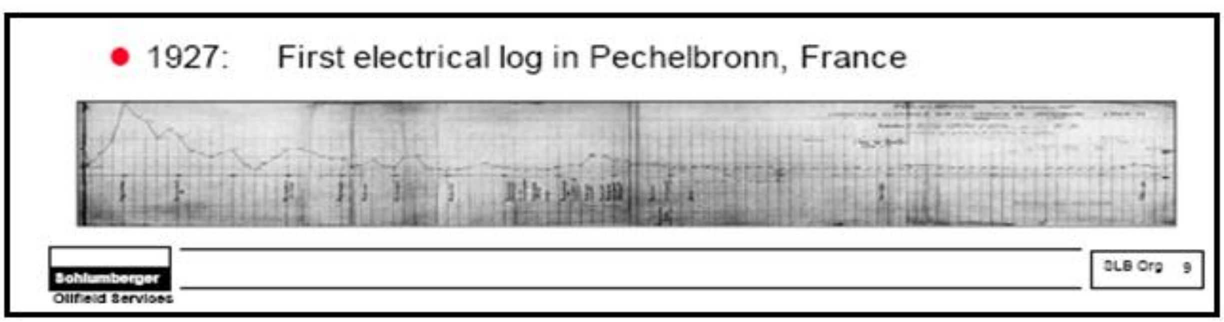
Logging (from the Greek "dia," meaning "through," and "graphein," meaning "to draw") or, more commonly, by the American term "log" (which means log, roll...) refers to continuous recording of variations, as a function of depth, of a given characteristic of the formations penetrated by a borehole.

Depending on these characteristics and when the measurements are recorded, we speak of mud logging, logging (or measurements) while drilling, or delayed logging, the latter being so called because they can only be performed after several tool runs and drilling cessation.

First of all, it is important to know that logging methods are geophysical techniques designed to facilitate the interpreter's task to the fullest extent. Interpretation is sometimes visual (qualitative), allowing for the rapid provision of very important information:

- regarding the presence of a reservoir (water or hydrocarbons).
- concerning the nature of the fluid saturating this reservoir.
- and sometimes even regarding the nature of the formations penetrated by the borehole.
- etc.

II.3.Historique



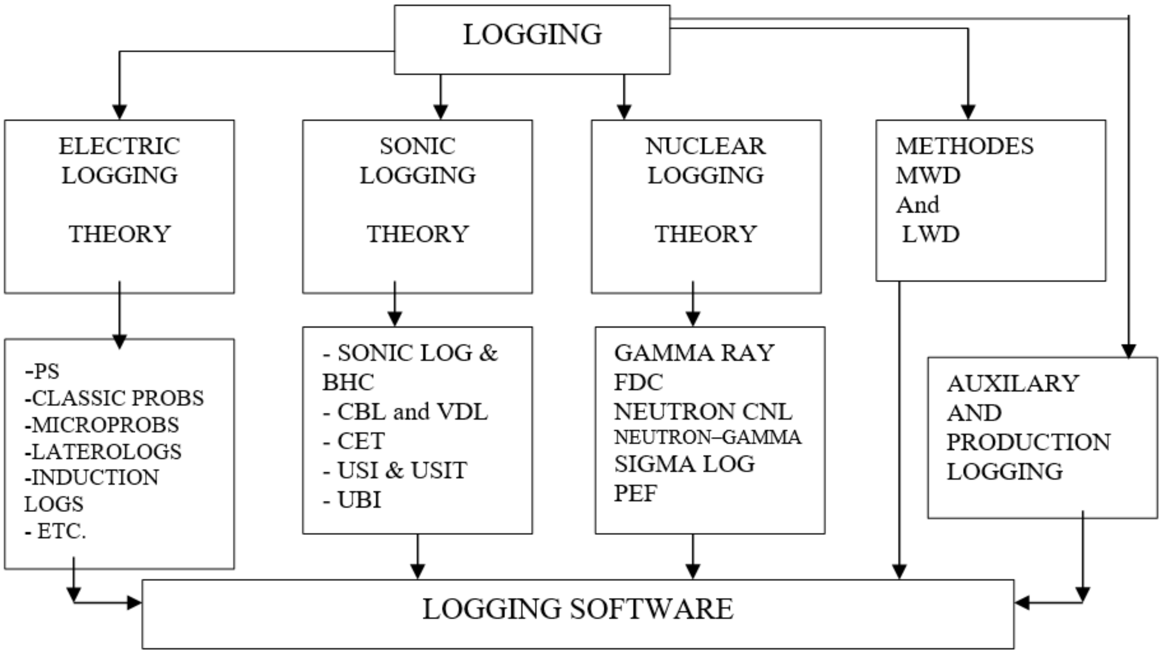
FigureII.1 : First electrical log in Pechelbronn.**[3]**

It was on September 5, 1927, in Pechelbronn, Alsace, that, for the first time in the world, geophysical measurements were conducted in a borehole to identify the formations penetrated and detect oil-bearing layers. This inaugural logging, the result of the work of two brothers, Conrad and Marcel Schlumberger, consisted of a series of point measurements, spaced one meter apart, of the resistivity of geological formations**(Figure II.1)**. Its authors gave it the evocative and highly prescient name of "electric coring," indicating thereby that this method somehow replaced the coring of formations, a costly operation with uncertain success, as core losses could occur due to the lack of consolidation or fracturing of the formations penetrated (a "core" being a cylinder of rock sampled from the strata).

Today, the measured parameters are numerous and cover almost all fields of physics. The user thus has a vast amount of information to analyze the formations penetrated by a borehole, almost continuously.**[3]**

II.4.Introduction to Well Logging

Well logging methods encompass all geophysical techniques for studying the physical parameters of geological formations penetrated by drilling. These methods can be classified as follows:**[3]**



Besides conventional electrical well logging, a large portion of well logging techniques can be applied in **Measurement While Drilling (MWD),** meaning as a real-time measurement method during drilling (known as instant well logging methods), with two significant advantages:

- time savings and minimal invasion diameter allowing, with the use of small-radius probes.
- to measure the true parameters of formations in the virgin zone.

Logging While Drilling (LWD) and Measurement While Drilling (MWD) then allow for initial analysis of the logs and extraction of various parameters such as:

- the position of permeable formations
- the nature of fluids saturating these formations
- the position of clay beds
- pressure
- temperature
- formability
- drilling speed
- inclination and azimuth of drilling
- etc.

Measurements While Drilling (MWD), now a standard practice, are performed by sensors inserted into the drill string, with their readings transmitted in real-time to the surface where they are continuously recorded and processed**(Figure II.2)**. Initially intended to geographically locate the bottom of the well as it progresses, MWD has gradually incorporated logging techniques typically conducted on completed wells (such as natural radioactivity measurements, electrical resistivity, acoustic formation response, and potentially in the future, nuclear magnetic resonance logging, etc.).**[3]**

FigureII.2 : Logging tools.**[3]**

MWD, now known as LWD (Logging While Drilling), allows for real-time characterization of the rock in terms of geological facies, porosity, fluid type, essentially determining the type of formation being drilled and thus providing geological orientation in addition to geographical. In the future, the emergence of seismic techniques while drilling, or SWD (Seismic While Drilling), which should enable better visualization of the formations ahead of the drilling tool, will further enhance our understanding of the subsurface**(Figure II.3)**.

FigureII.3: Inside the logging truck.**[3]**

II.5.MPLT (Memory Production Logging Tool):

II.5.1. History

Since introducing the first MPLT into the North Sea in 1985 Expro have successfully logged hundreds of wells worldwide to meet industry demands for increased quality and flexibility at a cost-effective price, Expro introduced the multi sensor MPLT. This purpose-built tool utilizes state of the art components to provide a rugged tool with high accuracy and expanded memory capacity. The tool is able to operate in deviated or horizontal wells and has the capability to log all types of multiphase flow and can be deployed via slickline, coiled tubing or e-line. All of the MS-MPLT sensors are compatible with the RAM PL tools.**[5]**

II.5.2. The Objective

The Objective of Production Logging is to provide information to the client to enable them to optimize recovery from their Assets

• Monitor Completion Performance.

• Establish Flow Profile, Zonal Contribution.

• Identify Cross Flow/Thief Zones.

• Identify Behind Pipe Flow.

• Fluid Typing/Source.

• Identify Well Problems, Gas/Water.

• Production.

• Identify Mechanical Problems.

• Provide Guidance for Remedial Work.

II.5.3. Description

The Memory Production Logging Tool is run on slickline or coiled tubing to acquire and store production logging data from up to fourteen downhole PL or other types of sensors. The tool is pro grammed and downloaded via an IBM compatible Notebook Computer. Once powered by a high-capacity Lithium battery within a separate battery holder (MBH), data is acquired and stored in accordance with a user defined ‘profile’. This controls the sensors logged and sampling rate. Sondex MEMLOG software is supplied with all memory tools, providing a graphical interface for programming and downloading the tool, together with capabilities for merging memory tool data with depth-time files from the Sondex Depth-Time Recorder. The tool is usually run mated to a QPS pressure gauge.**[4]**

II.5.4. Operating principle

Data from the logging sensors is transmitted via an 8 kHz Down Hole Tool Bus to the memory tool at the top of the string. Pulse and digital data is non-volatile flash memory chips under the control of a downhole processor. The tool can support all the standard Sondex memory telemetry tools and record readings from every sensor at up to 10 sets per second.

II.5.5. Features & Benefits

Features	**Benefits**
• Expanded memory capacity. • Single pin connections with telemetry. • Quartz pressure gauges. • Flexible. • On-site reporting.	• High resolution. • Portable for fast mobilisation, minimising rental period. • Accurate and reliable Can be run on slickline and coiled tubing. • Allows rapid decisions.

II.5.6. Optimization of MPLT

What makes a good MPLT?

- Planning (Objectives, Well Bore Environment).
- Survey Strategy (Well Conditions, Flow Rates).
- Tool String Configuration (Sensors).
- Logging Interval (Entire Section + Overlap).
- Stationary Measurements (Shut in + Flowing).
- Well Stability (Flowing Surveys).
- Well Stability (Shut in Survey).
- Cable Velocity (Speed Selection, Number of Passes).
- Accurate Surface Flow Rates.

What makes a bad MPLT?

- Well Not Shut in Long Enough to Equilibrate.
- Well Not Flowing in a Stable Condition.
- Incorrect Depth Correlation.
- Incorrect Survey Interval.
- Incorrect Sensor Selection.
- Inappropriate Spinner Selection.
- Decentralised Tool String.
- Inappropriate Speeds Used for the Passes.
- Inappropriate Survey Design.
- Tool Sensor Failures.

II.5.7. The equipment's of MPLT Operation

FigureII.4: MPLT tool string.**[7]**

The tool string has six parts**(FigureII.4)**:

1.Memory Battery Sub (MBS004).

2.CORRELATION TOOLS:

- Gamma Ray.
- Casing Collar Locator.

3.FLUID IDENTIFICATION TOOLS:

- Fluid Density.
- Fluid Capacitance – Water Hold-up.
- Gas Hold-up.

4.TEMPERATURE MEASUREMENT:

- Platinum Resistance Thermometer.

5.PRESSURE MEASUREMENT:

- Quartz Pressure Gauge.

6.FLOWMETERS:

- Caged Fullbore Flowmeter.
- Continuous Flowmeter.
- Inline Spinner Flowmeter.

II.5.7.1. Memory Battery Sub (MBS004)

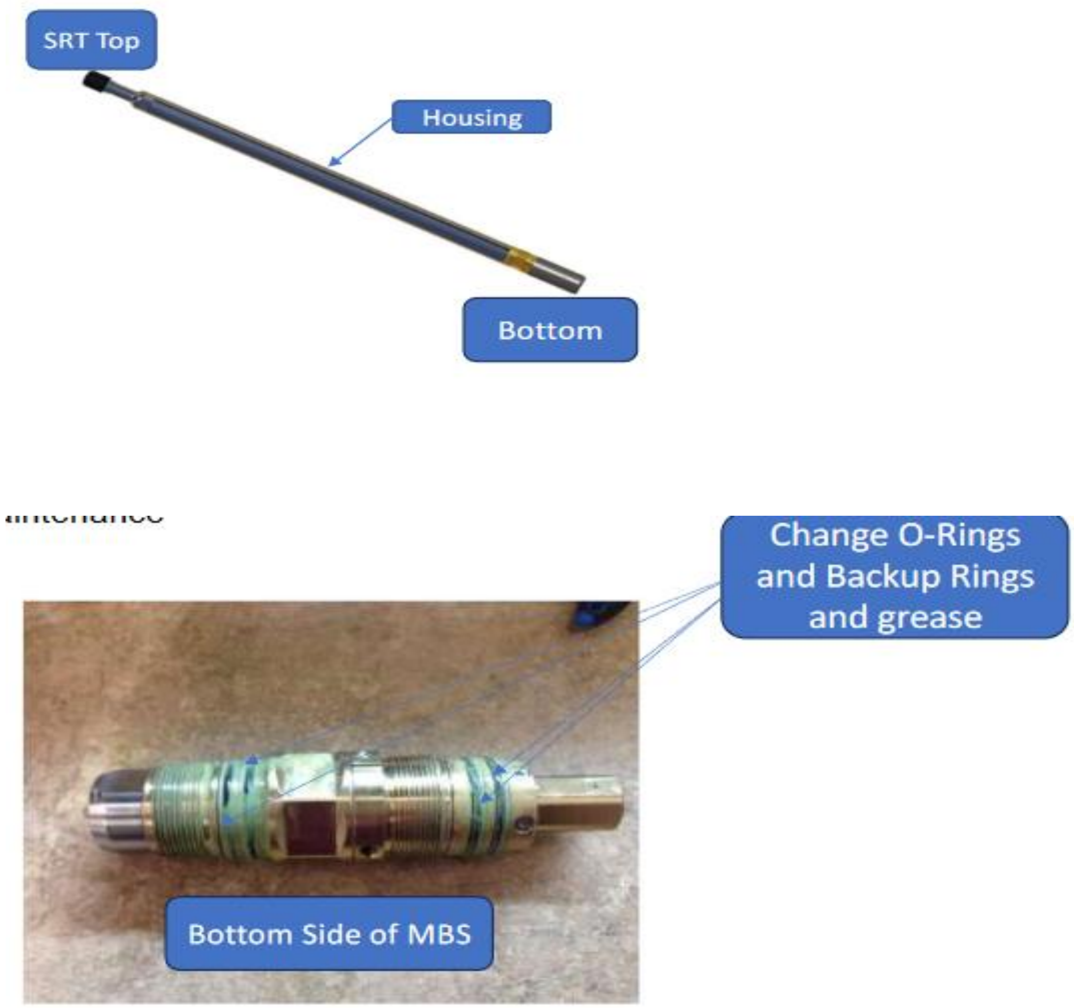
• The Memory Battery Sub**(Figure II.5)** (MBS004) is used inconjunction with the Memory Logging Tool(MLT002). The sub houses the 5 X CC cellbattery pack.

• Provides power to memory logging tool strings.

• The Top connection of MBS is 15/16” UN SuckerRod and bottom connection can connect only totop of MLT002.

• Battery used in MBS004 is 5-CC Cell 19.5V13AmH 165DegC.

• The MBS004 battery like all lithium batteriesmust be depassivated by the Probe BDU001depassification box.



FigureII.5: Memory Battery Sub.**[7]**

II.5.7.2. Correlation Tools

Two types of sensor used for correlation: **Gamma Ray and Casing Collar Locator.**

The Gamma is the primary means of depth correlation with the CCL run as a backup or on secondary runs. Both these sensors require a previous reference either from open or cased hole

- First open hole log is the **Base Log**
- First cased hole log (with CCL) is the **Reference Log**

It is common practice to put a Gamma pip tag at a known depth in the casing to assist in the depth correlation. To assist correlation with the CCL it is common to put pup joints in the casing liner or to use completion jewellery to assist with depth correlation.

II.5.7.2.1. Gamma Ray

The gamma ray scintillation detector**(FigureII.7)** is typically a sodium iodide crystal coupled with a photomultiplier tube to detect tiny flashes of light associated with penetrations of the crystal by gamma rays. These flashes are converted to electrical impulses, counted, and the count rate is presented on the log in API units. This detector is unshielded and records gamma radiation from all directions.

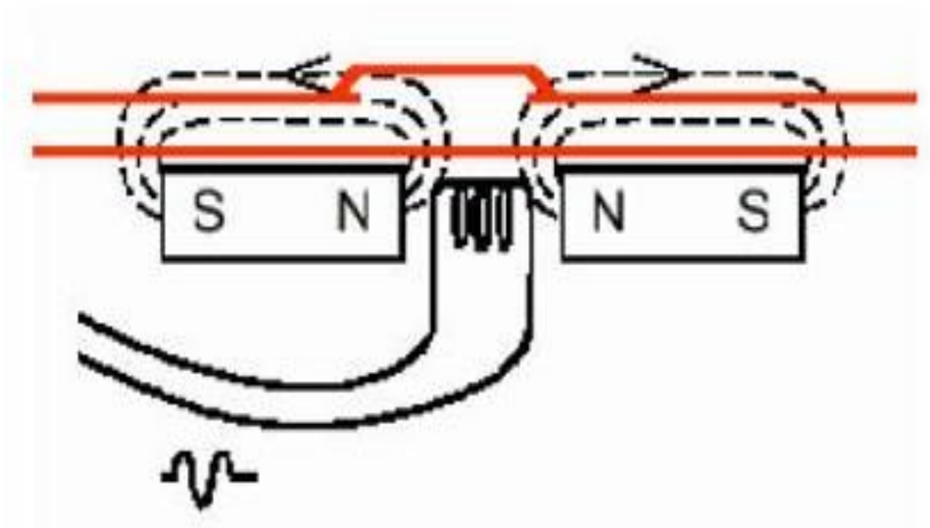
All rock emits some form of natural gamma radiation, differences in emission levels between rock types provide a trend signature. This trend signature or profile will remain unchanged over the life span of the well.

II.5.7.2.1.1. Applications

- Depth correlation.
- Measurement of fluid movement in conjunction with radioactive tracers.
- Identification of radioactive (LSA) Scale deposits (Qualitatively) .
- Bed definitions.
- shale content (open hole application).

II.5.7.2.2. Casing Collar Locator

The CCL is a coil situated between two magnets**(Figure II.6).** The magnetic flux of the magnets varies as the sensor passes through changes in metal volume.This change in flux induces a low frequency voltage in the coil that is amplified.The resulting frequency (hertz) is recorded and the output is plotted against depth and correlated to either the tubing or casing tally.



FigureII.6: CCLbetween two magnets.[5]

II.5.7.2.2.1Applications

- Depth correlation.
- Identification and location of downhole items, tailpipe, packers etc.
- Location of perforations.
- Determination of the operating position of downhole components, sleeves etc.

FigureII.7: Gamma CCL Tool (GCL).[7]

II.5.7.3. Fluid Identification

3 types of sensors used for fluid identification: **Fluid Density, Fluid Capacitance and Gas Hold-up.** Fluid identification devices are capable of making some measurement of the bulk flow. This measurement is useful in **determining** the fraction of volume or “hold-up” of fluid phases present in the flowing stream. In two phases flow a single FID, if correctly selected, is adequate to accurately determine the hold-up of each phase.

In three phase flow two FIDs are required to determine the hold-up of each phase.

II.5.7.3.1.Applications

- Identification and measurement of the composition of borehole fluids.
- Location of fluid levels, changes of fluid type.

II.5.7.3.2.Fluid Density – Radioactive

The FDR uses low energy gamma rays to determine the downhole fluid density during a production log. It provides a safe and reliable measurement that is unaffected by well deviation and flow rates.

Gamma rays are emitted from an Americium-241 source at one end of a measuring cell and are detected at the opposite end by a scintillation detector and photomultiplier. Well fluid flows through the cell and attenuates the received count rate in an inverse logarithmic function of the average fluid density. The detector is temperature stabilized and matched to the gamma energy of the source.

The tool can be calibrated in air and fresh water using Sondex supplied multipliers to derive calibration values applicable to oil and saltwater densities.

II.5.7.3.3.Fluid Density – Differential Pressure

The Differential Pressure Fluid Density Tool **(Figure II.8)** uses a differential pressure transducer to derive the density of wellbore fluids by measuring the hydrostatic pressure gradient of the fluids in the wellbore.

Wellbore hydrostatic pressure at points 2ft apart in the well is transmitted by silicone oil to a precision differential pressure transducer. The differential pressure at the transducer is the wellbore hydrostatic pressure between the ports less the hydrostatic pressure of the silicone oil.

After correction for well deviation, and changes in the properties of silicone oil with pressure and temperature, this differential pressure may be presented as a wellbore fluid density. Corrections for pressure and temperature are read from other transducers in the production logging toolstring, while correction for well deviation is made from the onboard accelerometer data.

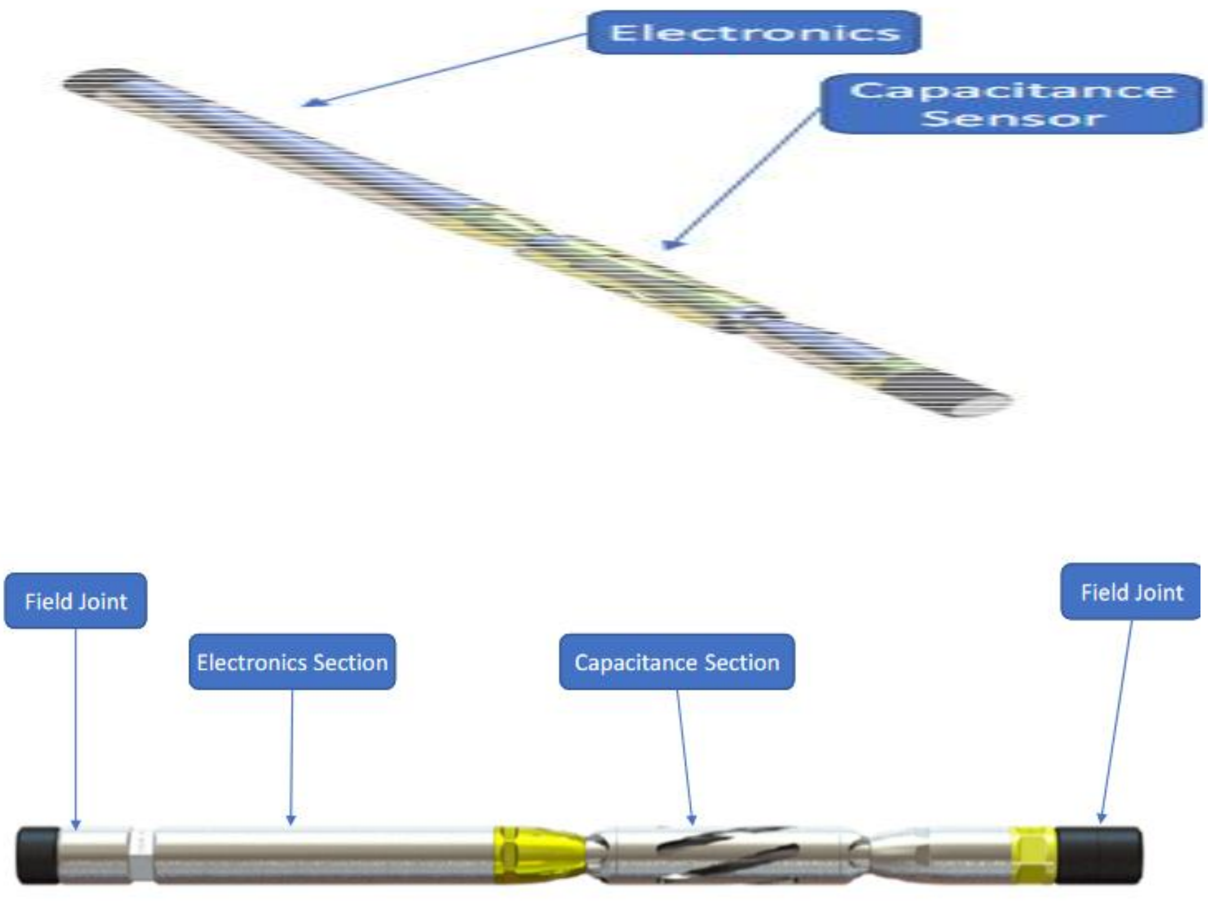
FigureII.8: Fluid Density – Differential Pressure. **[6]**

II.5.7.3.4. Fluid Capacitance Water Hold-up

The Enhanced Capacitance Water Hold-Up (CWH) Tool**(Figure II.9)** measures the dielectric constant of the surrounding borehole fluid to determine the water holdup with improved response characteristics.

Borehole fluid enters a hollow tube that surrounds an insulated rod at the center. The tube wall and the insulated rod form the electrodes of a capacitor. As hydrocarbons and water have different dielectric constants, the capacitance is a function of the dielectric constant of the fluid between the rod and wall of the tube. This capacitance is incorporated in the frequency determining circuitry of an oscillator. The frequency of the oscillator is therefore a function of the type of fluid that is present in the borehole.

The dielectric constant of water is 80, oil is around 10 and air has a value of 1. Salinity has minimal effect on tool measurement. The enhanced measurement has improved response characteristics particularly at water holdup values greater than 50%. The improved design also minimizes the "watering out" effect that can, under certain circumstances, result in the tool continuing to read water even though the surrounding fluid has been replaced by hydrocarbons.



FigureII.9: Fluid capacitance.**[7]**

II.5.7.3.5. Gas Hold-up Tool (GHT)

The Gas Hold-up Tool**(Figure II.10)** provides a reliable full-bore measurement of gas volume fraction, independent of flow regime or well deviation. The tool response is representative of the entire cross section of the well-bore within the casing and is almost completely independent of salinity, water hold-up, oil/water densities and material outside the casing.

The GHT emits low energy gamma rays from a small 3 millicurie Cobalt-57 source inside the tool, the gamma rays undergo a variety of interactions with well-bore fluids surrounding the tool; these include backscattering, photo-electron absorption and Compton Scattering. A sodium-iodide scintillation detector in the tool is positioned a short distance away from the source such that it will detect back scattered gamma rays. Less dense fluids, such as gas, produce less backscatter, hence detailed count rate is low in gas and high in liquids.

The short source-detector spacing reduces statistical errors associated with gamma ray detection as a result of Compton Scattering or photo-electron absorption. Calibration checks are carried out in air and water to ensure the tool is reading correctly before running in hole.

The tool is supplied with a shielded carrying case which alleviates the need for source insertion/removal.

FigureII.10: Gas Hold-up Tool (GHT). **[5]**

II.5.7.4. TEMPERATURE MEASUREMENT

Platinum Resistance Thermometer:

The PRTs used to give a high precision reading of wellbore temperature**(FigureII.11)**. Because of the small size of the tip it also has a very rapid response time.

The change of resistance of a length of platinum wire with changing well temperature is used to drive a voltage controller oscillator which is digitised and output as a frequency.

The high thermal conductivity copper tip is isolated with a low thermal conductivity body which allows for high resolution measurement even with high differential temperatures between the well fluid and the tool body.

Applications:

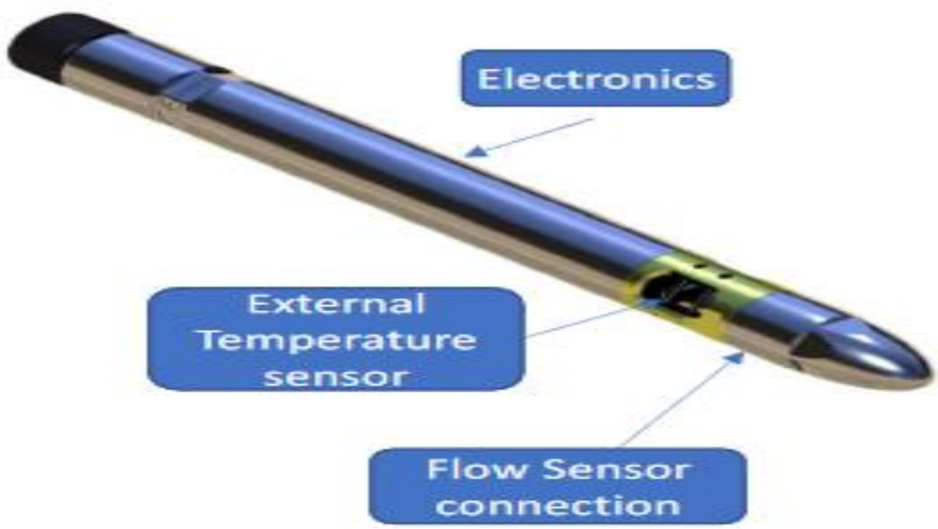
• Location of fluid entries into a reservoir (injection).

• Identification of fluid movement behind casing and tubing strings.

• Identification of cement tops behind casing.

• Location of fluid entry points in the wellbore.

• Identification of leaks.



FigureII.11: Platinum Resistance Thermometer.**[7]**

II.5.7.5: PRESSURE MEASUREMENT

Quartz Pressure Sensor:

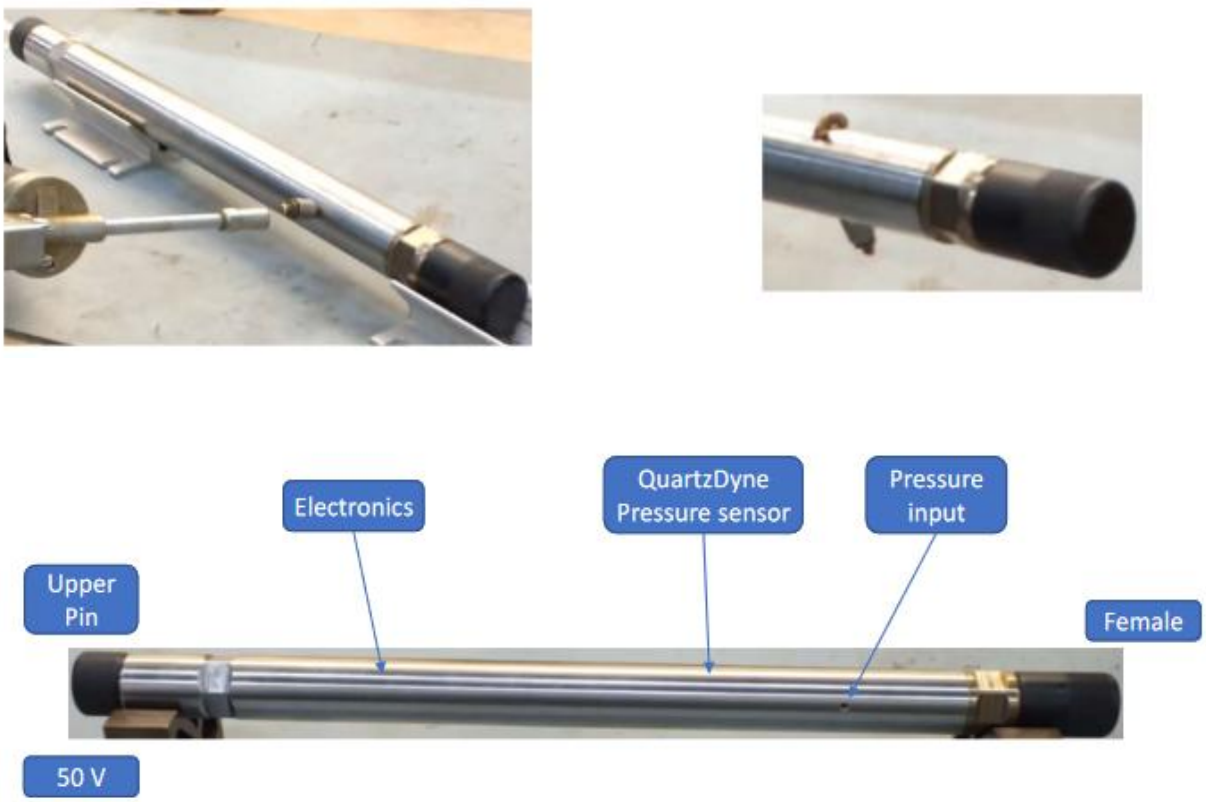
The QPG tool uses an industry standard precision quartz crystal pressure transducer. The tool measures pressure and gauge temperature **(FigureII.12)**.

Wellbore pressure is transmitted through an isolating metal bellows to a volume of silicone oil which surrounds the quartz pressure crystal. Changes in hydrostatic pressure alter the resonant frequency.

A second crystal, not subjected to external pressure, provides temperature compensation and allows calculation of precision, high resolution, pressures.

Applications:

- Draw-Down and Build-Up Pressure Transient Analysis.
- Down-Hole Pressure Gradient Measurement.



FigureII.12: Quartz dyne Pressure Sensor.**[7]**

II.5.7.6. Flowmeters

The main function of the flowmeter is to calculate bulk flow rate and determine the production profile over the perforated interval. Also used for identifying crossflow between zones (thief zones), injection monitoring and leak detection.

Nearly all flow measurements in producing wells are made with spinner type flowmeters. Spinner type flowmeters are preferred for vertical production wells where one, two, or three phases may be present, since spinners respond to the bulk flow rate regardless of phase makeup. They are also used in injection wells.

Additional sensors such as the fast response temperature and fluid identification tools can be used to assist in the qualitative interpretation of the flow rate data especially in multi-phase flow regimes.

II.5.7.6.1. Caged Full Bore

The CFB flowmeter is closed while running in hole, opening automatically when it leaves the tubing to enter the casing**(Figure II.13)**. Should a restriction be encountered during logging, the flowmeter will close and fold the spinner until the restriction is passed, thus avoiding damage to the blades.

The spinner runs on precision bearings. Rotation is sensed by zero drag Hall effect detectors allowing the measurement of very low flow rates.

Normal output is 10 pulses per revolution with directional indication.

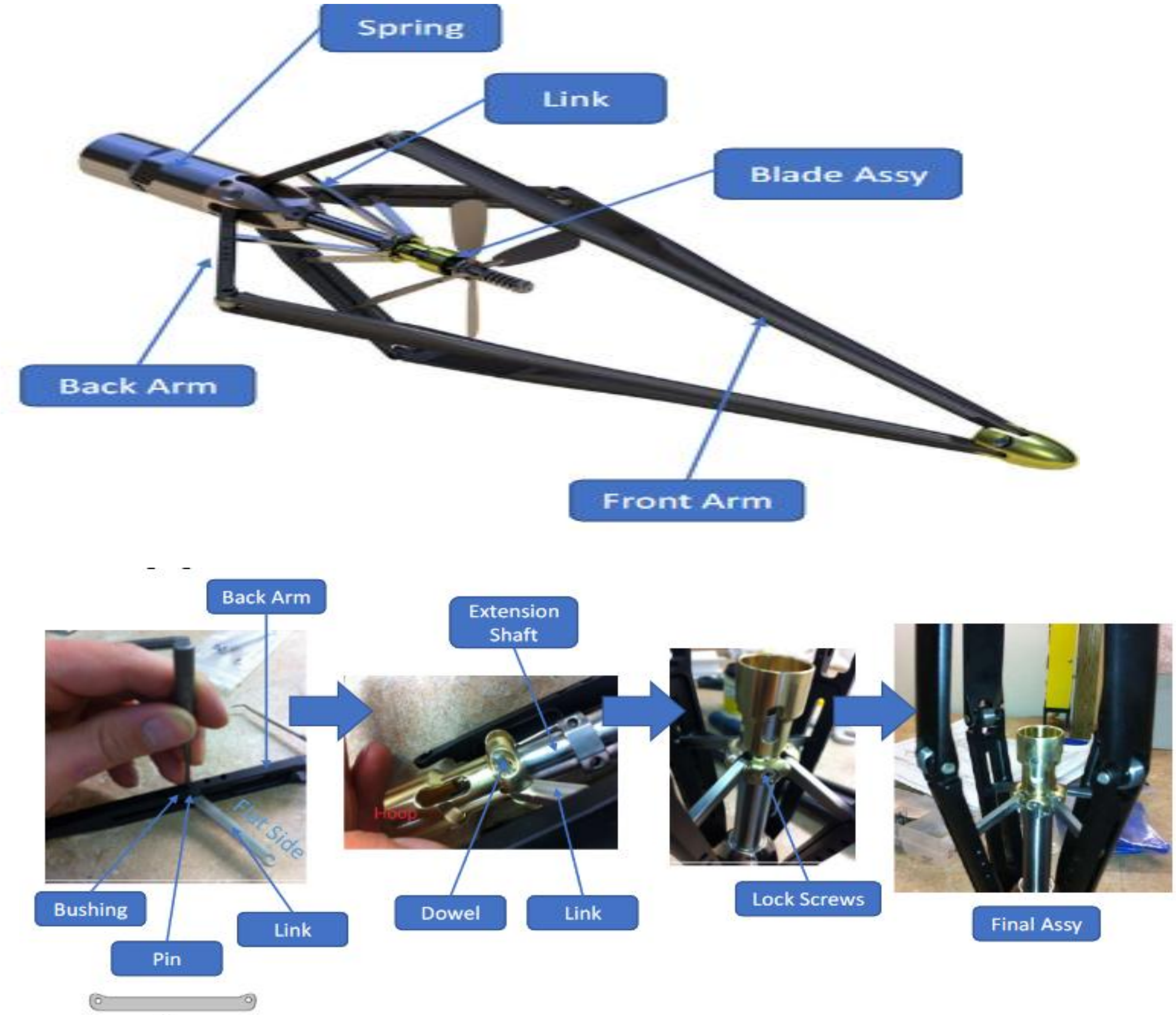
Applications:

• Measurement of flow/injection profile over perforated interval.

• Location of fluid entries into borehole.

• Identification of cross-flow, thief zones.

• Measuring Low Flow Rates.



FigureII.13: Caged Full Bore.**[7]**

II.5.7.6.2. Continuous Flowmeter Spinner

The CFS is a continuous recording spinner positioned at the bottom of the PLT string (**FigureII.14)**, it has a fixed OD & impeller diameter which is matched to the minimum I.D. of the completion. Available in a number of sizes to suit the particular application.

The impeller is very well protected and gives good results in very high fluid velocity wells.

The spinner runs on precision bearings. Rotation is sensed by zero drag Hall effect detectors allowing the measurement of very low flow rates.

Normal output is 10 pulses per revolution with directional indication.

Applications:

• Production Profiling in Tubing across Sliding Side Doors.

• Offers better protection in wells known to have debris.

• Logging inside sand screens / slotted liners.

• Injection Monitoring.

FigureII.14: Continuous Flowmeter Spinner.**[5]**

II.5.7.6.3. In-Line Spinner

The ILS flowmeter is a very short with an electrical through connection and can be placed anywhere in the MPLT string**(Figure II.15)**.

When run in combination with a full-bore flowmeter the ILS allows for production profiling in tubing and casing within one logging run but this tool is usually run as a backup flowmeter.

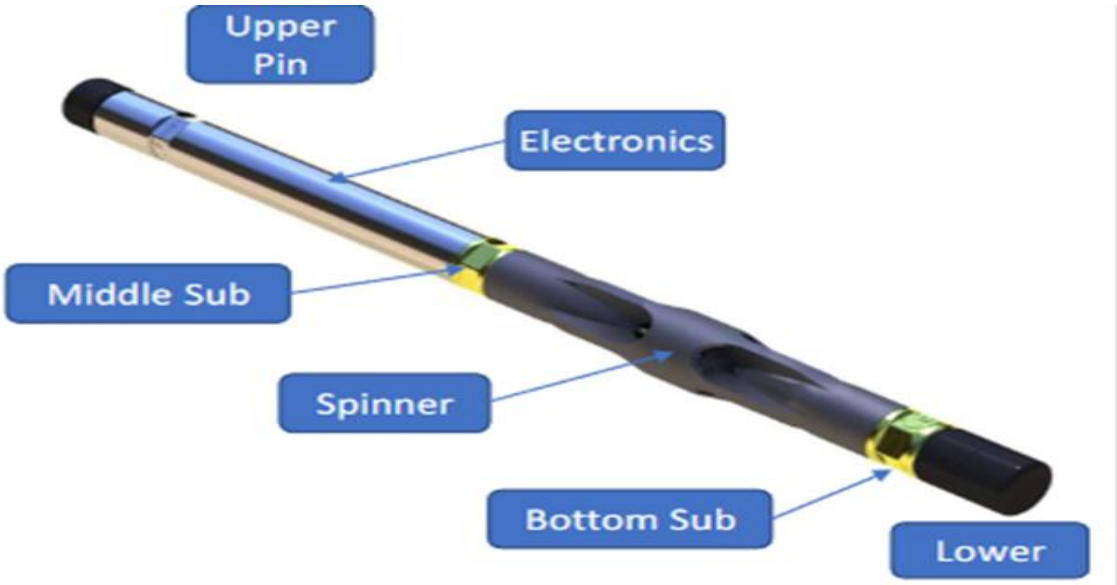
The impeller is very well protected and gives good results in very high fluid velocity wells.

The spinner runs on precision bearings. Rotation is sensed by zero drag Hall effect detectors allowing the measurement of very low flow rates.

Normal output is 10 pulses per revolution with directional indication.

Applications:

- Production Profiling in Tubing across Sliding Side Doors.
- Tubing Leak Detection
- Back up spinner in Horizontal wells.
- Logging inside sand screens / slotted liners



FigureII.15: In-Line flow meter Spinner.[7]

II.5.7.7. Production Dual Caliper (X-Y)

The caliper incorporates a pair of arm mechanisms set at 90 degrees to each other and measures the casing inside diameter in the X and Y axes **(Figure II.16)**. The assembly is fully collapsible down to tool diameter for running into and pulling out of hole.

The arms are spring loaded and follow the ID of the tubing and casing. Each arm operates as an independent unit exerting a constant radial force in any casing diameter.

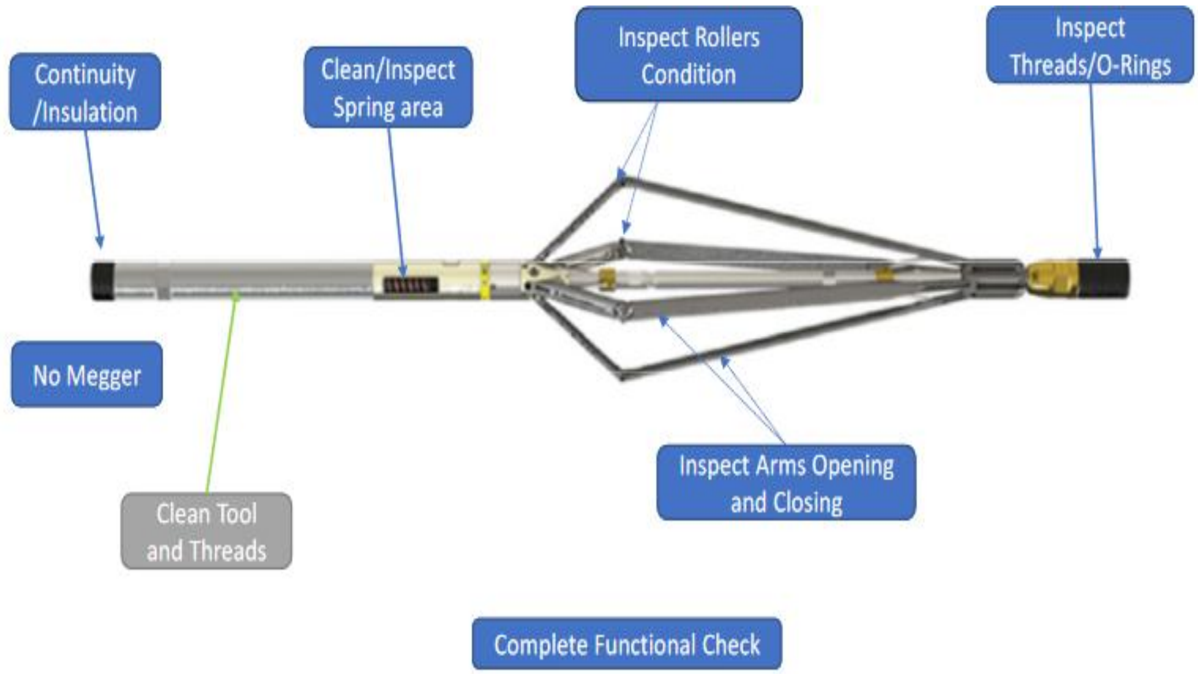
Linear variable differential transformer (LVDT) sensors protected within the main shaft accurately measure, by induction, the position of the coupled collars external to the shaft.

The caliper is calibrated using rings of known internal diameter.

Applications:

- Determination of X-Y diameters at 90 degrees.
- Measuring of casing deformation and major corrosion.
- Detection of scale build up in casing and tubing.
- Correction of spinner derived fluid velocity for varying casing or open hole completion diameter.
- Identifying ID to correlate with changes in hold-up patterns.

Identifying ID to correlate with changes in hold-up patterns.



FigureII.16: Production Dual Caliper. [7]

Conclusion:

The MPLT tools play a very important role in the petroleum industry, as they serve to solve several problems encountered during production. Among the most important MPLT tools, we find the Spinner, which plays a crucial role in calculating fluid velocity, and subsequently determining flow rate.

II.6. Technical Specification

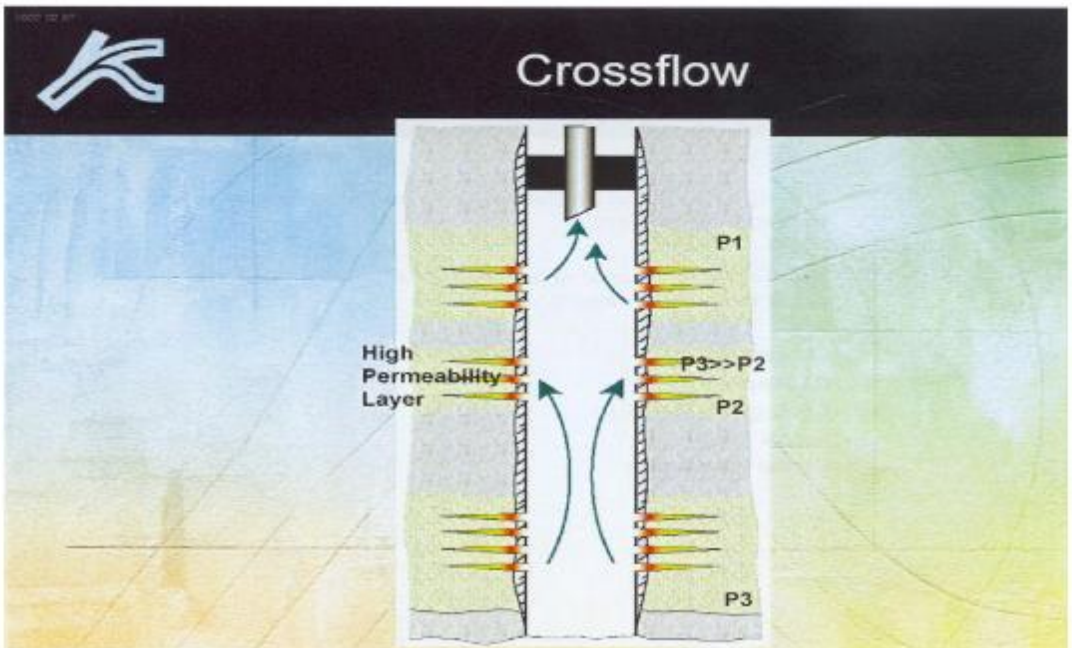
Memory	
Type	Non-volatile EEPROM.
Size	Expandable up to 16Mb.
Sample rate	Multiples of 0.1 sec.
Data set	Minimum of 30,000 on all channels.
Length / OD	2ft / 111/16" (0.61m / 43cm).
Full-bore Flowmeter	
Size	Various for use in up to 9 5/8" casing.
Measurement range	100 to over 30,000 bbl/day in 7" casing.
Length / OD	2.95ft / 111/16" (0.89m / 43cm).
In-line Flowmeter	
Size	2 5/8" and 111/16".
Measurement range	600 to over 60,000 bbl/day.
Length / OD	1.44ft / 111/16" (0.43m / 43cm).
CCL	
Type	Passive
Length / OD	1.53ft / 111/16" (0.46m / 43cm).
Gamma Ray	
Type	Scintillation.
Sensitivity	1 cps / API unit.
Length / OD	2.2ft / 111/16" (0.67m / 43cm).
Water Hold-up	
Type	Capacitance.
Measurement	range 0.01 to 1 (accuracy decrease at high values).

Length / OD	2.18ft / 111/16" (0.66m / 43cm).
Pressure	
Type	Shear quartz.
Accuracy	±3.2 psi (±0.22 bar).
Repeatability	±0.005% of full scale.
Length / OD	1.02ft / 111/16" (0.29m / 43cm).
High Resolution Temperature	
Type	Platinum resistance.
Accuracy	±0.5ºC.
Resolution	0.09ºC.
Length / OD	1.02ft / 111/16" (0.29m / 43cm).
All sensors are rated to 150ºC	
Radio Active Fluid Density	
Type	Radio active source.
Length / OD	2.18ft / 111/16" (0.66 / 43cm).
X-Y Caliper	
Type	4 arm.
Length / OD	3.25ft / 111/16" (1m / 43cm).

Chapter III: Overview of Cross Flow

Introduction

This chapter gathers general information about cross flow, including its definition, types, and the main causes of this issue. We also mention the advantages and disadvantages of this phenomenon. Additionally, we have examined the method of cross flow detection. The description of the cross-flow phenomenon is depicted in the figure**(FigureIII.1)**.



FigureIII.1: Description of the cross-flow phenomenon.**[8]**

1.Bibliographical synthesis on cross flow

Most studies on cross flow focus on interlayer cross flow during production or injection, with notable works conducted by Russell and Parts (1962) and Gao and Deans (1988). Cross flow between wells during shut-in has been clearly demonstrated by Yusupov et al. (1971), both experimentally and theoretically. Modine (1992) implemented a superposition method to model cross flow in a numerical simulator, finding this method to be reasonably accurate, simple, and economical. Fedorov (2001) considered the non-steady operation of a well in a two-layer reservoir with identical properties except for permeability, and studied the effect of shut-in on the well, including cross flow behaviour at the beginning of injection and also when the injection rate changed.

The effects of vertical heterogeneity on fluid flow have been extensively studied. Lefkovits et al. considered slightly compressible single-phase flow when a wall is constructed in multiple layers with impermeable shales separating them. Russell and Prats solved this flow problem for two radially delimited layers with unobstructed cross flow between them. This work extends some of their basic results to the multi-layer case. They also summarized the results of studies on cross flow in the 1960s. Streltsova-Adams reviewed the literature on groundwater hydrology regarding leaking aquifers and obtained solutions for various two-layer flow problems. Gao developed a semi-permeable wall model for studying cross flow in multi-layer reservoirs. With this model, Gao and Dean studied the behaviour of unstable flow and cross flow in two-layer reservoirs when a well produces from both layers at a constant total rate. Recently, Gao, Ehlig-Economides, and Joseph examined the effects of skin storage on the well for the same problem. Pendergrass and Berry studied the influence of stratification order in multi-layer reservoirs with interlayer cross flow and concluded that the influence is negligible in well tests. Gao developed a semi-permeable wall model to mathematically simplify the flow problem in layered systems with cross flow. The model assumes that all vertical flow resistance is concentrated in the walls between layers, so the pressure in a given layer depends only on the position and time of the area. Local flow through the barrier between layers (the semi-permeable wall) is proportional to the local pressure difference across the wall. The vertical flow resistance of the semi-permeable wall is described by its semi-permeability. The model is suitable for cases where the reservoir length/thickness ratio is significant (> 10) and/or the vertical resistance of low-permeability shales between layers is much greater than that of the layers. By using semi-permeable walls, the model ensures that the pressure of each layer is in balance in the vertical directions at all times and that the storage capacity of each layer is neglected concerning vertical flow. **[9]**

2.Definition

Cross flow, also known as transverse flow, in an oil well occurs when two production zones with different pressure characteristics are allowed to communicate during production. Fluid from the reservoir flows from the high-pressure zone to the low-pressure zone, resulting in an equalization of the latter.

Fluids flow in certain layers of the well to the reservoir and in others from the formation to the well. This is commonly observed in highly stratified reservoirs where communication between different layers primarily occurs through wells.

During fluid injection into a complex reservoir, a different pressure gradient is generated across the face of each permeable layer due to differences in layer properties such as permeability, thickness, and porosity, as well as differences in state resulting from factors such as depletion, injection, and thermal effects. The differential pressure gradients generate driving forces in the well during shut-in, causing the injected fluid to move from the high-pressure layer (typically lower permeability) to the low-pressure layers (typically higher permeability).

The behaviour of cross flow depends on the initial pressure in the permeable layers and can be referred to as natural cross flow (identical or naturally initial pressures) and forced cross flow (different initial pressures due to exploitation). Cross flow can induce sand production, liquefaction in high-pressure layers, formation damage, and permeability reduction in lower pressure layers**(Figure III.2)**, so understanding cross flow during well shut-in is important from a production and reservoir engineering perspective, especially in unconsolidated or poorly consolidated sandstone reservoirs.

In multiple reservoir fields - for example, the Gulf of Mexico, Gulf of Guinea, North Sea, etc. - having reservoir sands hydraulically separated by more or less continuous shale layers with thicknesses of 1 to 100 m, injection wells in such cases are generally drilled and completed in multiple reservoir layers. During injection, different pressure gradients in different layers are generated, and the controlling factors are the injection rate (Q) and the petrophysical properties of each layer - i.e., porosity (φ), permeability (k), total compressibility (CT), where the exponent (i) refers to the number of layers.**[9]**

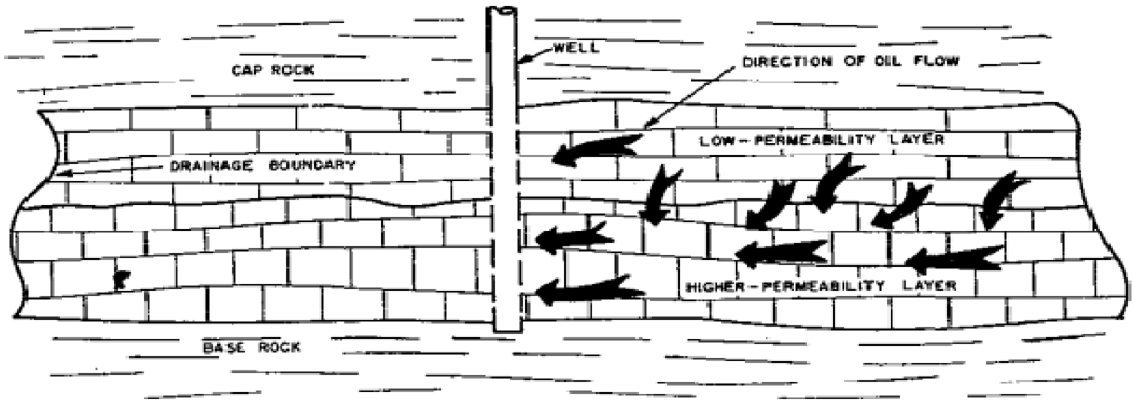


Figure III.2: Diagram of a multilayer system with cross.**[10]**

3.Classification of Cross Flow

3.1 For a Producing Well

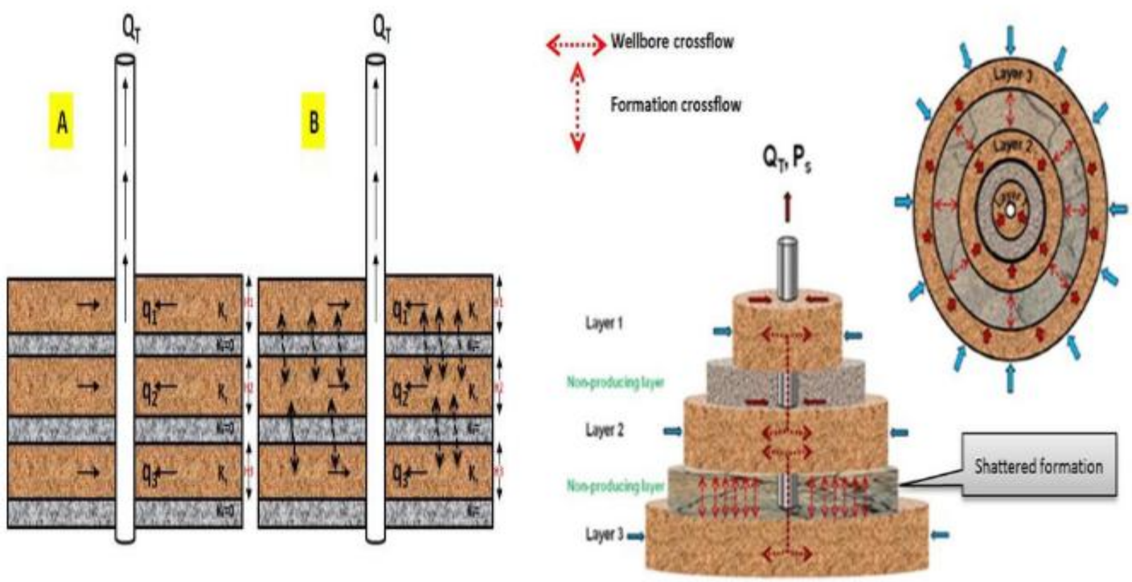
Formation cross flow is considered one of the most important parameters in the modeling and simulation of production from multilayer oil and gas reservoirs. Firstly, formation cross flow must be characterized and defined to determine if communication exists between the layers. If cross flow occurs between the layers in the z-direction, the pressure and production behavior must be predicted considering the effect of formation cross flow between the layers. This phenomenon is considered in this study as it is common in shale reservoirs, and the phenomenon (formation cross flow) is incorporated into the general mass balance diffusivity equation.

The term "wellbore cross flow" in a multilayer reservoir is applied when fluid flows from one layer to another through the wellbore. Additionally, formation cross flow comes into play when fluid is transported through media layers in the reservoir. This means that oil or gas transfers from one layer to another if the vertical permeability between these layers allows the fluid to flow through the layers.

There are mainly two types of cross flow responsible for production from the reservoir: wellbore cross flow and formation cross flow. The former occurs when horizontal flow passes from one layer to another through the open hole or the production line of the well, while the latter is where vertical flow occurs between the layers, as shown in **(FigureIII.3).[10]**

Wellbore cross flow can occur in the well at any time during the reservoir's life when pressure differences occur between the independently produced layers. On the contrary, formation cross flow occurs at any stage of the reservoir's life under the following circumstances:

- Vertical permeability between the layers must be present.
- Pressure difference between these layers must also be available.**[10]**



FigureIII.3: Diagram of formation and wellbore cross flow.**[10]**

3.2 For an Injector Well

The solution utilizes a finite implicit difference approach over multiple layers of sandstone with different permeabilities separated by impermeable rock layers. Normal and forced cross flows for each layer during shut-in are calculated and compared to various PLT flow rate measurements. Forced cross flow generally appears to be longer and has a higher flow rate than normal flow.

3.2.1 Natural cross flow

The driving mechanism of natural cross flow is the difference in diffusivity between the layers. Natural cross flow occurs when all layers are in equilibrium of hydrostatic pressure with each other under the condition of no flow. The pressure in each layer is:

$$p^{i+1} = p^i + \rho_w g(z^{i+1} - z^i).$$

ρ_w is the density of the injected water.

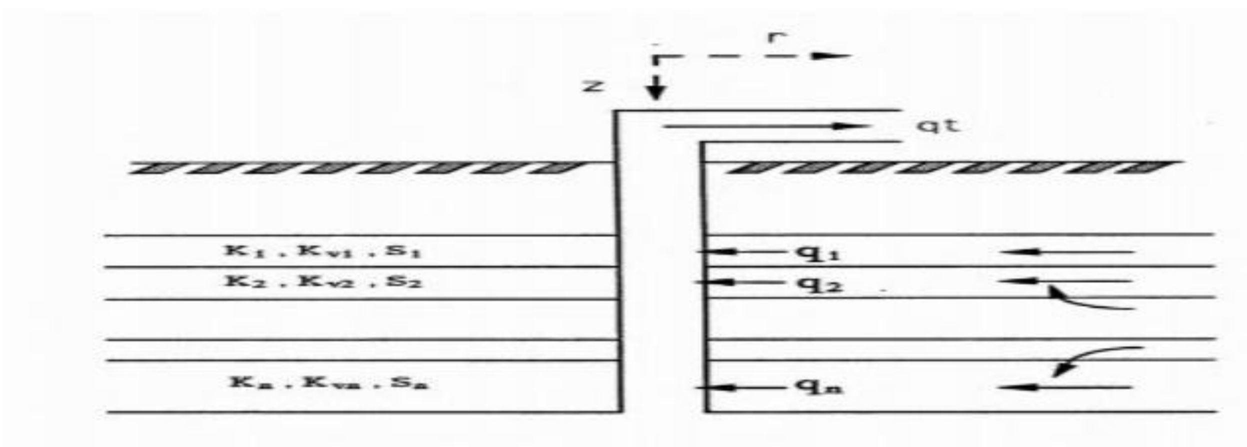
g is the gravitational acceleration.

z_i is the vertical depth of layer**i**.

The main driving mechanism for natural cross flow is the difference in diffusivity between layers:

$$(D=\frac{k}{\phi \mu_w c_t})$$

Where (**k**) is permeability,(phi) is porosity, (mu) is viscosity, and (c) is compressibility.Note that this case does not exclude cases of overpressure or under pressure because it is the differences in pressure and diffusivity between layers that are important, and they are not absolute values.**[10]**



FigureIII.4: Diagram of a multilayer system with cross flow formation.**[10]**

3.2.2. Forced cross flow

Forced cross flow occurs when, due to production activities, the injected layers are not in hydrostatic pressure equilibrium because of injection/production activity—meaning cases where there is differential depletion or pressurization of different layers. The pressure difference between the layers is the main driving force for forced cross flow.

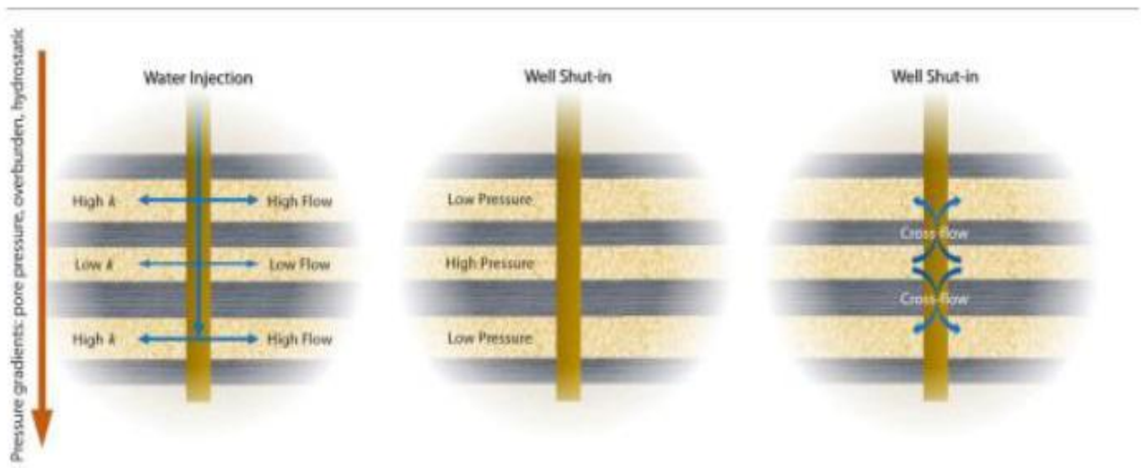


Figure III.5: Schematic representation of cross flow between wells in a multilayer reservoir.**[10]**

4. Causes of Cross Flow

Whenever there is a pressure difference between two layers, cross flow occurs if there is communication between the layers.

Generally, differences in radial permeability and skin factor are the most significant reasons for causing formation cross flow.

A more permeable layer produces rapidly, causing a greater pressure drop. Thus, at the same distance from the well, the formation pressure becomes higher in the less permeable layer than in the more permeable layer, and fluid from the reservoir starts flowing from the less permeable to the more permeable layer.

This cross-flow phenomenon has many characteristic effects both on well pressure response and on the production rate of each layer. In this chapter, many interesting features of a multilayer reservoir with formation cross flow are discussed.**[10]**

5. The problems caused by cross flow in the well are

Cross flow can cause sand production in the well, and this particulate material can also be transported into the low-pressure layer. This will alter the well injection response and may lead to perforation plugging (accumulation of sand in the well), or it can obstruct or damage the downhole equipment that controls zonal injection. Exceptionally, transverse flow can reach an initial rate of several thousand barrels per day, which can even affect reservoir behaviour beyond the immediate well region. These problems are most significant in low-porosity sandstone reservoirs; for example, there was a case reported in the Norwegian Sea field where cross flow and associated sand production during shutdown led to injectivity losses and complete well blockage due to sand layer liquefaction (Santarelli et al., 2000).

Wells with multiple producing layers or even highly variable permeability are the first warning signs of impending issues when a well is shut in. During production, the bottom hole pressure will typically be low enough to sustain flow from all zones, but when flow is stopped, high-pressure to low-pressure cross flow may begin. The mixture of gases, oils, and waters from different zones can create numerous problems, some of which are extremely difficult to eliminate.

Multiple input sources with different pressures will result in cross flow during pressure build-up during a shutdown. High-pressure zones with low permeability will flow into low-pressure zones with high permeability. At a minimum, this cross flow will create relative permeability effects. Relative permeability effects may be minor in the high-permeability zone and much more severe in a low-permeability zone where capillary blocking effects dominate flow.

Water injection wells often develop tubing leaks resulting in cross flow between two formations. Cross flow can be upward or downward depending on the respective location of each formation and the gravitational hydrostatic column between formations.**[10]**

6. Cross flow detection

There appear to be four general methods for determining the degree of communication between contiguous layers:

- petrophysical analyses.
- flow tests on cores.
- formation tests.
- analyses of production and pressure performance.

Only the first two, and perhaps the third, can be used to determine the degree of communication before the well is completed; production and pressure performance analyses.

Conclusion:

After conducting thorough research on the cross-flow phenomenon, we found that there were two different aspects, one positive and the other negative.

The positive aspect lies in the importance of this phenomenon and the extent of its impact on the economy, productivity, and profitability. From there, we can mention the most important positive points of cross flow:

Firstly, a much shorter period of time is needed to reach a given economic rate. Secondly, oil recovery is significantly higher due to the fact that tight layers are effectively depleted. Thirdly, periodic test interpretation is easier.

While the negative aspect is the damage caused by sand production due to cross flow, which in turn leads to a decrease in permeability and therefore productivity over time, as well as equipment damage.

Case Study

IV.1.Introduction

The Rhourd_nouss oil field encounters several issues and changes such as reduced oil productivity and the phenomenon of cross-flow, which varies from one well to another. Moreover, a single well may exhibit multiple factors of different origins. Our study on the wells... (**RN111, RNSE68, RNA8**) based on the study and interpretation of the MPLT (Multi-Phase Liquid Tracer), aims to locate the source of water influxes and determine if its wells are candidates for cross-flow.

This study elaborates on all the decisions made by the company to remedy solutions aimed at improving recovery.

Our evaluation is based on two important criteria:

1. Well gauging data from different dates.

2. Results of interpretation conducted by the EMERAUD software (Schlumberger), utilizing MPLT data.

Les résultats de l'interprétation faite par le logiciel EMERAUD (Schlumberger) utilisant les données du MPLT.

This work presents the results of a practical internship as part of the final year project at Sonatrach Production and Engineering Division, Rhourd_nouss.

IV.2.Data used

- Well data: Wellhead, Downhole equipment, Casing, Perforations.
- Gauge data: Pt, Pp, Tt, Nozzle diameter, Qo, Qw, Qg, WC,[**RN111** (du 29/06/2000 au 15/09/2023), RNSE**68** (09/03/2011 au 07/12/2023), **RNA8** (du29/06/2000 au 15/09/2023)**].**
- Data provided by MPLT recordings: Qt, Taux, Qo, Qw, Qg, Density, PFD, TFD, [**RN111** (du 29/06/2000 au 15/09/2023),**RNSE68** (09/03/2011 au 07/12/2023), **RNA8** (du29/06/2000 au 15/09/2023)**].**
- Geological data: Reservoirs: TAGI, SIL(B1-A1), Screen interval, Screen midpoint, depths.
- PVT data: Viscosity μ, compressibility ct, Bo, etc.

Note: These data are retrieved from Sonatrach's company database.

IV.3. Description and Usage of Emeraude Software

Emeraude is a computer tool (software) provided and developed by the oil company Schlumberger. This software provides logs that enable well monitoring or the development of a program for them.**[11]**

For the implementation of the Emeraude log, the software operates according to the following steps:

IV.3.1 . DocumentInitialization :General data

Open-hole logs and deviated investigation data are loaded. This data is used for depth matching of MPLT and also to correct the response of certain tools, as well as input for multiphase flow correlations. **[11]**

If saturation and porosity logs are also loaded, Emeraude will automatically create a track displaying the formation fluid volumes. **[11]**

IV.3.2 . Investigation: Load the PL data

The passes and stationary data are loaded from LIS, LAS, and ASCII files.

Automatic tracks are designed to provide an instant view of the log, while custom views can be created using snapshots and templates, allowing for quick navigation through the data**. [11]**

IV.3.3 . InterpretationMPLT: Define the reference channels

The reference channels will be used to complete the PVT properties and also for regression during the calculation of the participation rates of the zones. **[11]**

Pressure, temperature, and any apparent hold-up or density channels must be defined. If more than one access is selected, a lateral average will be applied. **[11]**

IV.3.4Output:log andreports:

The result of the interpretation is presented in cumulative and contribution profiles with phase percentages. This can be in downhole conditions or standard conditions. A construction report can be printed and previewed, which includes predefined sections. It is possible to produce a report in MS-Word using the OLE interface of Emeraude. **[11]**

IV.4. Discussion of the Interpretation

IV.4.1.Well RN111

IV.4.1.1. Well, RN111 history:

The well RN111 is a gas-producing well, drilled in 2008 (11/08/2008 to 31/12/2008) by the TP198 drilling rig. This well is located in the Rhourde Nouss area. Coordinates of Well:

X(UTM): 283 274,49m   Y(UTM): 3 288 412,85m

Z sol : 261m   Z table : 271,51m

With a bottom depth of 3947m, it began production in 2009. This well is completed with a simple 3-1/2-inch carbon steel completion as of 11/01/2017 with tubing (3.5 in, 9.2lbm/ft).

It is a candidate for a workover aimed at cementing the 4.5 liner and perforating in the TAGI in 2017 (from 21/11/2016 to 12/01/2017)**(Figure IV.1)**.

Figure IV.1: Map showing the position of well RN111.

IV.4.1.2. MPLT Interpretation (Performed at 31/Aug/2022)

This operation aims to evaluate the zonal contributions of the perforations in the TAGI, B1, A2, and A1 reservoirs and to assess if there is any cross-flow between these reservoirs.

The operation was only conducted in shut-in mode; the flowing mode was cancelled due to the well's negative startup, where Pt=0.

Tableau IV.1: Gauge data for well RN111.

Well	date	head pressurePsi	Head temperature C°	Qgaz m3/j	Qcond m3/j	Qwater L/h
RN-111	23/07/2009	967	75	33779	13.9	10000
	24/07/2009	959	65	17301	11.2	8000
	25/07/2009	895	76	37996	16.8	12800
	05/09/2009	1032	58	16958	4.7	6000
	06/09/2009	1050	64	23942	9.4	8600
	07/09/2009	1008	73	32377	11.6	11200
	08/09/2009	942	84	39858	14.0	11900
	10/08/2010	1019	61	19532	4.7	7400
	11/08/2010	996	71	26720	9.3	9000
	12/08/2010	970	77	32983	9.3	10500
	13/08/2010	905	78	40521	14.0	10600
		ISOLATE Lower QHA Reservoir and perforate Upper Silurian				
	24/12/2016	1322	34	104204	24.2	TRACES
	25/12/2016	1123	36	116329	21.8	TRACES
	26/12/2016	963	37	123639	19.3	TRACES
	15/02/2017	921		120057	19.3	
	16/02/2017	1100		104931	19.3	
	23/02/2017	1336		94793	19.3	
	24/02/2017	1130		110837	24.2	
	25/02/2017	954		122860	24.1	15
	10/08/2022	382	52	21618	0.7	0

Tableau IV.2: Parameters recorded at the station at 2601 meters of well RN111.

Recorded parameters	Pressure	Temperature	Density	Flow Meter
	kgf/cm²	°C	g/cm3	Rps
At the beginning of the operation	2060	101.7	0.11	0

Tableau IV.3: Perforations of well RN111.

Top-Bottom	Canon	Type	Reservoir	Densite	Phasing	Obs
2603 à 2607,5	Canon 2" HSD	PJN 2006 HMX	TAGI	6	60	PERFORATE
2609 à 2610,5	Canon 2" HSD	PJN 2006 HMX	TAGI	6	60	PERFORATE
2616 à 2618	Canon 2" HSD	PJN 2006 HMX	TAGI	6	60	PERFORATE
2628 à 2632	Canon 2" HSD	PJN 2006 HMX	TAGI	6	60	PERFORATE
2712 à 2714	Canon 2" HSD	PJN 2006 HMX	SIL-B1	6	60	PERFORATE
2732 à 2733	Canon 2" HSD	PJN 2006 HMX	SIL-B1	6	60	PERFORATE
2771 à 2776	Canon 4"1/2	SDP3	SIL-A2	6	60	PERFORATE
2772 à 2776	Canon 2" HSD	PJN 2006 HMX	SIL-A2	6	60	REPERFORAT
2776 à 2782	Canon 4"1/2	SDP3	SIL-A2	6	60	PERFORATE

Tableau IV.4: PLT Shut-in RN111 Result.

	Station	Spin	Pressure	Temp	Den
S1	2601	0	2060	101.7	0.11
S2	2614	0	2064	101.8	0.11
S3	2700	-2.4	2165	105.7	0.95
S4	2750	-2.4	2235	107	0.95
S5	2800	0	2304	108	0.95

VI.4.1.2.1.The Tool Reading

- The MPLT recording from 31/08/2022 showed some fluctuations in the measured parameters. The Spinner provided different readings (see Annex). The first recording at 2601m showed zero spinner rotation because the well was in shut-in mode and there were no fluid flows. However, at the third station at 2700m, a spinner speed of -2.4 Rps was observed until 2770m. Additionally, the Spinner showed zero speed at the end of the operation.
- The temperature profile (see Annex) indicates that the temperature increased until the end of the operation (reaching 108°C).
- The measured density at the bottom of the well showed high values. The density profile (Annex) demonstrates that the density increased up to (d=0.95).
- The wellhead pressure did not fluctuate during the MPLT recording. Similarly, the bottom hole pressure increased up to (2304 psi) at 2800m.

VI.4.1.2.2. Interpretation and Reading of the MPLT

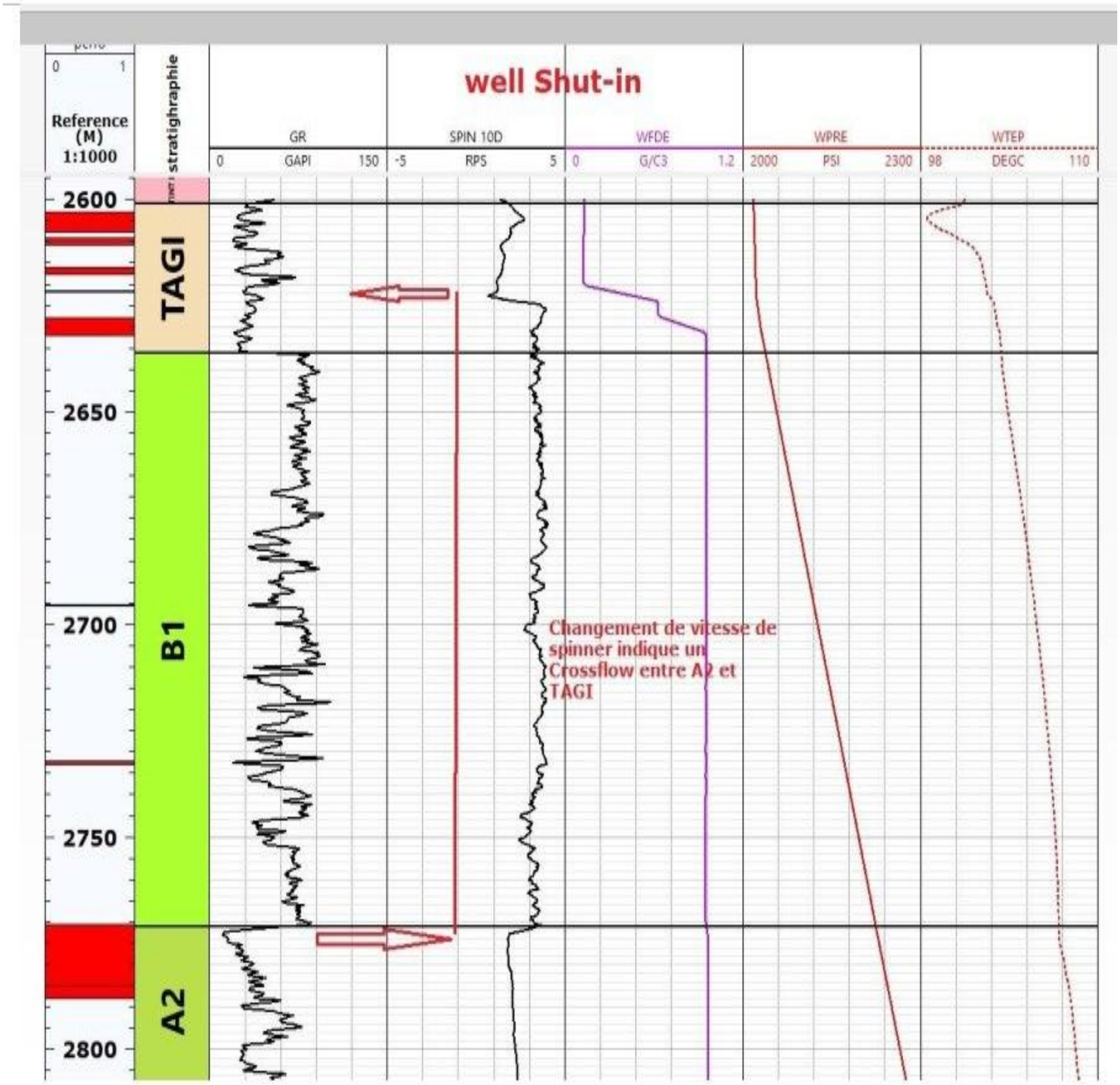


Figure IV.2: Interpretation MPLT -Shut-in RN111.

Job Objective:

Perform MPLT-DEFT Log to Evaluate Zonal contributions of Perfs in the TAGI, B1 and A2 Reservoirsand to assess if there is any cross-flow between these reservoirs.

REMARKS:

- Tool was run as per tool sketch All logging intervals as per client request.
- Shut in passes performed from 2601m to 2810m at 10,20,30 & 40 m/mn Shut in Stations performed at 2601m, 2614m, 2700m, 2750m & 2800m SIWHP 1500 Psi.
- Maximum Recorded temperature 108 degC from PBMS-A RTD Sensor.
- Maximum Recorded pressure 2808 Psi Flowing passes cancelled due to well not starting up.

The shut-in interpretation shows that:

- There is cross-flow between reservoir A2 and TAGI.
- The stations between the two reservoirs indicate that there is flow from A2 to TAGI.

IV.4.2.Well RNA8

The well RNA8 is a gas-producing well, drilled in 1997 (25/09/1997 to 23/11/1997) by the TP181 drilling rig. This well is located in the Rhourde_Nouss area. Coordinates of Well:

X(UTM): 282100.5 m   Y(UTM): 3284350m

Z sol : 284.17m   Z table : 276.55m

With a bottom depth of 2535m, it began production in 2000. This well is completed with a simple completion as of 06/12/1997 with tubing (4.5 in, 13.5lbm/ft)**(Figure IV.3)**.

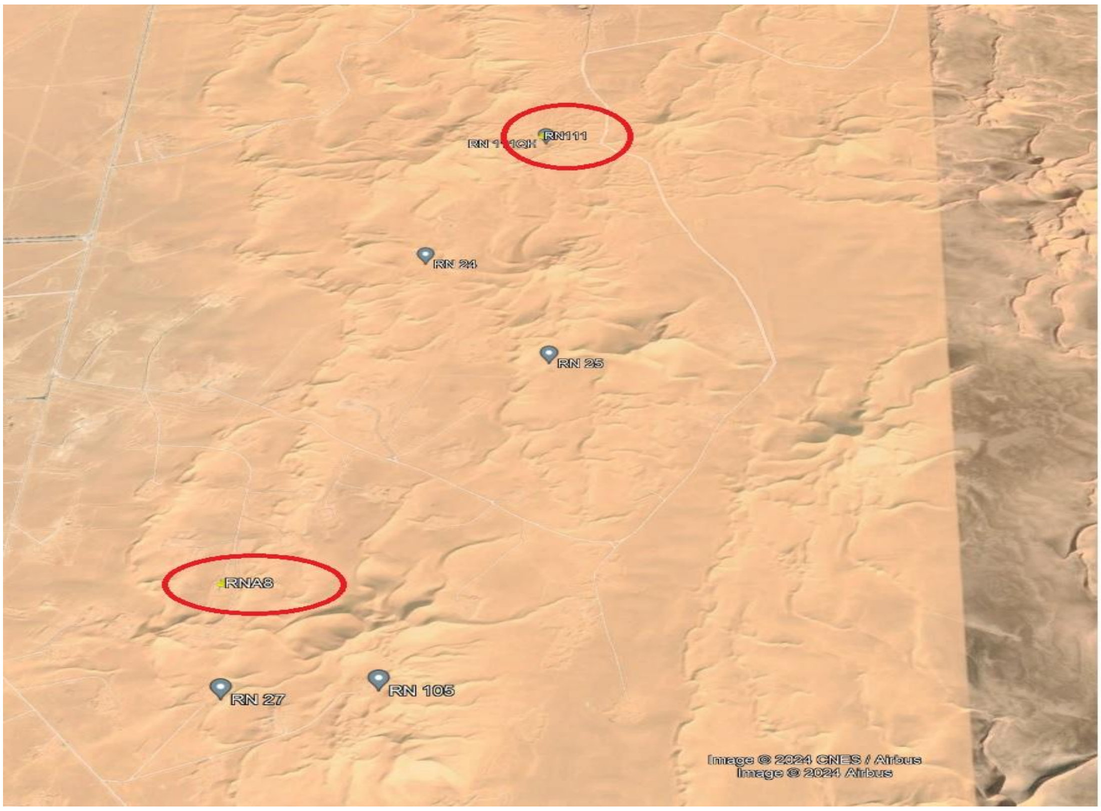


Figure IV.3: Map showing the position of well RNA8.

IV.4.2.2. MPLT Interpretation (Performed at 09/Oct/2023)

This operation has two objectives:

1. Establish production profile for RNA-8 by running PLT-STD.
2. To assess whether there is any water production or not

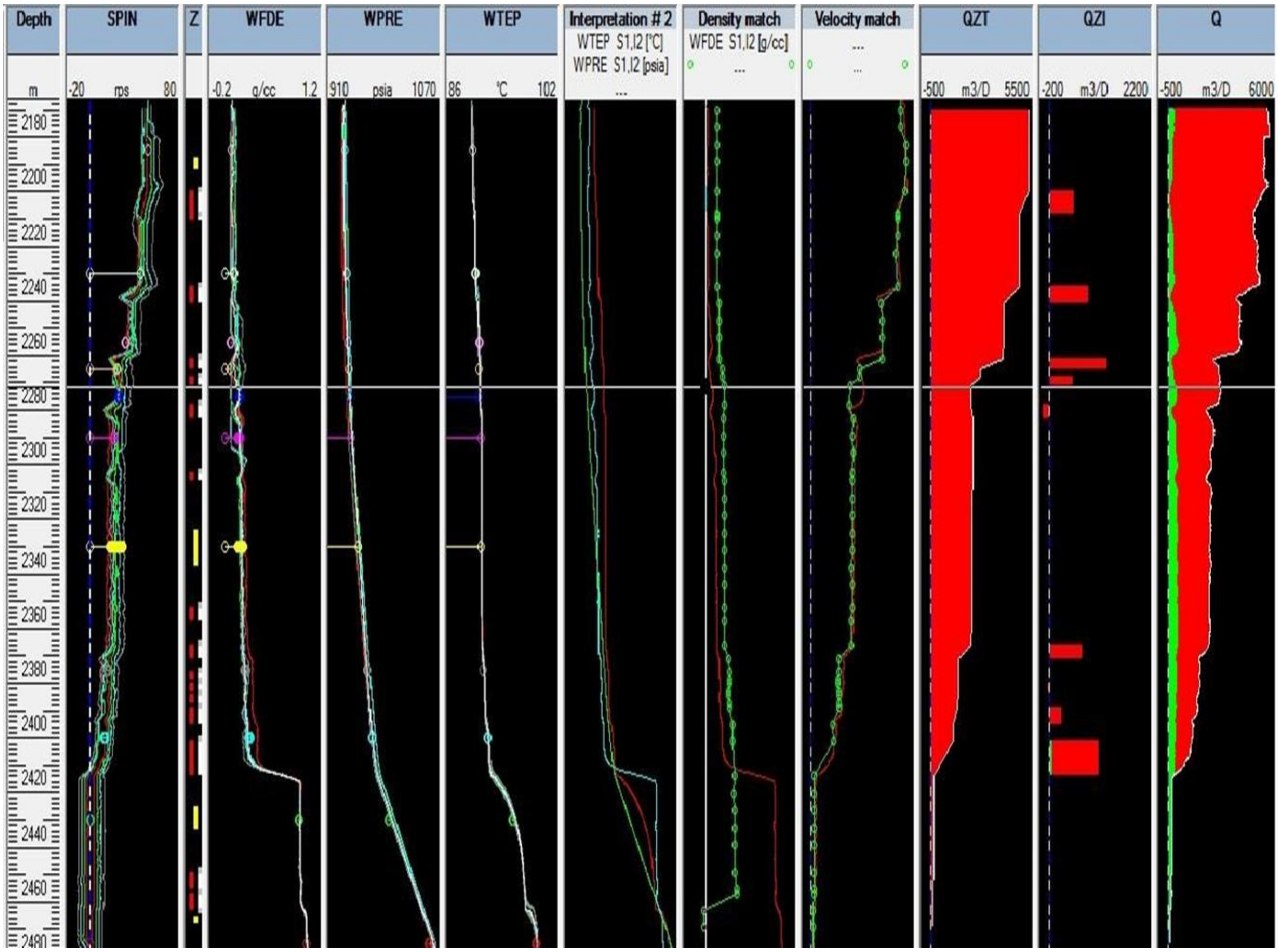


Figure IV.4: The evolution of bottom well parameters (Density, Temperature, GR) from 09/10/2023 Well RNA8.

Tableau IV.5: Gauge data for well RNA8:

Puits	date	Pression tete Psi	Temp tete C°	Qgaz m3/j	Qcond m3/j	Qwatre L/h
	29/06/2000	2554	74	663012	118.8	50
	01/07/2000	2430	74	819040	140.8	65
	22/12/2001	2335	74	519983	77.7	60
	06/07/2003	2125	74	479702	53.4	45
	26/09/2005	1792		514846	42.7	50
RNA8	11/02/2007	1580	72	600111	57.2	50
	21/01/2008	1662	64	283987	37.4	160
	31/01/2009	1816	69	309500	40.5	40
	20/04/2009	1654	71	511669	51.7	60
	12/01/2010	1695	63	209489	38.5	70
	19/01/2011	1668	69	402491	37.2	60

	29/11/2012	1590	68	300403	28.8	32
	16/02/2013	1606	63	239292	22.8	30
	09/06/2014	1570	58	131961	10.0	17
	09/06/2014	1570	59	138075	11.5	17
	08/10/2015	1570		117873	23.9	67
	11/11/2017	903	62	480947	22.9	66
	11/11/2017	970	60	407353	17.2	73
	11/11/2017	831	63	490689	20.1	110
	21/11/2018	764	64	422893	7.2	30
	01/06/2019	752	65	375315	10.3	20
	18/09/2019	768	56	233342	8.7	38
	08/09/2020	772	48	359466	10.8	50
	12/04/2021	752	69	214676	6.6	20
	29/10/2021	930	58	559862	23.2	0
	29/10/2021	847	59	613138	25.2	0
	01/12/2021	902	52	549405	18.5	30
	03/12/2022	787	54	334881	6.6	35
	15/09/2023	730	70	267284	5.0	33

Tableau IV.6 : Parameters recorded in the downhole gauge of well RNA8.

Recorded parameters	Pressure	Température	Density
	psi	°C	g/cm3
At the beginning of the operation (S01)	1060	98.8	1.02
At the end of the operation (S11)	930	90	0.11

Tableau IV.7 : Perforations of well RNA8.

Perforations : Date	Top a Bottom	Canon	Type	Reservoir	Densite	Phasing
21-09-2021	2200 à 2208	2"7/8	PERFORATE	TINT-I	6	60
21-09-2021	2209 à 2210	2"7/8	PERFORATE	TINT-I	6	60
21-09-2021	2235 à 2241	2"7/8	PERFORATE	TINT-I	6	60
21-09-2021	2261 à 2265	2"7/8	PERFORATE	TAGI	6	60
21-09-2021	2268 à 2271	2"7/8	PERFORATE	TAGI	6	60
21-09-2021	2278 à 2283	2"7/8	PERFORATE	TAGI	6	60
21-09-2021	2303 à 2306	2"7/8	PERFORATE	SIL-B1	6	60
26-12-1999	2352 à 2357	TAG SDT	PERFORATE	SIL-A2	6	60
26-12-1999	2366 à 2371	TAG SDT	PERFORATE	SIL-A2	6	60

Tableau IV.8 : Zone Contributions, Réservoir Condition by Pass.

Zone	Production %	Qt res condition m3/d
2200-2208	9,88	537,63
2209-2210	-0,12	-6,79
2235-2241	15,45	840,62
2261-2265	23,04	1253,4
2268-2271	9,44	513,69
2278-2283	-2,65	-144,25
2303-2306	0,36	19,83
2352-2357	0,44	24
2366-2371	13,06	710,65
2376-2383	0	0
2380-2383	-0,39	-21,44
2384-2387	0,48	26,31
2389-2395	4,73	257,43
2401-2414	19,45	1058,41
2449-2455	0,26	13,89
2457-2463	12,14	12,14
Total	100	5300,9

Tableau IV.9 : Zone Contributions, Réservoir Condition by Pass.

Zone	STATION	Spin rotation rps	Contribution %
2200-2208 2209-2210	2185	51,8	11,97
2235-2241	2230	45,6	25,48
2261-2265	2255	32,4	15,06
2268-2271	2265	24,6	-3,09
2278-2283	2275	26,2	7,53
2303-2306	2290	22,3	4,25
2352-2357 2366-2371	2330	20,1	7,72
2376-2383 2380-2383 2384-2387 2389-2395	2375	16,1	5,79
2401-2414	2400	13,1	22,39
2449-2455 2457-2463		1,5	2,9
	2475	0	0

Tableau IV.10: Contribution by reservoir.

Réservoir	Contribution %
T INT 1	37.45
TAGI	19.5
B1	4.25
A2	35.9
A1	2.9

VI.4.2.2.1.The Tool Reading

- The MPLT recording from 09/Oct/2023 showed some fluctuations in the measured parameters. The Spinner provided different readings (see Annex). The first recording at 2200m showed 70 Rps spinner rotation and remains in diminution until -15 Rps in the 2420m. Additionally, the Spinner showed -15 rps speed at the end of the operation.
- The temperature profile (see Annex) indicates that the temperature increased until the end of the operation (reaching 89C).
- The measured density at the bottom of the well showed high values. The density profile (Annex) demonstrates that the density increased up to (d=1).
- The bottom hole pressure increased up to (1060psi) at 2475m.

VI.4.2.2.2. Interpretation and Reading of the MPLT

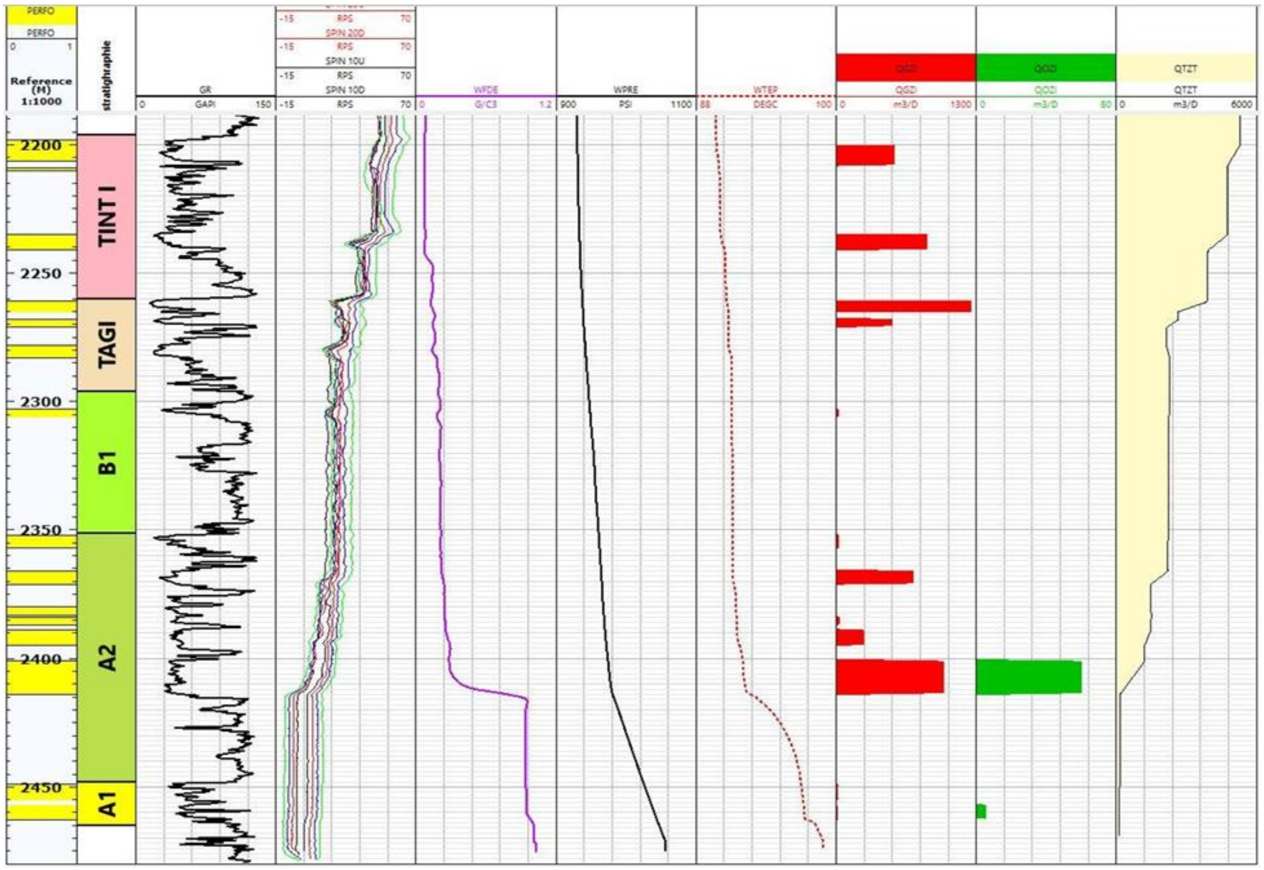


Figure IV.5: InterpretationMPLT RNA8.

Lob Objective:

Establish production profile for RNA-8 by running PLT-STD.

REMARKS:

- All Wellsite data provided by the client.
- Tool string ran as per tool sketch.
- PFCS Ran with 3.5 in Spinner.
- Log Correlated to: RESERVOIR MONITORING TOOL RMT done by HESP on Passes performed between TLI 2185 m and BLI 2475 m @10, 20, 30 and 40 m/mn.
- Stations performed at 2475, 2430, 2400, 2375, 2330, 2290, 2275, 2265, 2255, 2230 and 2185.

According to the interpretation of the PLT log, it is noted that:

- There is no water production.
- Pressure PFD = 930 psi.
- There is a slight absorption at the TAGI reservoir level (2278-2283).

Surface flow rate per **MPLT**:

Qg m3/d	Qc m3/d	Qw m3/d
284400	51,59	0

Surface flow rate per **WT:**

Qg m3/d	Qc m3/d	Qw m3/d
267411	4.95	0.8

IV.4.3.Well RNSE68

IV.4.3.1.Historique de puits

The well RNSE68 is a gas-producing well, drilled in 1983 (03/02/1983 to 20/06/1983) by the TP132 drilling rig. This well is located in the Rhourd_Noss area. Coordinates of the well:

X(UTM) : 283 500.188 m Y(UTM) : 3 275 450,25m

Z sol : 261.94m Z table : 266.34m

With a bottom depth of 2600m, it began production in 1996. This well is completed with a simple completion 4” ½ 13% Cr after a workover operation in 1993.

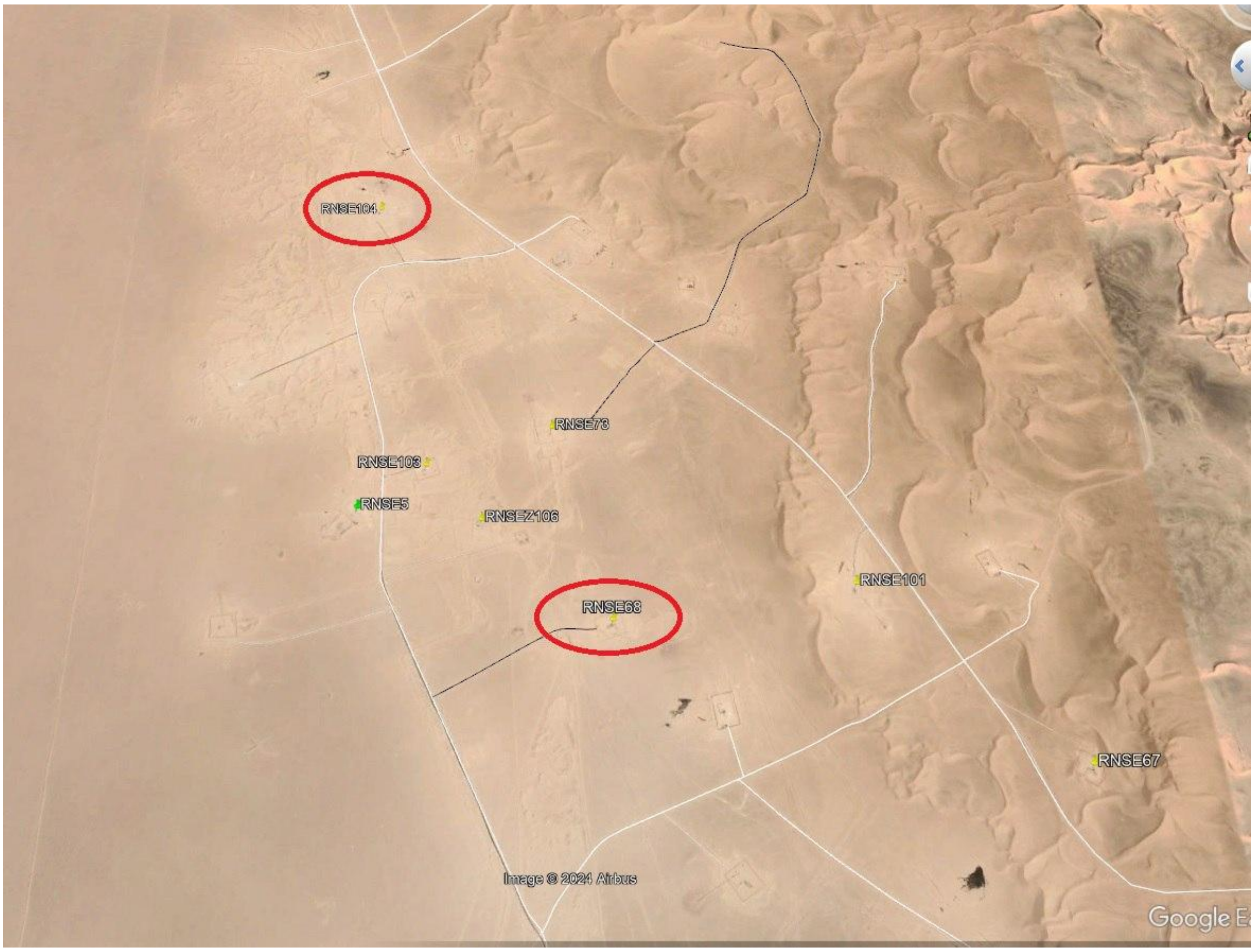


Figure IV.6:Map showing the position of well RNSE68

IV.4.3.2.Interprétation of MPLT (realized on 07/10/2023)

This operation aims to determine the production profile and location of water sources after well cleaning stimulation.

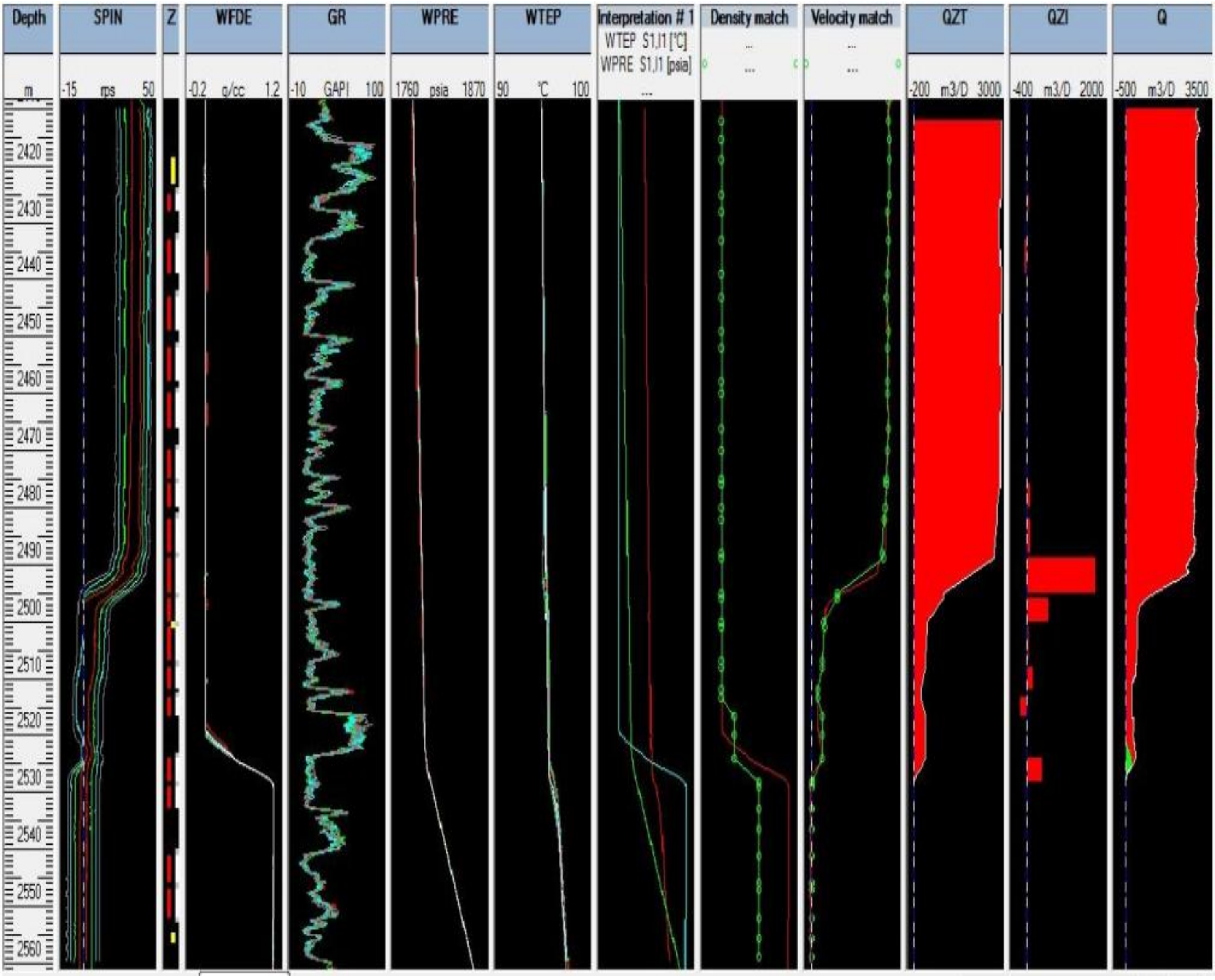


Figure IV.7: The evolution of bottom well parameters (Density, Temperature, GR) from 07/10/2023 Well RNSE68.

Tableau IV.11 : Gauge data for well RNSE68.

Puits	date	Pression tete Psi	Temp tete C°	Qgaz m3/j	Qcond m3/j	Qwatre L/h
RNSE-68	05/08/1996	2330	74	897507	93.6	70
	15/04/1997	2282	75	876032	60.5	66
	01/07/1998	2167	73	569798		80
	13/08/2000	2210	71	871276	67.8	80
	14/08/2000	2055	72	961088	73.4	80
	13/02/2002	2165	75	841239	56.9	90
	18/08/2003	1975	74	844549	47.9	75
	26/04/2007	1726	67	816059	25.5	90
	22/05/2008	1653	68	771021	19.1	90
	12/05/2009	1661	68	775574	19.8	75
	22/04/2010	1691		698593	18.9	94
	01/09/2011	1640	72	738920	16.8	80
	28/03/2012	1746	68	652374	15.7	80
	07/02/2013	1523	66	765816	17.2	99
	16/02/2014	1659	67	668913	15.6	100
	16/02/2014	1725	68	631335	14.2	100
	16/02/2014	1799	68	581135	12.8	100
	08/03/2015	1692	68	672869	10.5	85
	10/03/2016	1576	71	710011	10.3	94
	01/09/2018	1406	66	634358	4.0	44
	25/04/2019	1428	61	573414	3.6	40
	08/10/2019	1396	56	614285	3.5	40
	10/07/2020	1368	57	574169	3.4	50
	18/03/2021	1328	62	527750	1.1	20
	16/09/2021	1361	53	543849	1.9	75
	15/03/2022	1474	58	323426	2.2	20
	20/03/2023	1409	73	252962	2.0	30
	07/10/2023	1442	73	304973	1.8	0

Tableau IV.12 : Parameters recorded in the downhole gauge of well RNSE68.

Recorded parameters	Pressure psi	Température °C	Density g/cm3
At the beginning of the operation (S01)	1847	97.2	1.07
At the end of the operation (S10)	1780.79	94.78	0.08

Tableau IV.13: Perforations of well RNSE68.

Perforations : Date	Top a Bottom	Canon	Type	Reservoir	Densite	Obs
23/02/1985	2425.5 à 2428.5	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2433 à 2439	Scallop 2"1/8		TAGS		PERFORATE
11/1/2024	2433 à 2439	HSD 2"	PJN-2006	TAGS	6	PERFORATE
23/02/1985	2443 à 2449	Scallop 2"1/8		TAGS		PERFORATE
11/1/2024	2443 à 2449	HSD 2"	PJN-2006	TAGS	6	PERFORATE
23/02/1985	2452 à 2458	Scallop 2"1/8		TAGS		PERFORATE
11/1/2024	2455 à 2457	HSD 2"	PJN-2006	TAGS	6	PERFORATE
23/02/1985	2460 à 2466	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2470 à 2475	Scallop 2"1/8		TAGS		PERFORATE
11/1/2024	2471 à 2474	HSD 2"	PJN-2006	TAGS	6	PERFORATE
23/02/1985	2476 à 2480	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2482 à 2488	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2489 à 2495	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2496 à 2500	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2501 à 2507	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2508 à 2512	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2513.5 à 2516.5	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2524 à 2528	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2529 à 2533	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2541 à 2546	Scallop 2"1/8		TAGS		PERFORATE
23/02/1985	2547 à 2552	Scallop 2"1/8		TAGS		PERFORATE
11/1/2024	2553 à 2559	HSD 2"	PJN-2006	TINT-II	6	PERFORATE

VI.4.3.2.1.Tool Readings

The MPLT used during data acquisition from well RNSE-68 consists of: flowmeter, densitometer, thermometer, manometer, GR (Gamma Ray), CCL (Casing Collar Locator), caliper, and capacitance.

Densitometer readings follow almost the same profile for all recording passes. It indicates a value of 0.11 up to 2519m, near the depth of 2520 m. Beyond that, the density increases very slightly, indicating a value of 1.08 up to 2560m, suggesting a probable production of a mixture of water and gas.

The temperature profile shows a slight increase, reaching a maximum value of 97°C at 2550m.

The Spinner reading is very poor, indicating a value of 0 rps at 2560m due to salt deposits in the screens, which create turbulence in the flow. Similarly, flow behind the screens greatly affects the Spinner reading profile, resulting in difficulty obtaining a stable velocity profile and thus difficulty achieving satisfactory calibration during interpretation.

IV.4.3.3. Comparison between MPLT log of October and July 2023 -Flowing

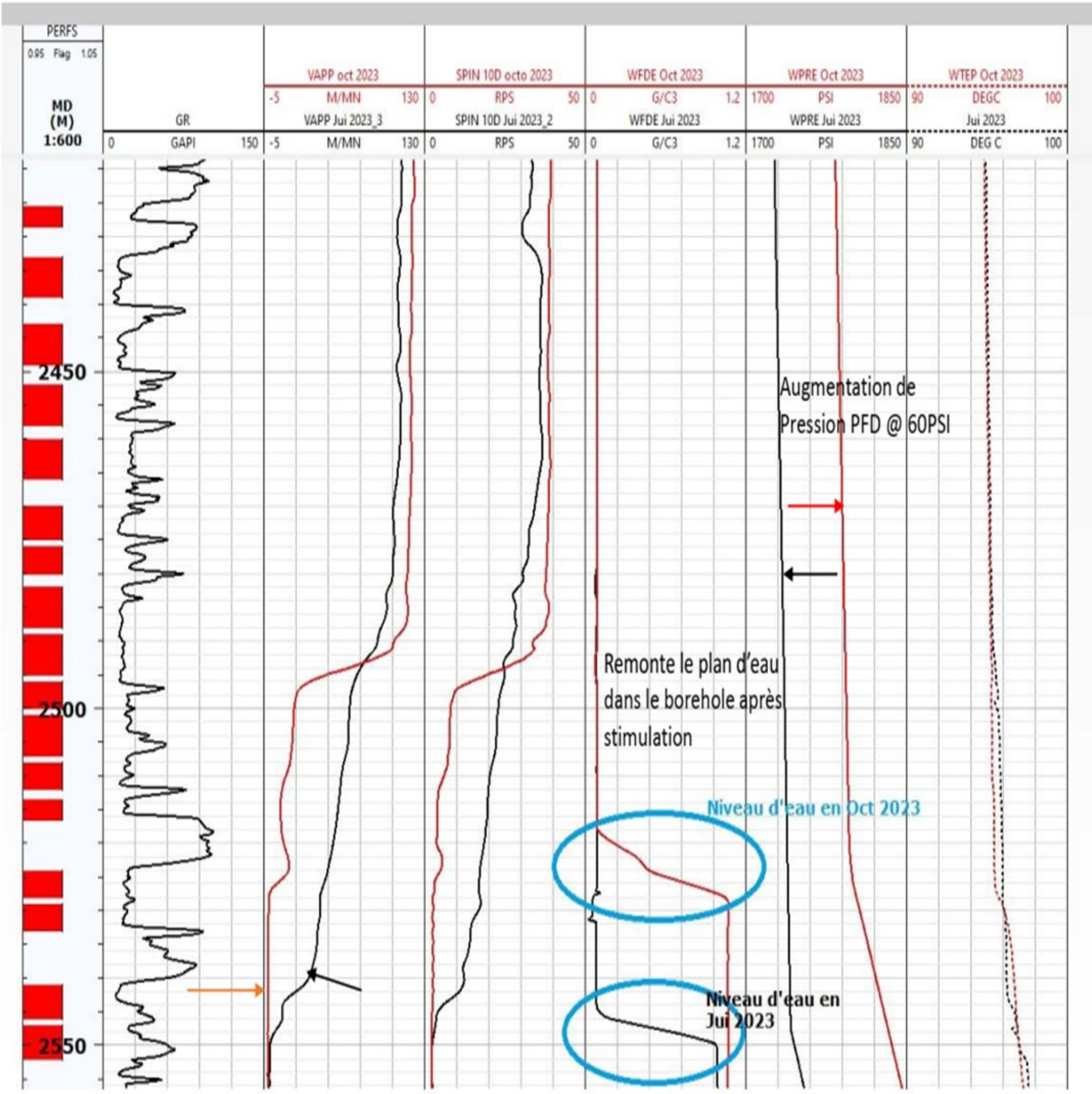


Tableau IV.14: Comparaison Zone Contributions, Reservoir Condition by Pass**.**

Zone	Production October %	Production Juil %	Qt reservoir condition October 2023 m3/d	Qt reservoir condition Jui 2023 m3/d
2425-2428	1,46	0	47,88	0
2433-2439	-1,44	2.69	-47,42	76.42
2443-2449	0,27	0	8,9	0
2452-2458	-0,09	0	-2,86	0
2460-2466	0,21	4.79	6,8	136
2470-2475	0,36	0	11,78	0
2476-2480	2,63	1.9	86,56	53.92
2482-2488	2,82	10.7	92,6	303.51
2489-2495	52,02	16.13	1710,95	457.67
2496-2500	15,88	4.68	522,27	132.78
2501-2507	1,55	2.98	50,83	84.47
2508-2512	5,39	3.57	177,26	101.17
2513.5-2516.5	-4,55	8.43	-149,78	239.21
2524-2528	11,34	7.35	373	208.58
2529-2533	0	6.78	0	192.35
2541-2546	0	17.31	0	491.04
2547-2552	0	9.05	0	256.65
Total	100	100	2897,79	2644.48

Tableau IV.15 : Zone Contributions, Reservoir Condition by Station.

Station	Zone	Spin rotation rps Jui 2023	Contribution % Jui 2023	Spin rotation rps Oct 2023	Contribution % Oct 2023
2410	2425-2428	33.7	0	43,4	0
2432	2433-2439	33.7	0.3	43,4	0
2442	2443-2449	33.6	4.15	43,4	1,58
	2452-2458				
	2460-2466				
2469	2470-2475	32.2	9.2	42,7	--3,83
	2476-2480				
	2482-2488				
2488	2489-2495	29.1	34.72	44,4	102
	2496-2500				
	2501-2507				
	2508-2512				
2513	2513.5-2516.5	17.4	4.75	0	0
2520	2524-2528	15.8	13.06	0	0
	2529-2533				
2538	2541-2546	11.4	24.33	0	0
2546.5	2547-2552	3.2	9.5	0	0
2560	2560	0	0	0	0

Tableau IV.16: Comparison of contribution between MPLT 2023 and 1985.

Zone	Contribution Jui 2023	Contribution Oct 2023	Contribution 1985
2425-2428	0	1,46	0
2433-2439	2.69	-1,44	8.1
2443-2449	0	0,27	3.7
2452-2458	0	-0,09	8
2460-2466	4.79	0,21	3.4
2470-2475	0	0,36	11.6
2476-2480	1.9	2,63	7.2
2482-2488	10.7	2,82	4.6
2489-2495	16.13	52,02	7
2496-2500	4.68	15,88	0
2501-2507	2.98	1,55	9.8
2508-2512	3.57	5,39	13.5
2513.5-2516.5	8.43	-4,55	0.3
2524-2528	7.35	11,34	1
2529-2533	6.78	0	8.4
2541-2546	17.31	0	13.4
2547-2552	9.05	0	0
Total	100	100	100

After comparing the MPLT conducted in July 2023 and October 2023, we find that:

- The production has not changed.
- An increase in reservoir flow rate (Qt) is observed, with a value of 2897.79 m3/d in October 2023 and a value of 2644.48 m3/d in July 2023.
- There is no water production.
- There is a change in contribution between July 2023 and October 2023 compared to 1985.
- There are zones that are not contributing.
- The water level has risen between July and October, reaching up to 2520 m.

According to the interpretation of MPLT log, it is noted that:

- There is no change in total WT flow rate.
- A slight increase in bottomhole and head pressure @60 psi.
- Water level rise in the borehole (possibly CTU water).
- Significant improvement in the zone 2489-2495m (52%).
- Lower zones no longer produce after stimulation (flooded with water).
- No water production.
- Total surface flow rate Qt of MPLT.

IV.4.3.3.1. Recommendation

Based on the PLT results, we recommend:

- Raising the water level in the borehole to free the lower zones.
- Re-perforating the zones that are not contributing.

IV.4.3.3.2. Evolution of bottom parameters (d, T, GR) from 2007 to 2015

- As shown in the profiles in the figure above, we notice that the GR (Gamma Ray) has remained roughly the same.
- A change in density is observed in the zone between 2520 m and 2550 m.
- Qualitatively, the temperature profile has not changed.
- The spinner profile remains disturbed.
- An increase in bottom hole pressure (PFD) of 60 psi is noted.

Conclusion:

The analysis and evaluation of the previously mentioned data using the EMERAUD software allowed us to conclude that:

- The MPLT conducted on well **RN-111** showed the existence of cross flow between the TAGI and A2 reservoirs.
- The MPLT conducted on well **RNA-8** indicated that there is no water production and there is a discrepancy between the values obtained from MPLT and WT.
- The MPLT conducted on well **RNSE-68** showed a rise in the water level in the borehole, but no water production.

CONCLUSION

CONCLUSION GENERALE

Following our study and research on the importance of MPLT in the cross-flow phenomenon detection program, we have come to the following conclusions:

- The Rhourde-nouss region is an important oil region in Algeria, where encountered fluids include gas, condensate gas, and oil.
- Hydrocarbon accumulations are found in Triassic, Silurian, and Ordovician reservoirs.
- MPLT is a crucial tool in well monitoring, enabling us to make decisions to address operational challenges.
- MPLT is the primary tool for cross-flow detection.
- Cross-flow is detected after a thorough study of various criteria and through different methods as per well requirements (mechanical, chemical, etc.).

For well RN-111, MPLT interpretation conducted on 31/09/2023 indicates cross-flow between reservoir A2 and TAGI, with flow from A2 to TAGI. For well RNA-08, MPLT conducted on 09/10/2023 reveals:

- No water production.
- Absorption at TAGI reservoir level (2278-2283).
- Discrepancy between surface flow rate by MPLT and WT.

According to MPLT interpretation conducted from Oct 2023 to Jul 2023 on well RNSE-68, it is observed that:

- No change in total WT flow rate.
- Slight increase in bottomhole and head pressure @60 psi.
- Rise in water level in the borehole (possibly CTU water).
- Significant improvement in zone 2489-2495m (52%).
- Lower zones no longer produce after stimulation (water flooded).
- No water production.

RECOMMENDATIONS

Based on this study conducted on the Rhourde-Nouss field and considering the constraints encountered during our research and work, we recommend the following:

- Schedule MPLT measurements immediately after well shutdown to detect cross-flow.

- Cross-flow should be detected in shut-in mode only.
- It is important to perform gauging more frequently, especially after interventions decided upon based on MPLT interpretation, and also to shorten the intervals between gauging. This will provide more data, facilitate interpretations, and confirm the effectiveness of operations.

- It is advisable to conduct periodic tests to check and analyze the water level to avoid undesirable deposits.

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BIBLIOGRAPHIE

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Annexes

Annexe A:The technical data sheets of the wells.

FICHE TECHNIQUE DE PRODUCTION — **RN111**

sonatrach
EXPLOR & PROD PRODUCTION DIREC. RNS Div. EP Serv Tech. Puits

Coordonnées UTM	Puits	Forage	Complétion	Workover
X(UTM): 283 274,49m Y(UTM): 3 288 412,85m Z sol: 261m Z table: 271,51m	Puits : DEV Structure : RNS Réservoirs : TAGI, SIL(B1-A1) Collecteur :	Appareil: TP198 Début : 11/08/2008 Fin : 31/12/2008 Fond MD: 3947m	N°: 02 Type : Simple 3"1/2 acier carbone Appareil : TP188 Début : 06/01/2017 Fin : 11/01/2017	N°: 01 But : Cimentation du liner 4,5 et perforations dans le TAGI Appareil : TP188 Début : 21/11/2016 Fin :12/01/2017

TETE DE PUITS

Composant	Type	Diam	Série	Nbr	Obs
PLAQUE DE BASE	ITAG	20"3/4 x 18"5/8	5000X3000		
CASING SPOOL	ITAG	20" 3/4 x 13"5/8	3000 x 5000		
CASING SPOOL	ITAG	13"5/8 x 11"	5000 x 5000		
PACK OFF FLANGE		11"	5000		
TUBING HEAD		11" x 7"1/16	5000		
ADAPTEUR		7"1/16 x 4"1/16	5000		
VANNE MAITRESSE		4"1/16	5000		
CROIX		4"1/16	5000		
VANNE AUTOMATIQUE		4"1/16	5000		
VANNE LATERALE		4"1/16	5000		
VANNE DE CURAGE		4"1/16	5000		
TOP CUP		4"1/16	5000		

EQUIPEMENTS DE FOND

Designation		Top	Long	ID	OD	Grade	Filet	Poids	Nbr	Obs
16-OLIVE		0	0,46							
15-REDUCTION 3"1/2x4"1/2		0,46	0,28							
14-PUP JOINT		0,74	3	2,992	3,5	L3	NVAM	9,2		
13-COLONNE TUBING		3,74	2558,56	2,992	3,5	L3	NVAM	9,2		
12-SIEGE ' X '	DRILLE	2562,3	0,35	2,815	3,5		NVAM			
	ELECTRIC	2574,3								
11-JOINT TUBING		2562,65	9,54	2,992	3,5	L3	NVAM	9,2		
10- MANCHON		2572,19	0,22		3,5					
9-REDUCTION4"1/2x3"1/2		2572,41	0,09				NVAM			
8- PUP JOINT		2572,5	0,46	3,92	4,5			13,5		
7- RATCH LACH		2572,96	0,57							
6-PACKER	DRILLE	2573,53	1,82							
	ELECTRIC	2585,5								
5- PUP JOINT		2575,35	0,98		5					
4-REDUCTION 3"1/2x5"		2576,33	0,13							
3-JOINT TUBING		2576,46	9,56	2,992	3,5	L3	NVAM	9,2		
2-SIEGE ' XN '	DRILLE	2586,02	0,38	2,666	3,5		NVAM			
	ELECTRIC	2598								
1-SABOT		2586,4	1							

TUBAGES

Tubages		Top-Bottom	Phase	Sabot	ID	OD	Grade	Filet	Poids	Obs
CASING-30"		0 à 70	36"	69	29	30	X52	ST2	157,5	6 joints
CASING-18"5/8		0 à 449	26"	449	17,755	18,625	K55	FT BUTT	87,5	34 joints
CASING-13"3/8		0 à 1937	16"	1937	12,415	13,375	N80	FT BUTT	68	162 joints
CASING-9"5/8		0 à 607	12"1/4		8,535	9,625	P110	HSE	53,5	51 joints
CASING-9"5/8		607 à 2243	12"1/4	2242	8,681	9,625	P110	TB	47	116 joints
CASING-7"		0 à 3374	8"1/2	3373	6,184	7	P110	NVAM	29	
LINER 4"1/2	Blank	3322 à 3622	6"		3,92	4,5	P110	NVAM	13,5	40 joints
	Slotted	3622 à 3947	6"	3946	3,92	4,5	P110	NVAM	13,5	31 joints

PERFORATIONS

Date	Top-Bottom	Canon	Type	Reservoir	Densite	Phasing	Obs
29/07/2022	2603 à 2607,5	Canon 2" HSD	PJN 2006 HMX	TAGI	6	60	PERFORATE
29/07/2022	2609 à 2610,5	Canon 2" HSD	PJN 2006 HMX	TAGI	6	60	PERFORATE
29/07/2022	2616 à 2618	Canon 2" HSD	PJN 2006 HMX	TAGI	6	60	PERFORATE
29/07/2022	2628 à 2632	Canon 2" HSD	PJN 2006 HMX	TAGI	6	60	PERFORATE
29/07/2022	2712 à 2714	Canon 2" HSD	PJN 2006 HMX	SIL-B1	6	60	PERFORATE
29/07/2022	2732 à 2733	Canon 2" HSD	PJN 2006 HMX	SIL-B1	6	60	PERFORATE
18/12/2017	2771 à 2776	Canon 4"1/2	SDP3	SIL-A2	6	60	PERFORATE
29/07/2022	2772 à 2776	Canon 2" HSD	PJN 2006 HMX	SIL-A2	6	60	REPERFORATE
17/12/2016	2776 à 2782	Canon 4"1/2	SDP3	SIL-A2	6	60	PERFORATE
17/12/2016	2782 à 2788	Canon 4"1/2	SDP3	SIL-A2	6	60	PERFORATE
12/10/2016	3653 à 3658	2"1/8	REPERFORATE	G.OUARGLA	6	60	Cimenté
12/10/2016	3730 à 3736,5	2"1/8	PERFORATE	Q. HAMRA	6	60	Cimenté
12/10/2016	3739 à 3745	2"1/8	PERFORATE	Q. HAMRA	6	60	Cimenté
12/10/2016	3750,5 à 3753	2"1/8	PERFORATE	Q. HAMRA	6	60	Cimenté
29/08/2014	3653 à3658	ABRASIJET	PERFORATE	G.OUARGLA			Cimenté
26/08/2014	3692 à 3694,5	ABRASIJET	PERFORATE	G.OUARGLA			Cimenté
25/08/2014	3697,5 à 3699	ABRASIJET	PERFORATE	G.OUARGLA			Cimenté
23/08/2014	3701 à 3703	ABRASIJET	PERFORATE	G.OUARGLA			Cimenté
23/08/2014	3703,5 à 3706,5	ABRASIJET	PERFORATE	G.OUARGLA			Cimenté
21/08/2014	3709 à 3711	ABRASIJET	PERFORATE	G.OUARGLA			Cimenté
18/08/2014	3714 à 3716,5	ABRASIJET	PERFORATE	G.OUARGLA			Cimenté
28/08/2014	3731,5 3733,5	ABRASIJET	PERFORATE	Q.HAMRA			Cimenté
11/01/2009	3222 à 3947		Crépine	G.O - QHA			Cimenté

PLUG ET RESTRICTION

Date	Top - Bottom	Type	Obs
08/12/2016	3059,74 à 3776,5	B.CIMENT	
15/08/2014	3776,5 à 3947	B.CIMENT	

DEVIATIONS

Designation	MD	TVD	Phase	INCL	AZ

DONNEES DE PRESSIONS

Date	Compagnies		
Duses	24/64	32/64	34/64
PFS (Psi)			
PFD (Psi)			
Ptête (Psi)			
T tête (°c)			

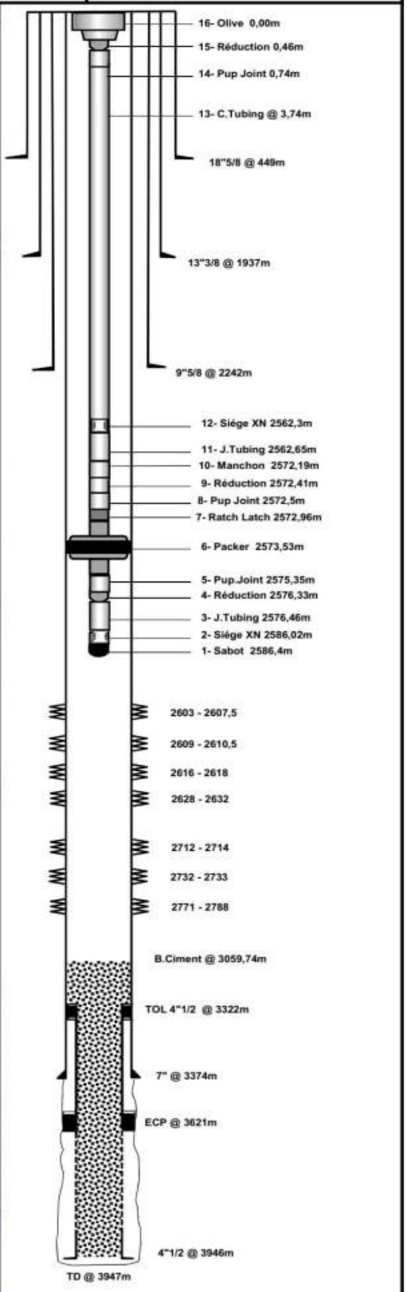

Figure Annexes A-1: RN111 Well completion.

EXPLOR & PROD PRODUCTION DIREC. RNS Div, EP Serv Tech, Puits	**FICHE TECHNIQUE DE PRODUCTION**			**RNA8**
	Collecteur: C12	Puits Product Gaz	Telephone:	M Service:
	X(UTM): 282100.5	Y(UTM): 3284350	Z sol: 284.17	Z table: 276.55
	Debut Forage: 25-09-1997	Fin Forage: 23-11-1997	Appareil: TP181	Fond MD: 2535
	Type Completion :- Debut 01-12-97 Fin 06-12-97 -Appareil TP182Simple			

Tete d'erruption : Composant Type Diam Serie Nbr Obs

Composant	Type	Diam	Serie	Nbr	Obs
1-PLAQUE DE BASE	STREM FLOW	20"3/4	3000	1	
2-CASING SPOOL	STREM FLOW	20"3/4 x 13"5/8	3000 x 5000	1	
3-CASING SPOOL	STREM FLOW	13"5/8 X 11"	5000	1	
4-TESTING FLANGE		11"	5000	1	
5-TUBING HEAD	COOPER	11" x 9"	5000	1	
6-ADAPTEUR	COOPER	9" x 4"1/16	5000	1	
7-VANNE MAITRESSE	COOPER	4"1/16	5000	1	
8-CROIX	COOPER	4"1/16	5000	2	
9-VANNE AUTOMATIQUE	COOPER	4"1/16	5000	1	
10-VANNE LATERALE	COOPER	2"1/16	5000	1	
11-VANNE SOMMET	COOPER	4"1/16	5000	1	
12-TOP CUP	COOPER	4"1/16	5000	1	

Equipements de Fond Designation |Top | Type - Diam - Long - Drift - Poids - Grade - Nbr - Obs

Designation		Top	Type - Diam - Long - Drift - Poids - Grade - Nbr - Obs
10-COLONNE TUBING		0	- 4.5 - 2132.01 - 3.92 - 13.5 - N80 - - 4"1/2 N.VAM N8013% Cr
9-SIEGE	DRILLER	2132,01	X - 4.5 - .46 - 3.313 - - - 1 -
	ELECTRIC	2141,2	
8-JOINT TUBING		2132,47	- 4.5 - 11.84 - 3.92 - 13.5 - N80 - 1 - 4"1/2 N.VAM N8013% Cr
7-RATCH LATCH		2144,31	- 4.5 - .52 - 3.92 - - - 1 -
6-PACKER	DRILLER	2144,83	HYDRAULIQUE - 7 - 1.82 - 3.875 - - - 1 - Otis Hydraulique 13% Cr7"
	ELECTRIC	2154	
5-MILLOUT EXTENSION		2146,65	- 5 - 1.67 - 4.125 - 18 - - 1 - 5" N.VAM 18# 13% Cr5"
4-REDUCTION		2148,32	- 5 - .4 - 3.92 - - - 1 - 13% Cr5" x 4"1/2
3-JOINT TUBING		2148,72	- 4.5 - 11.84 - 3.92 - 13.5 - N80 - 1 - 4"1/2 N.VAM N8013% Cr
2-SIEGE	DRILLER	2160,56	X - 4.5 - .47 - 3.135 - - - 1 -
	ELECTRIC	2169,7	
1-SABOT		2161,03	- 4.5 - .21 - 3.92 - - - 1 -

Tubages : Tubages: | de Top a Bottom|Phase | Sabot | ID | OD | Poids | Grade | Ecl | Filet | Obs

Tubages	de Top a Bottom	Phase | Sabot | ID | OD | Poids | Grade | Ecl | Filet | Obs
CASING-18" 5/8	0 a 525	24 | 523 | 17.755 | 18.625 | 87.5 | K55 | | STC | SABOT-47JTS CSG 18"5/8-87.5-K55-A
CASING-13" 3/8	0 a 1664	17.5 | 1580 | 12.415 | 13.375 | 68 | N80 | | LTC | SABOT+2JTS CSG9"5/8+1ANN DFU
CASING-9" 5/8	0 a 1914	12.25 | 1913 | 8.681 | 9.625 | 47 | P110 | | VAM | SABOT+2JTS CSG9"5/8+1ANN DFU
CASING-7"	0 a 2535	8.5 | 2533 | 6.184 | 7 | 29 | P110 | | VAM | SABOT A CANAL+2JTS 7"+ANNEAU+CSG7

Perforations : Date | Top a Bottom | Canon | Type | Reservoir | Densite | Phasing | Obs

Date	Top a Bottom	Canon | Type | Reservoir | Densite | Phasing | Obs
21/09/2021	2200 à 2208	2"7/8 | PERFORATE | TINT-I | 6 | 60 |
21/09/2021	2209 à 2210	2"7/8 | PERFORATE | TINT-I | 6 | 60 |
21/09/2021	2235 à 2241	2"7/8 | PERFORATE | TINT-I | 6 | 60 |
21/09/2021	2261 à 2265	2"7/8 | PERFORATE | TAGI | 6 | 60 |
21/09/2021	2268 à 2271	2"7/8 | PERFORATE | TAGI | 6 | 60 |
21/09/2021	2278 à 2283	2"7/8 | PERFORATE | TAGI | 6 | 60 |
21/09/2021	2303 à 2306	2"7/8 | PERFORATE | SIL-B1 | 6 | 60 |
26/12/1999	2352 à 2357	TAG SDT | PERFORATE | SIL-A2 | 6 | 60 |
26/12/1999	2366 à 2371	TAG SDT | PERFORATE | SIL-A2 | 6 | 60 |
21/09/2021	2367 à 2370,45	2"7/8 | PERFORATE | SIL-A2 | 6 | 60 |
21/09/2021	2376 à 2379	2"7/8 | PERFORATE | SIL-A2 | 6 | 60 |
26/12/1999	2380 à 2383	TAG SDT | PERFORATE | SIL-A2 | 6 | 60 |
21/09/2021	2384 à 2387	2"7/8 | PERFORATE | SIL-A2 | 6 | 60 |
21/09/2021	2389 à 2395	2"7/8 | PERFORATE | SIL-A2 | 6 | 60 |
26/12/1999	2401 à 2414	TAG SDT | PERFORATE | SIL-A2 | 6 | 60 |
21/09/2021	2449 à 2455	2"7/8 | PERFORATE | SIL-A2 | 6 | 60 |
21/09/2021	2457 à 2463	2"7/8 | PERFORATE | SIL-A2 | 6 | 60 |

Plug et Restrictions : Date | Top | Bottom | Type | Obs

25-11-1997 | 2506 | | ANNEAU |

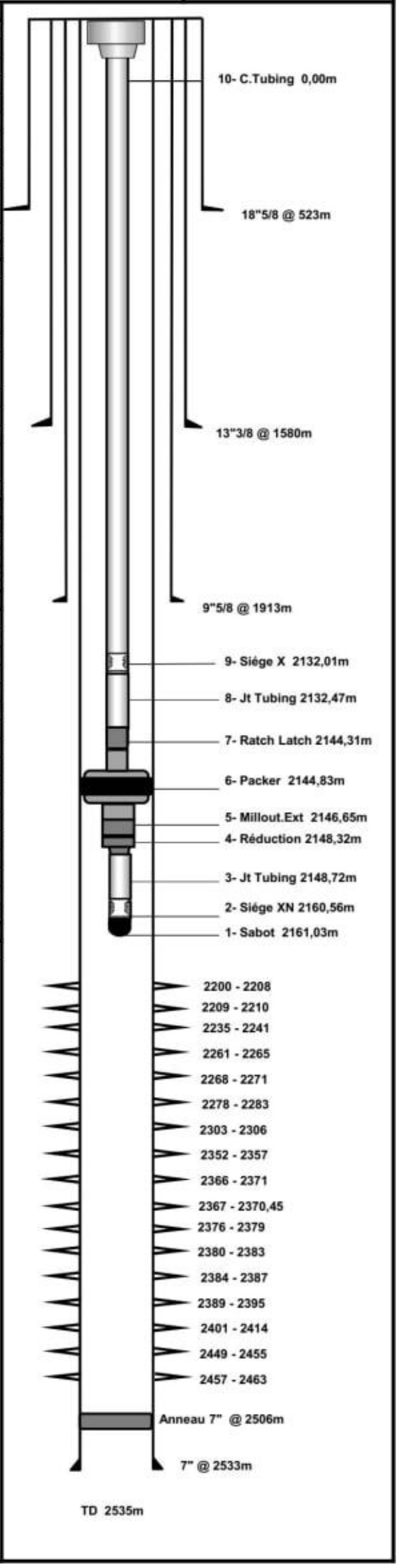

Figure Annexe A-2: RNA8 Well completion.

EXPLOR & PROD PRODUCTION DIREC. RNS Div. EP Serv Tech. Puits	**FICHE TECHNIQUE DE PRODUCTION**				**RNSE68**
	Collecteur:	Puits Producteur Gaz	Telephone:	M Service:	
	X(UTM): 283 500,188	Y(UTM): 3 275 450,25	Z sol: 261,94	Z table: 266,34	
	Début Forage: 03-02-1983	Fin Forage: 20-06-1983	Appareil: ENTP 132	Fond MD: 2600	
	Début WO 30-05-1993	Fin WO 25-07-1993	Appareil TP188	Num Wo 1	
	Type Completion :- Debut 19-07-1993 Fin 23-07-1993 - Appareil TP188 Simple 4"1/2 13%Cr				

Tete d'erruption : Composant Type Diam Serie Nbr Obs

Equipements de Fond Designation \|Top \| Type - Diam - Long - Drift - Poids - Grade - Nbr - Obs

12-OLIVE		0	| | 0,50 | | | | 1 |
11-COLONNE TUBING		0,5	| 4.5 | 2360,35 | 3,92 | 13,5 | C85 | 200 | NVAM
10-SIEGE	DRILLER	2365,5	X | 4.5 | ,47 | 3,313 | 13,5 | | 1 | NVAM
	ELECTRIC	2362,1	
9-JOINT TUBING		2365,97	| 4.5 | 11,84 | 3,92 | 13,5 | C85 | 1 | NVAM
8-RATCH LATCH		2377,81	| | 0,45 | | | | 1 |
7-PACKER	DRILLER	2378,26	| 5 | 1,82 | | | | 1 |
	ELECTRIC	2375	
6-MILLOUT EXTENSION		2380,08	| 5 | 1,64 | | | | 1 |
5-REDUCTION		2381,72	| 5 | ,41 | | | | 1 |
4-JOINT TUBING		2382,13	| 4.5 | 11,82 | 3,92 | 13,5 | C85 | 1 | NVAM
3-SIEGE	DRILLER	2393,95	XN | 4.5 | 0.43 | 3,135 | 13,5 | | 1 | NVAM NO GO 3"135
	ELECTRIC	2390,5	
2-PUP JOINT		2394,43	| 4.5 | 0.97 | 3,92 | 13,5 | C85 | 1 | NVAM
1-SABOT		2395,4	| 4.5 | 0.19 | | | | 1 |

Tubages : Tubages: \| de Top a Bottom\|Phase \| Sabot \| ID \| OD \| Poids \| Grade \| Ecl \| Filet \| Obs

CASING-18" 5/8	0 à 364,5	24 | 364,5 | 17.755 | 18.625 | 87.5 | J55 | | |
CASING-13" 3/8	0 à 1660	17.5 | 1660 | 12.415 | 13.375 | 68 | N80 | | | 42 jts
CASING-9" 5/8	0 à 2410	12.25 | 2410 | 8.681 | 9.625 | 47 | P110 | | | 63 jts
CASING-7"	0 à 2347	8.5 | | | 7 | | P110 | | |
TIE_BACK-7"	2347	8.5 | | | 7 | | | | |
LINER_SIMPLE-7"	2347 à 2599,3	8.5 | 2599,3 | 6.094 | 7 | 32 | P110 | | |

Perforations : Date \| Top a Bottom \| Canon \| Type \| Reservoir \| Densite \| Phasing \| Obs

23/02/1985	2425,5 à 2428,5	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2433 à 2439	Scallop 2"1/8 | | TAGS | | | PERFORATE
11/01/2024	2433 à 2439	HSD 2" | PJN-2006 | TAGS | 6 | 60 | REPERFORATE
23/02/1985	2443 à 2449	Scallop 2"1/8 | | TAGS | | | PERFORATE
11/01/2024	2445 à 2449	HSD 2" | PJN-2006 | TAGS | 6 | 60 | REPERFORATE
23/02/1985	2452 à 2458	Scallop 2"1/8 | | TAGS | | | PERFORATE
11/01/2024	2455 à 2457	HSD 2" | PJN-2006 | TAGS | 6 | 60 | REPERFORATE
23/02/1985	2460 à 2466	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2470 à 2475	Scallop 2"1/8 | | TAGS | | | PERFORATE
11/01/2024	2471 à 2474	HSD 2" | PJN-2006 | TAGS | 6 | 60 | REPERFORATE
23/02/1985	2476 à 2480	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2482 à 2488	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2489 à 2495	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2496 à 2500	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2501 à 2507	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2508 à 2512	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2513,5 à 2516,5	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2524 à 2528	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2529 à 2533	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2541 à 2546	Scallop 2"1/8 | | TAGS | | | PERFORATE
23/02/1985	2547 à 2552	Scallop 2"1/8 | | TAGS | | | PERFORATE
11/01/2024	2553 à 2559	HSD 2" | PJN-2006 | TINT-II | 6 | 60 | PERFORATE

Plug et Restrictions : Date \| Top \| Bottom \| Type \| Obs

\| 2582 \| \| Landing Collar \|

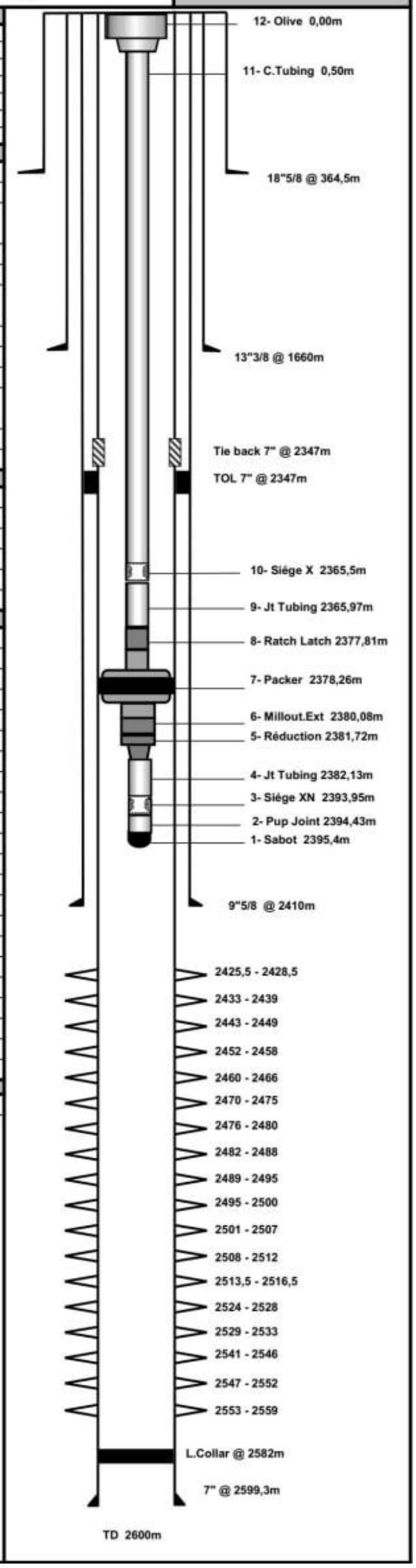

Figure Annexe A-3: RNSE-68 Well completion.

Annexe B:Allures of spinners, density, capacitances, temperatures, pressure,of wells.

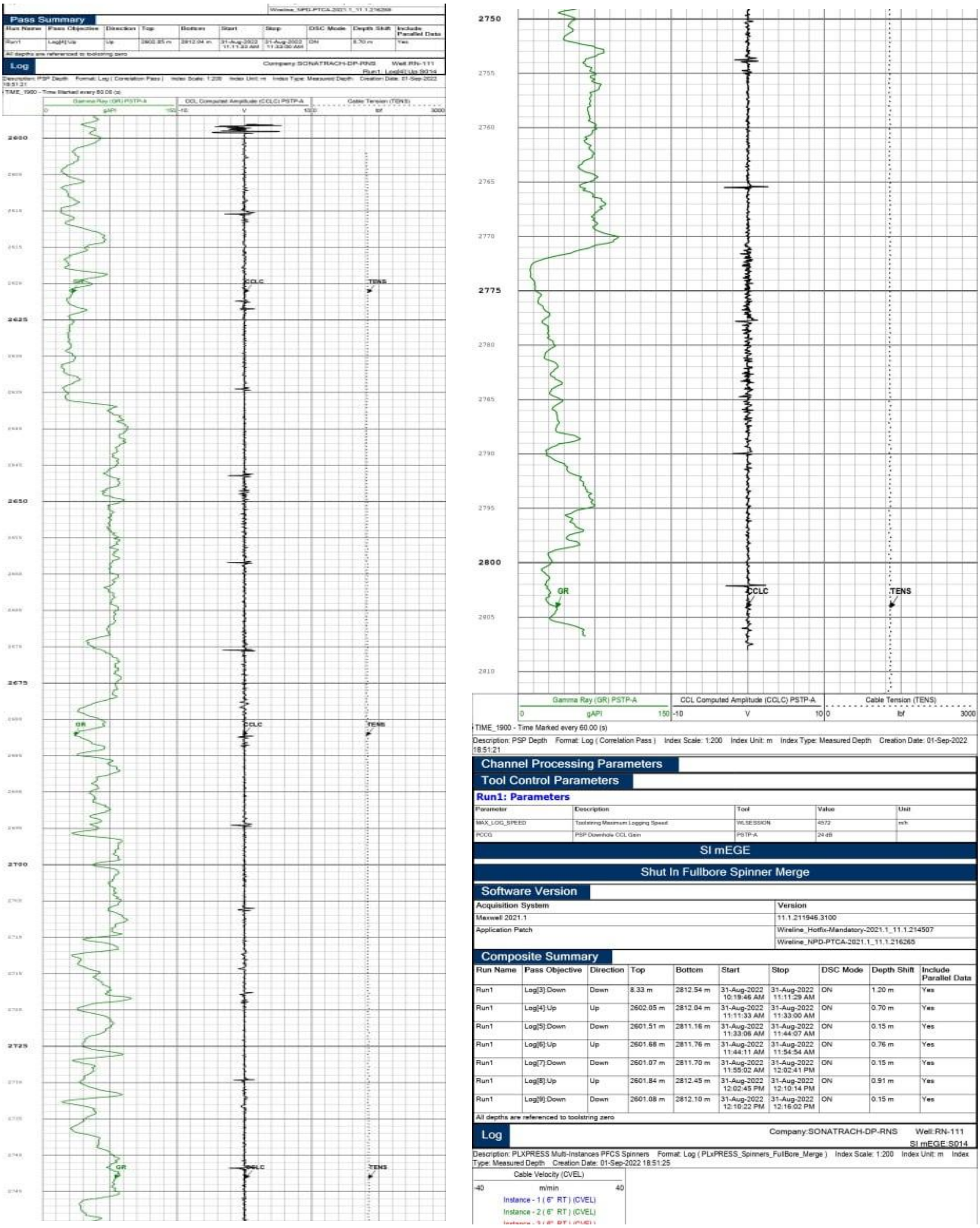

Figure Annexe B-1: Recording of MPLT GR, CCL, and TENS 01/09/2022 for RN111 well.

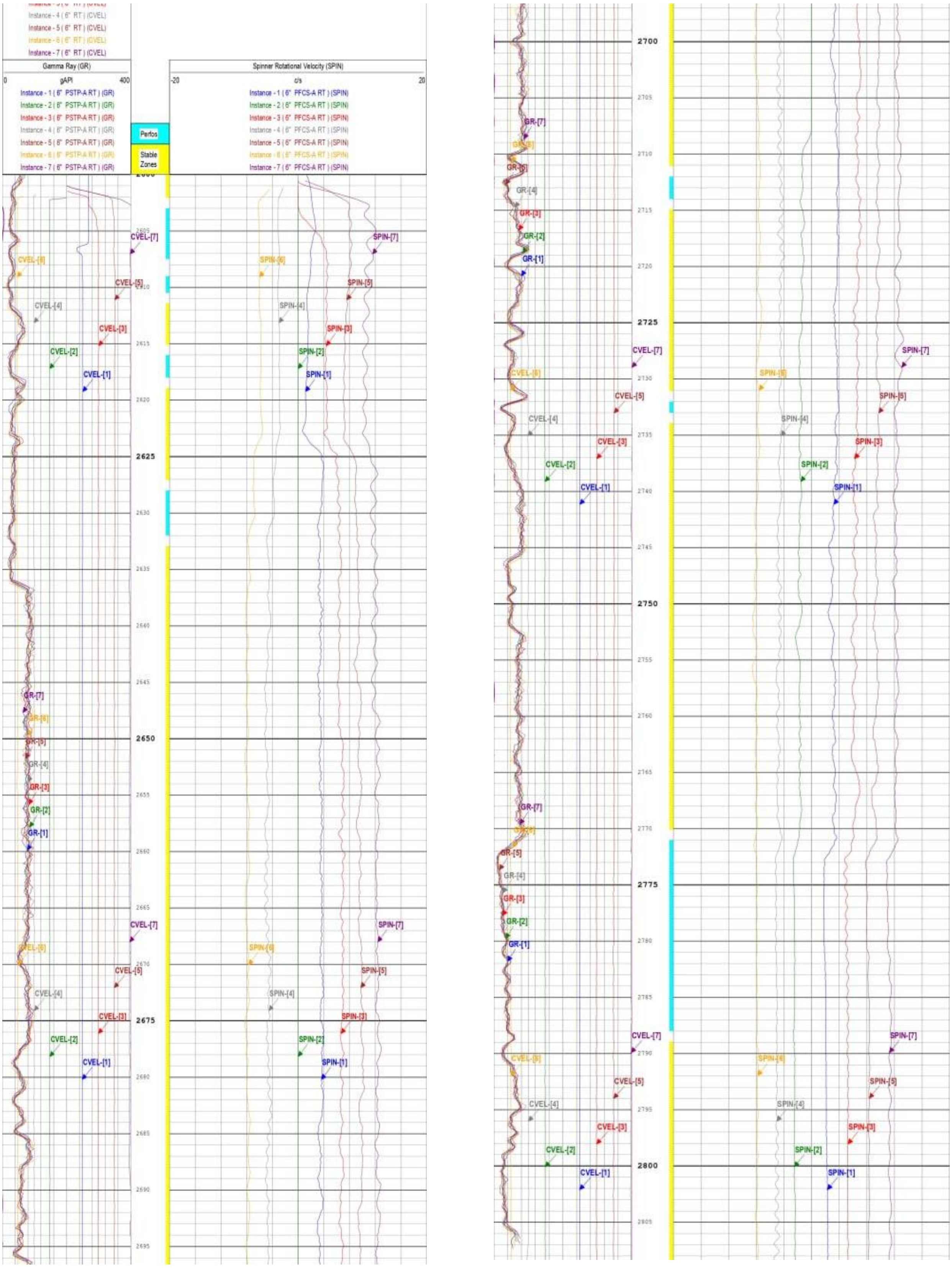

Figure Annexe B-2: Recording of MPLT CVEL, GR, Spin, of all runs 01/09/2022 for RN111 well.

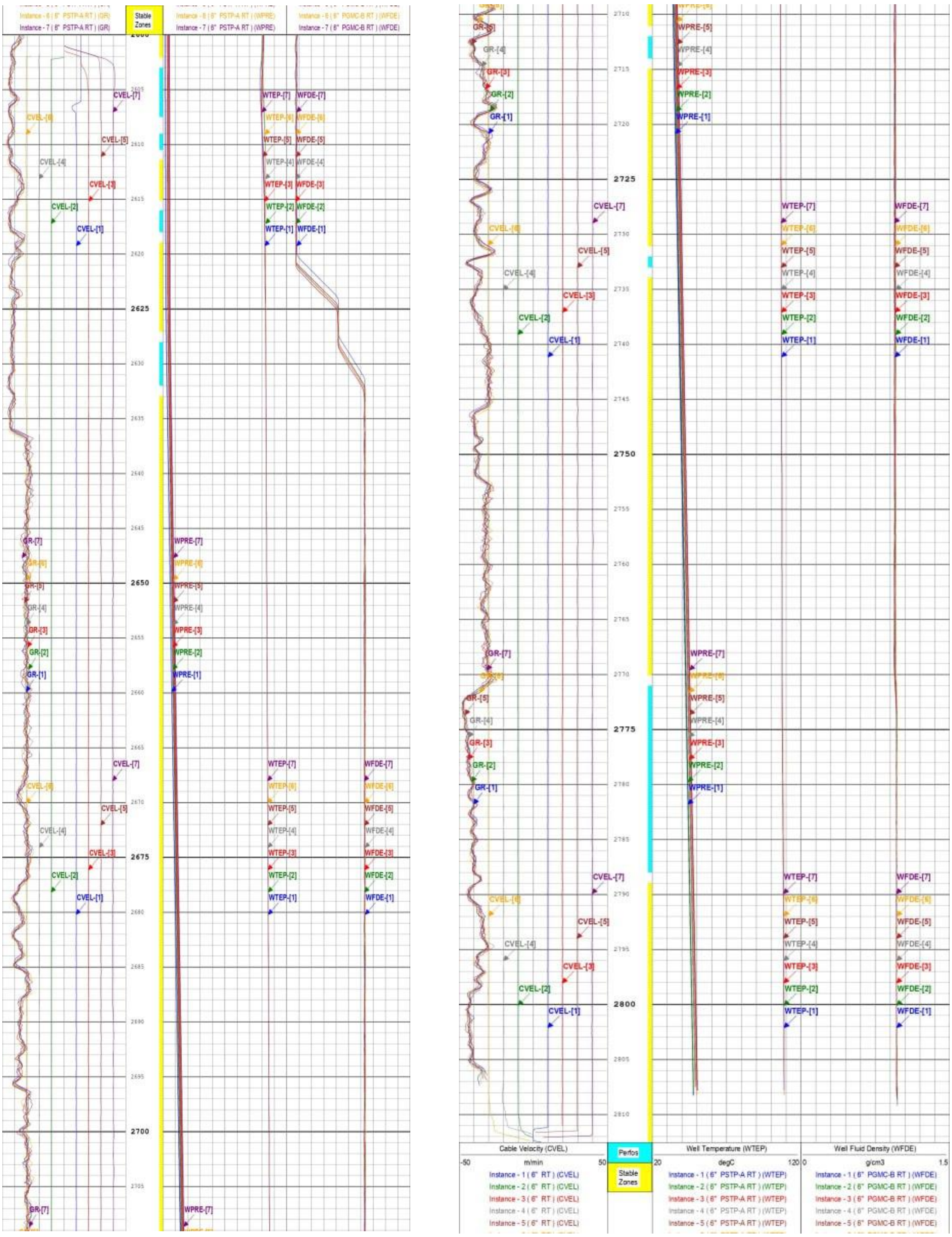

Figure Annexe B-3 : Recording of MPLT CVEL, GR, WTEP, WPRE, WFDE of all runs 01/09/2022 for RN111 well.

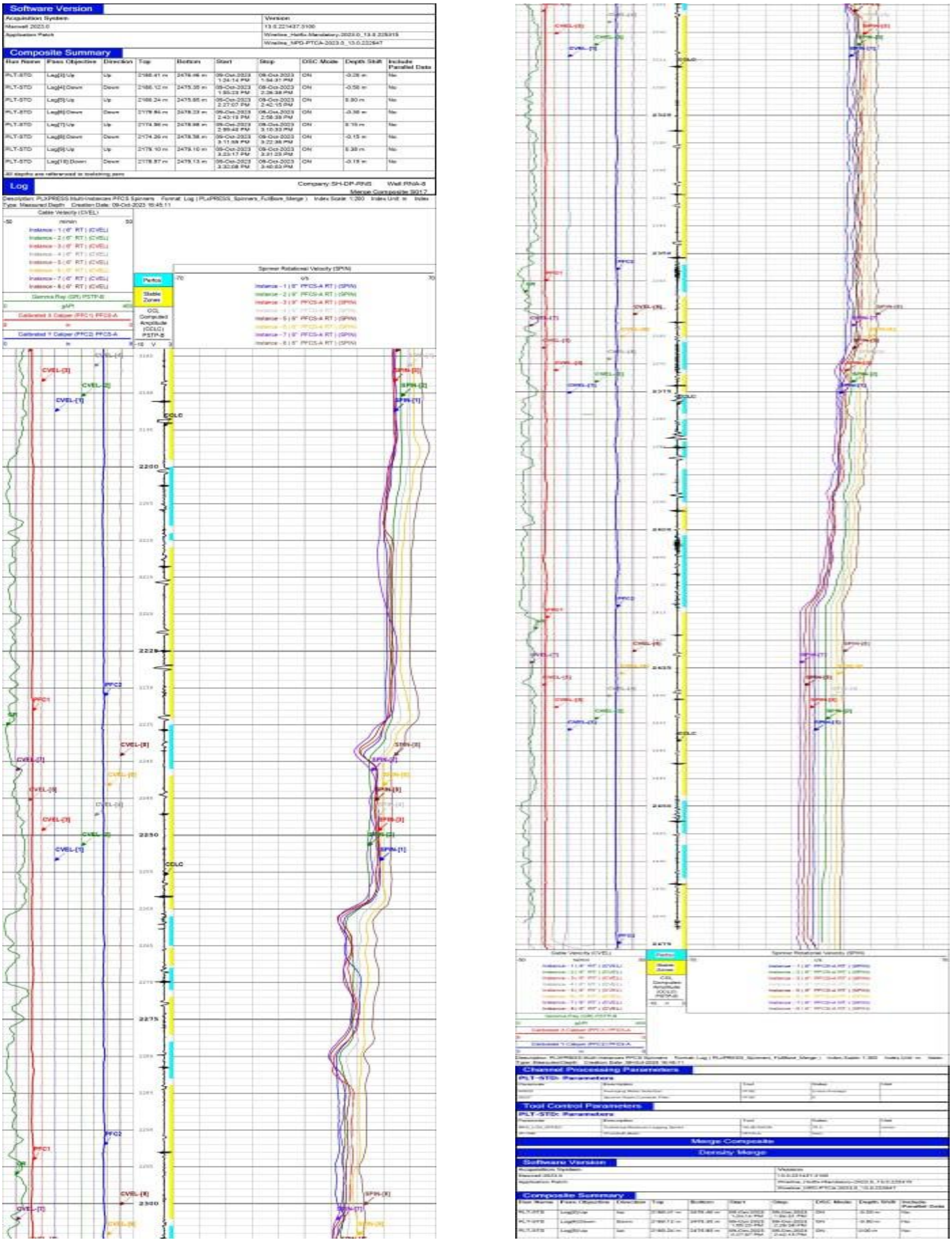

Figure Annexe B-4: Recording of MPLT CVEL, GR, Spin, Caliper X Y of all runs 09/10/2022 for RNA8 well.

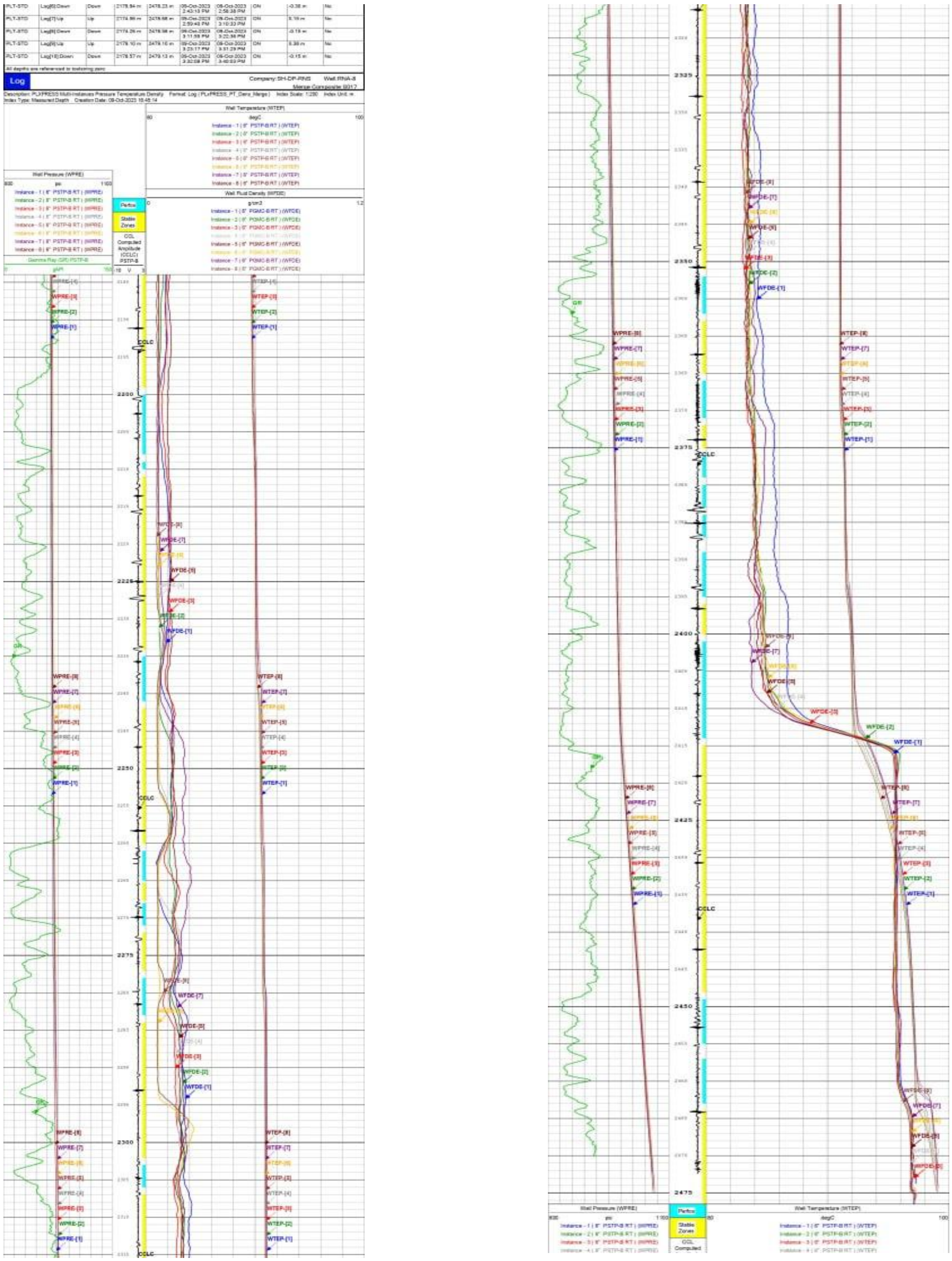

Figure Annexe B-5: Recording of MPLT GR, WPRE, WTEP, WFDE of all runs 09/10/2022 for RNA8 well.

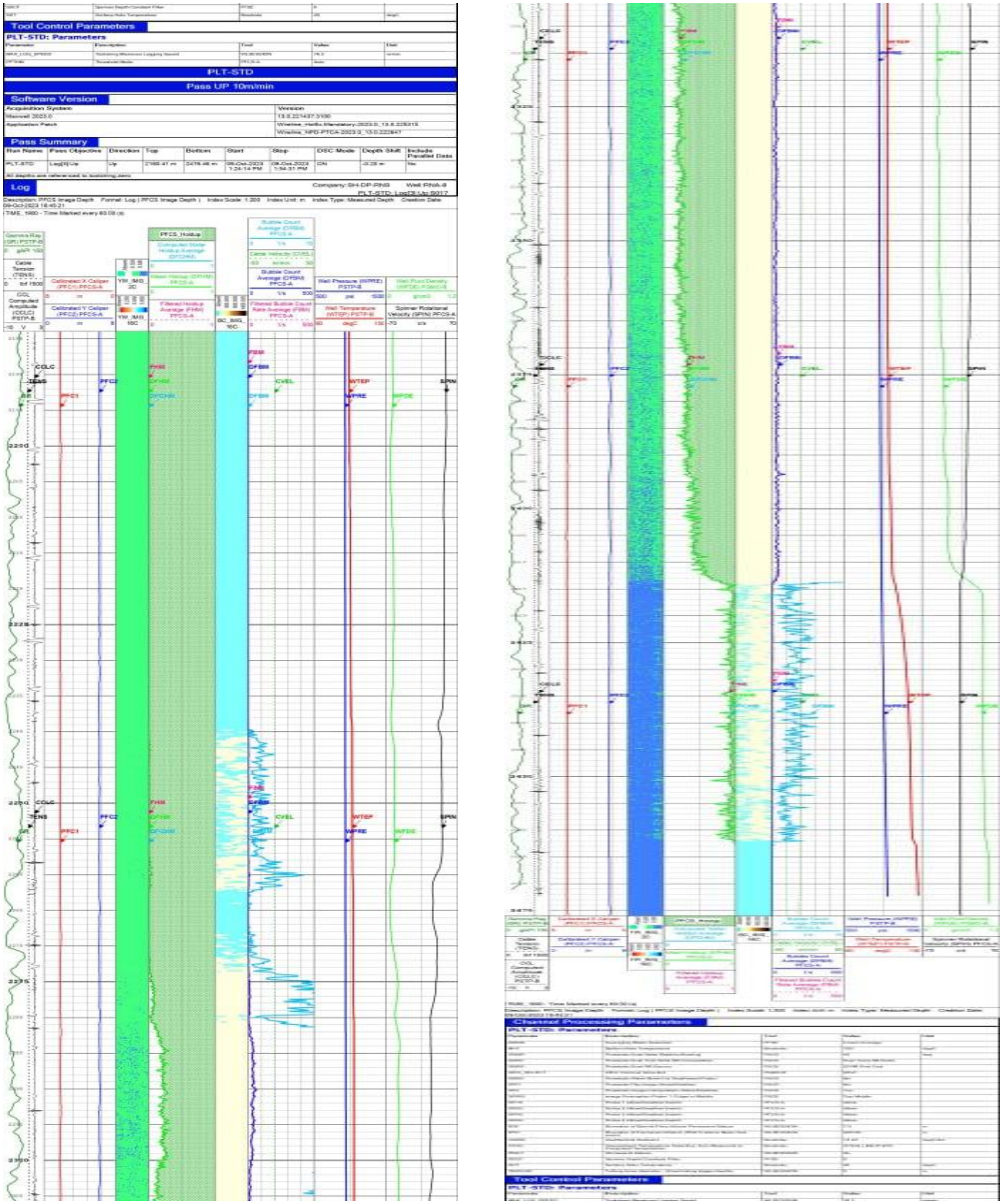

Figure Annexe B-6: Recording of MPLTGR, CCL, Caliper X Y, Water holdup, Bubble count average, WPRE, WFDE of all runs 09/10/2022 for RNA8 well.

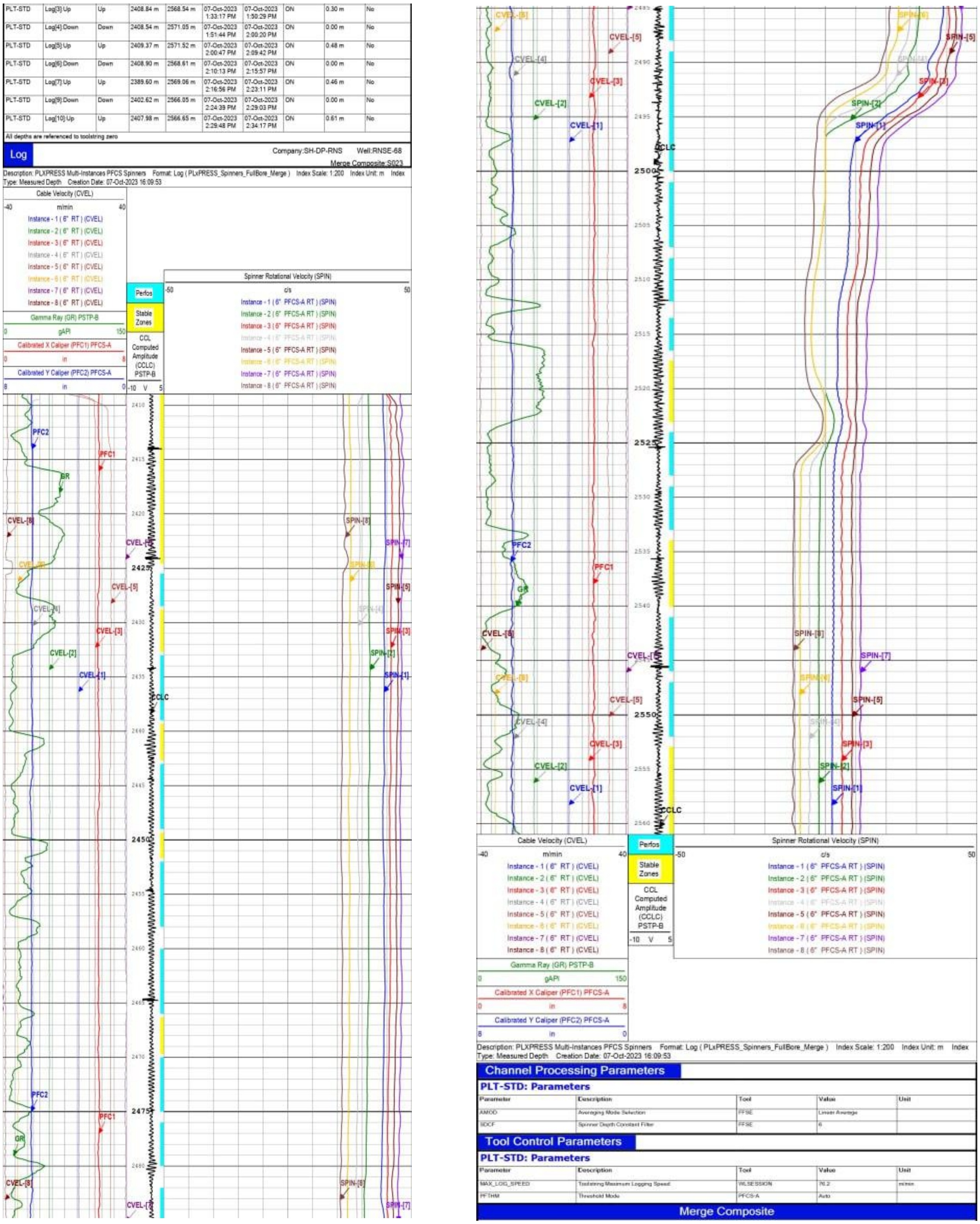

Figure Annexe B-7: Recording of MPLT CVEL, Caliper X Y, CCL GR, Spin of all runs 01/09/2022 for RNSE68 well.

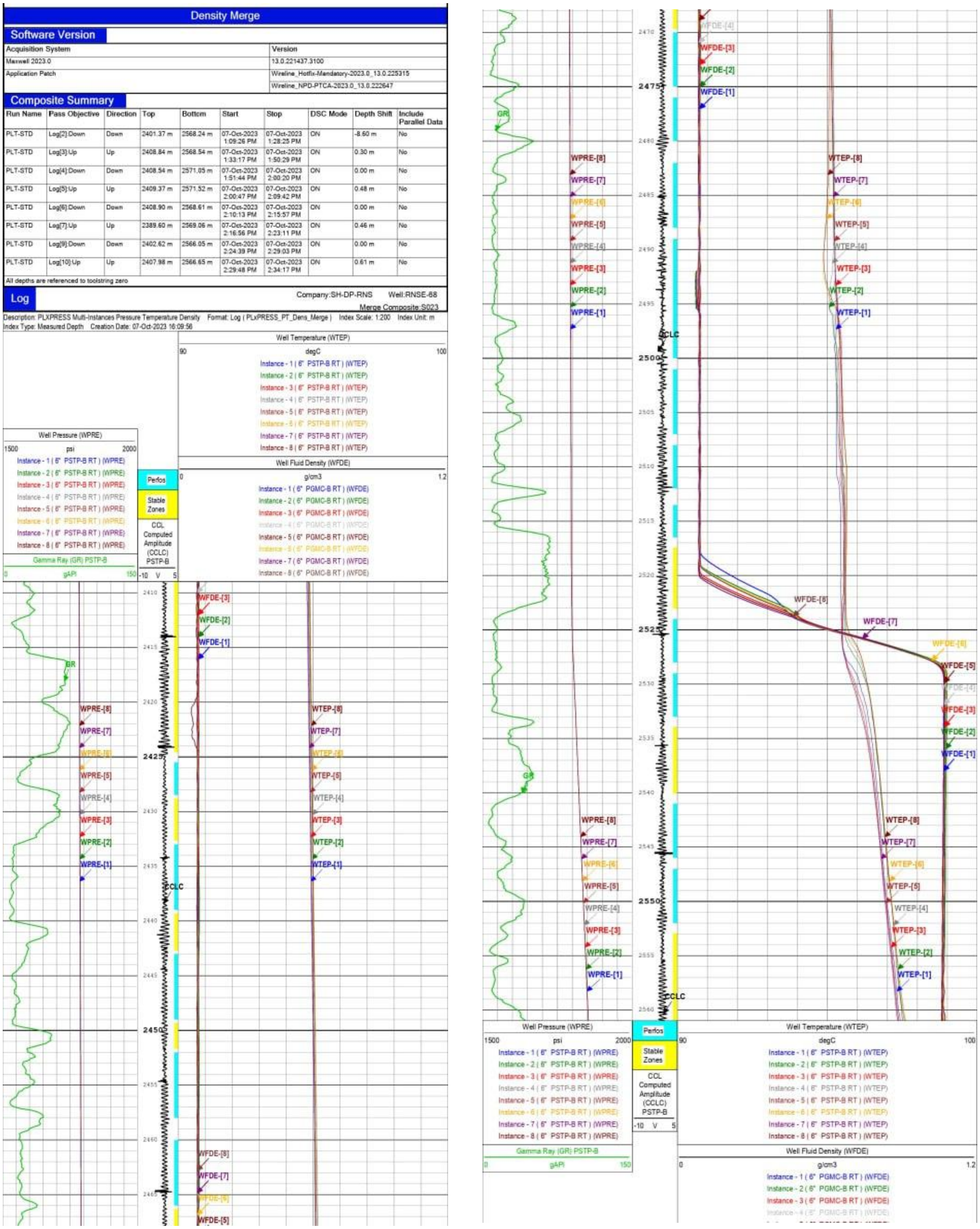

Figure Annexe B-8: Recording of MPLT GR, CCL, WPRE, WTEP, WFDE of all runs 07/10/2023for RNSE68 well.

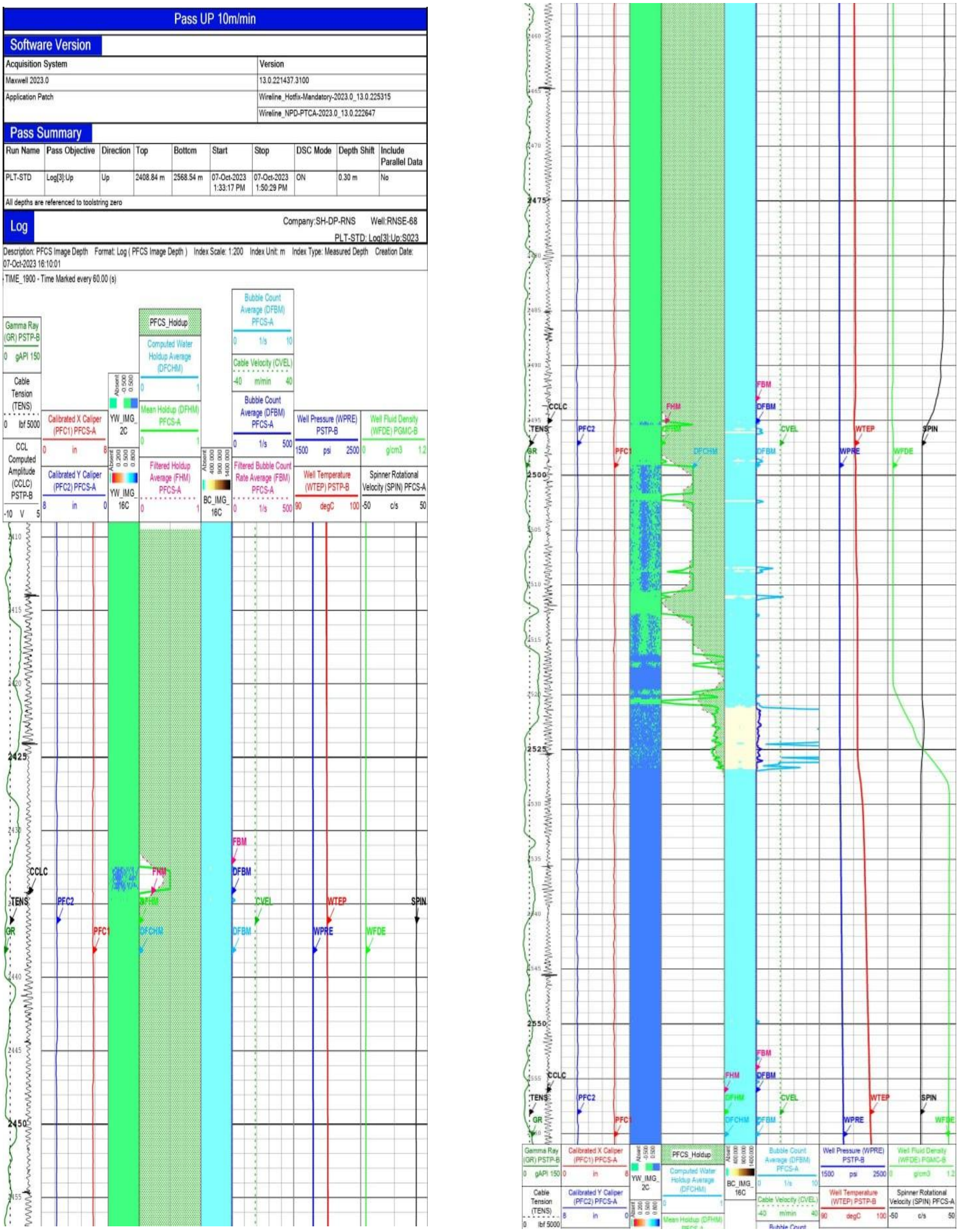

Figure Annexe B-9: Recording of MPLTGR, CCL, Caliper X Y, Water holdup, Bubble count average, WPRE, WFDE pass down 10m/min 07/10/2023for RNSE68 well.

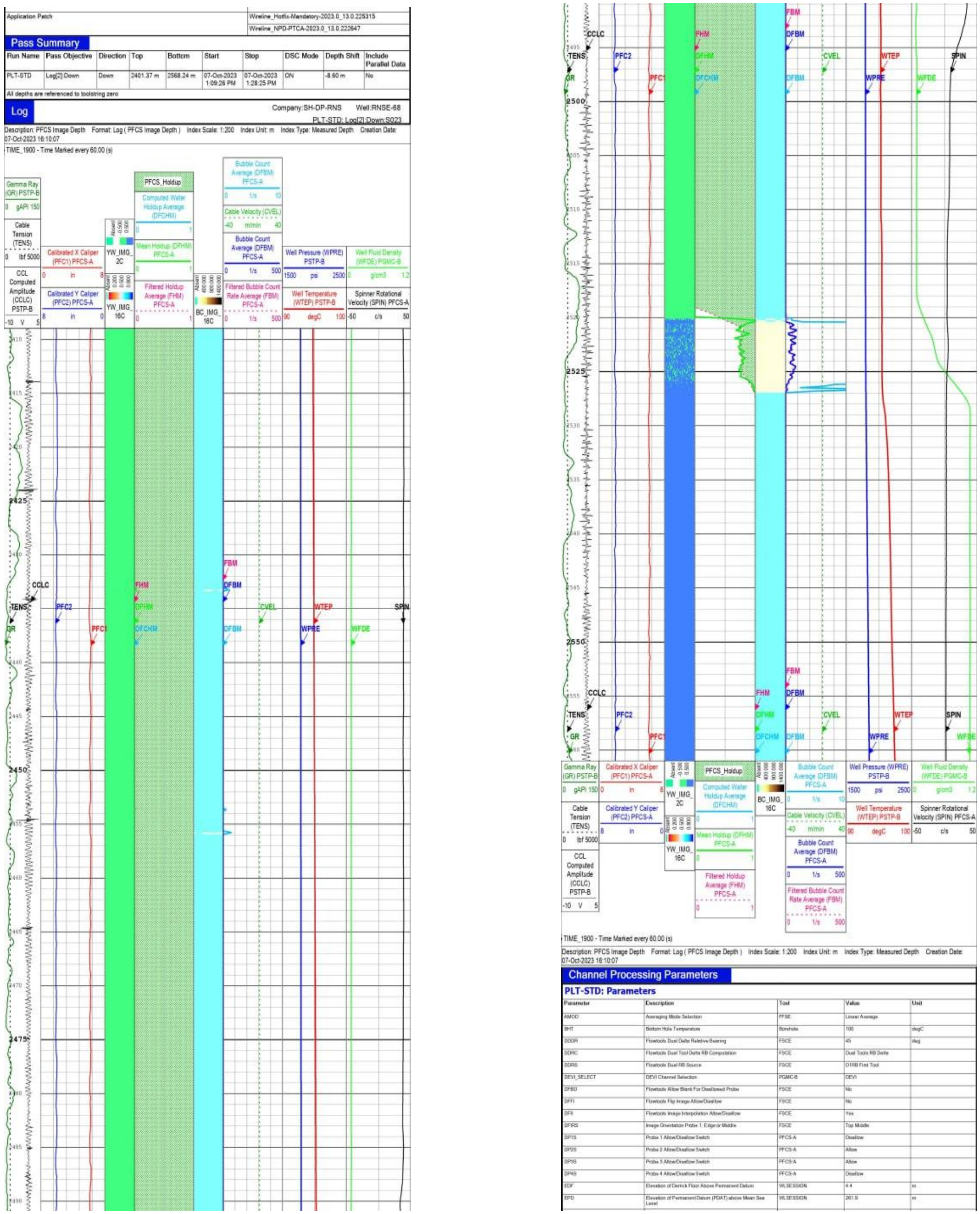

Figure Annexe B-10: Recording of MPLTGR, CCL, Caliper X Y, Water holdup, Bubble count average, WPRE, WFDE pass up 10m/min 07/10/2023for RNSE68 well.