



Foundation PL Course

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FOUNDATION PRODUCTION LOG INTERPRETATION COURSE

Module #1 Introduction

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Course Objective

COURSE MATERIAL COVERS:

- Tool theory of the most common Production Logging tools. (Flowmeter, Density, Temperature, Capacitance, Pressure)
- QA/QC Data quality, Pre-interpretation data editing
- Basics of PL interpretation
- Calibration and single-phase interpretation
- Simple multi-phase interpretation
- Application on real data, learning and using Emeraude

AFTER THE COURSE YOU SHOULD BE ABLE TO:

- Plan, coordinate and supervise a PL Job
- QAQC a PL data set
- Perform a spinner calibration
- Generate a simple multiphase PL interpretation

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PL Objectives

Production logging encompasses a number of well logging techniques run on completed injection or production wells, with the goal being to evaluate the well itself or the reservoir performance.

SPE Monograph 14, "Production Logging", Hill A.D.

The purpose of production logging is to provide the most detailed knowledge possible of the nature and behavior of the fluids in the well during production or injection"

Production Log Interpretation, Schlumberger



What is PL?

A record of one or more in-situ measurements that describe the nature and behaviour of fluids in or around the borehole during production or injection.

Production logs are now run for the purpose of:

- Monitoring & controlling the reservoir
- Analyzing dynamic well performance
- Productivity or injectivity of different zones
- Diagnosing problem wells
- Monitoring the results of a stimulation or completion.

The term is sometimes extended to include logs run to measure the physical condition of the well, completion and reservoir properties.

- Cement bond
- Pulse neutron logs
- Corrosion logs
- Radioactive tracer logs
- Noise logs



History of PL

The earliest production logs consisted of:

- Temperature logs (1930s)
- Flowmeters (1940s)
- Fluid-density and capacitance logs (1950s).
- Array probe measurements (1980's)

Flow-rate measurements were gradually improved by:

- the development of tracer logs
- improvement to the basic spinner flowmeter.

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Recent PL Developments

These tools were adequate for near-vertical wells with single or biphasic flow, but could be misleading in highly deviated, and especially in horizontal, wells.

New techniques were developed starting in the 1980s:

- Array tools to measure holdup at different points across the borehole
- Nuclear techniques to analyze the total holdup of all three phases. TPHI processing.
- Direct phase velocity measurements for the analysis of individual fluids. Oxygen Activation log.
- Complex flow structures and flow regimes have been studied more extensively using flow loops. - **Models & Correlations**

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PL Applications

PL can be used in all stages through the life of a well.

- Initial Completions
- Natural Production Wells
- Secondary Recovery Production Wells
- Injection Wells



Classical PL Applications

- Determine production profile – flowmeter, fluid identity, temperature
- Check for completion integrity... tubing, casing and packer leaks – flowmeter & temperature
- Check for channelling – temperature, flowmeter & tracer
- Check for operation of gas-lift valves – temperature
- Identify leaks
- Evaluate stimulation effectiveness. PL before & after
- Establish baseline PL with well in good shape
 - Determine if all perforations are effective
 - Determine Productivity Index
 - Determine individual reservoir pressures



Injection Wells

Applications include:

- Check for tubing, casing & packer leaks – Flowmeter, Temperature, Tracer, PNL
- Determine injection profiles – Flowmeter, Tracer
Are all the zones taking fluid?
- Check for channelling – Tracer, Temperature, PNL
- Check if regulator valves are working correctly – Flowmeter

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PL in Reservoir Engineering

The task of the reservoir engineering is similar to a financial investor:

- **How are my assets doing**
- **How can I improve the performance**
- **How can I maximize the value of the resources I have**

Condition for good asset management:

A Reservoir Model

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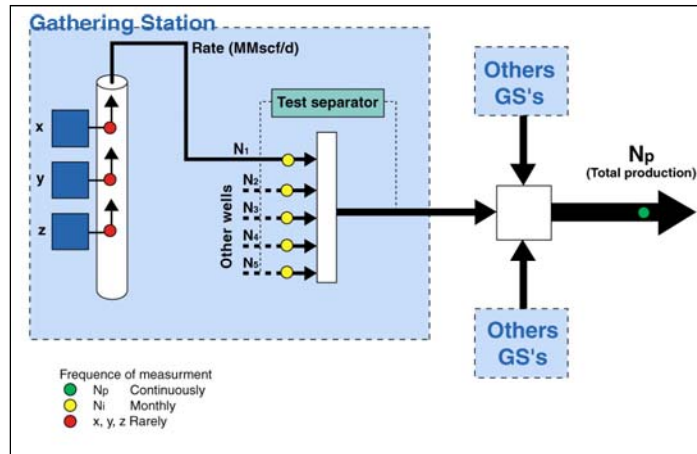
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Monitoring Total System

Surface Measurements: generally OK, but well produces from more layers.

Allocation: what is x, y, z for Oil, Gas and Water



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Reservoir model

A reservoir model describes the performance of the reservoir as function of time and production policies

It describes the theoretical performance

The model needs to be:

- checked
- calibrated

and adjusted with real observations:

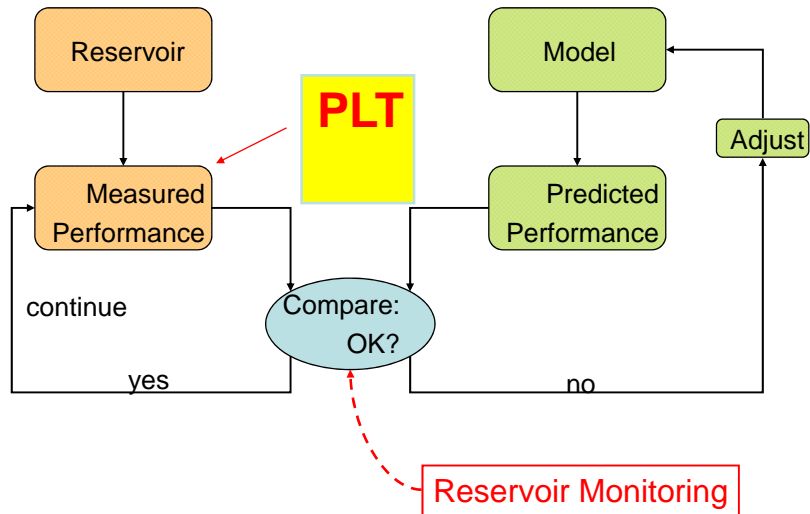
- reservoir/well monitoring

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Modeling & Monitoring



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Reservoir monitoring: PL

Production Logging:

Analysis of the well condition as function of depth, e.g. individual contribution of all reservoir layers

Multi-Rate Production Logging (MRPL):

Does this with the well flowing at different rates.

Potential source of information for:

- Reservoir pressure
- Permeability/Completion efficiency: PI (productivity index) and Skin/Permeability (in coordination with PTA program)

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Why PL: Conclusion

Modern software and the affordability of high precision tools have transformed the use of PL:

- Most surveys are easy to run (memory tools on slickline)
- Interpretation done by the engineers. They know what they need, and realize that PL can give the answer.
- PL can give unique information, unobtainable via any other method
- The client (e.g. petroleum engineer) is now the driver

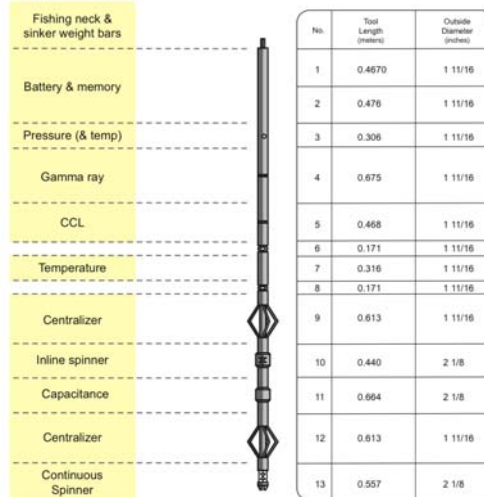
Production Logging is now a fully developed tool for Reservoir Monitoring

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Typical PL Toolstring



Sondex MPLT string

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Conveyance Methods: SRO

SURFACE READOUT: monoconductor cable etc.

Advantages

- Reliable
- Real time quality control of data at surface
- Program can be adjusted depending on results
- Can log all tool types and combinations

Disadvantages

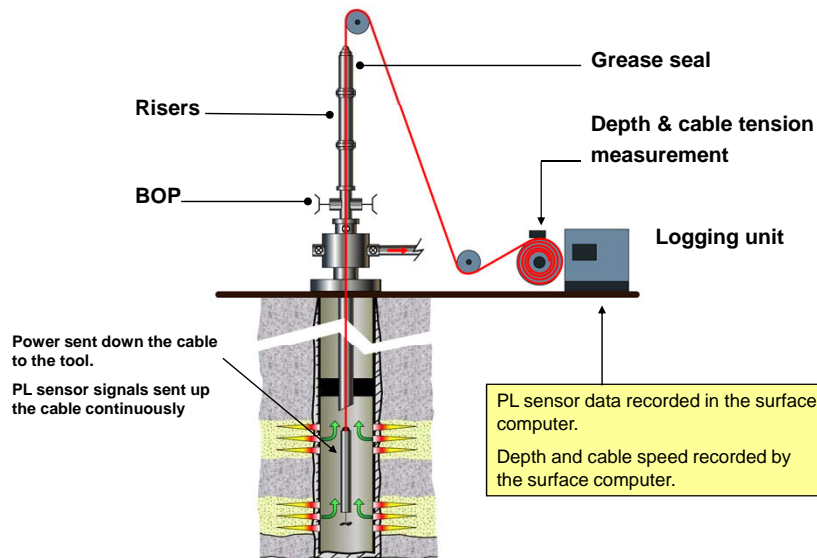
- Constraint in deviation ~60-70deg
- Usually more expensive than slickline in logistics
- Need surface data acquisition system (logging unit)

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PL operations: Surface Read-Out



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Conveyance Methods: Slickline

MEMORY: Slickline conveyed

Advantages

- Less costs, especially in logistics.
- Fast – no need for grease injection
- Easy to run
- Slickline unit available on most offshore facilities
- Portability

Disadvantages

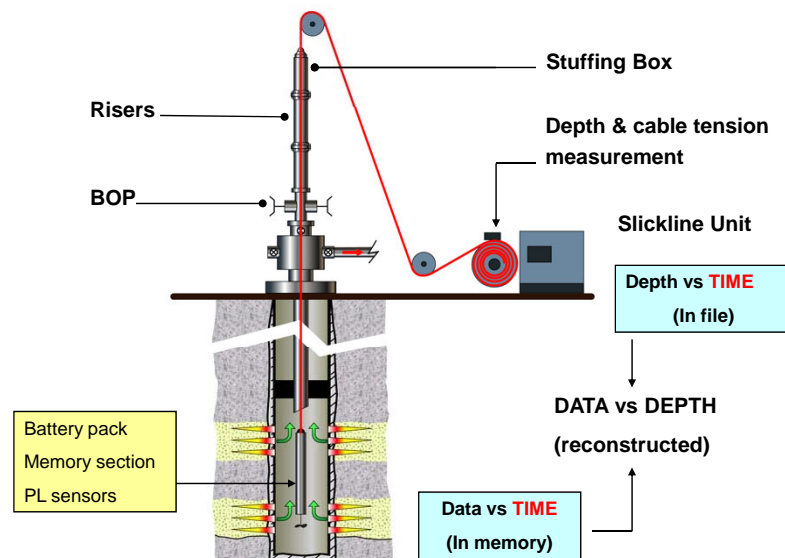
- Constraint in deviation ~60-70deg
- Once set, no change in acquisition mode
- No QA/QC at surface during acquisition
- Some limitations on sensors (power requirements)

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PL operations: Memory

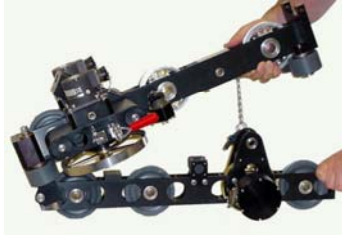


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Depth Measurement



Courtesy : NOV ELMAR

- Spring-loaded measure wheels measure the amount of wireline cable passing through.
- The measure wheels drive 1200 pulse/rps (600 pulses/ft) optical encoders that transmit electrical signals, to the logging computer, for depth and cable speed.
- Often an independently powered magnetic encoder is used for back up depth indication.

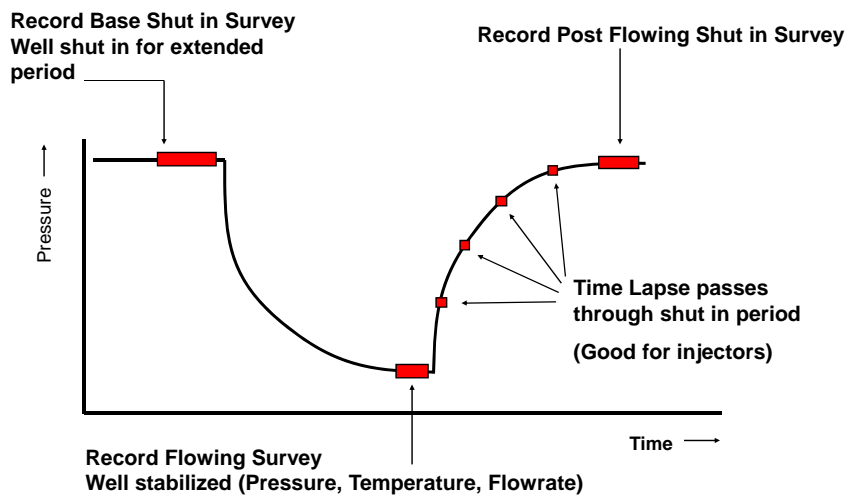


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Logging Sequence



*Note: Various constraints may limit the recording or extent of some of the surveys above.

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Shut in Survey: information

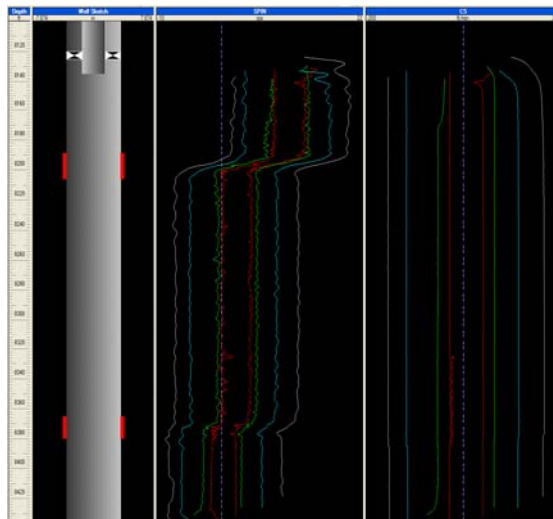
- **Identify fluid contacts in the wellbore**
 - could be useful for spinner calibration purposes
 - useful for Capacitance end point calibrations
- **Density reading of tool at downhole conditions**
 - possible PVT constraint values for interpreted phases
- **Shut in temperature profile**
 - for overlay with flowing temperature passes
 - establish geothermal temperature gradient
- **Identify crossflows**
 - for possible use in SIP and understanding of reservoir
- **Shut in bottom hole pressure profile**
 - and fluid pressure gradients

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Typical PL Job



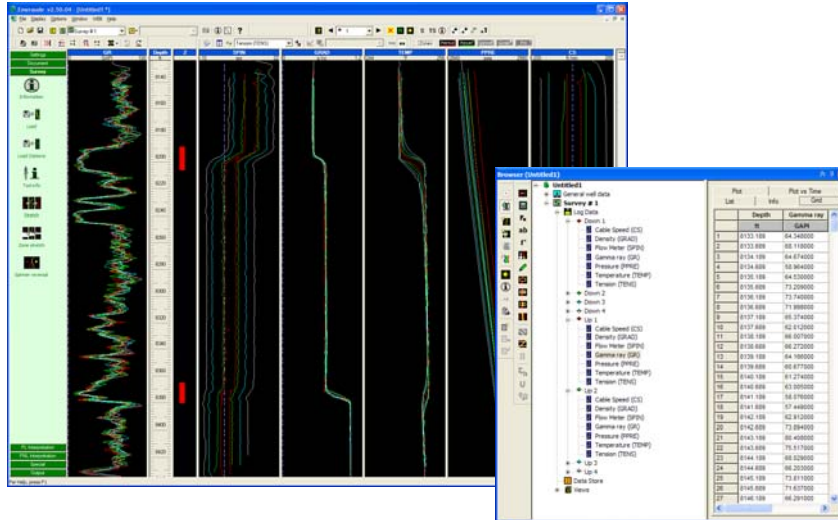
- How many passes are needed for an interpretation?
- Why do we log 3 or 4 up and down passes?
- Typical logging speeds
(Oilfield) 30, 60, 90, 120 ft/m
(Metric) 10, 20, 30, 40 m/min
- Normal logging sequence proceeds from slower to faster passes (order not critical)

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PL data

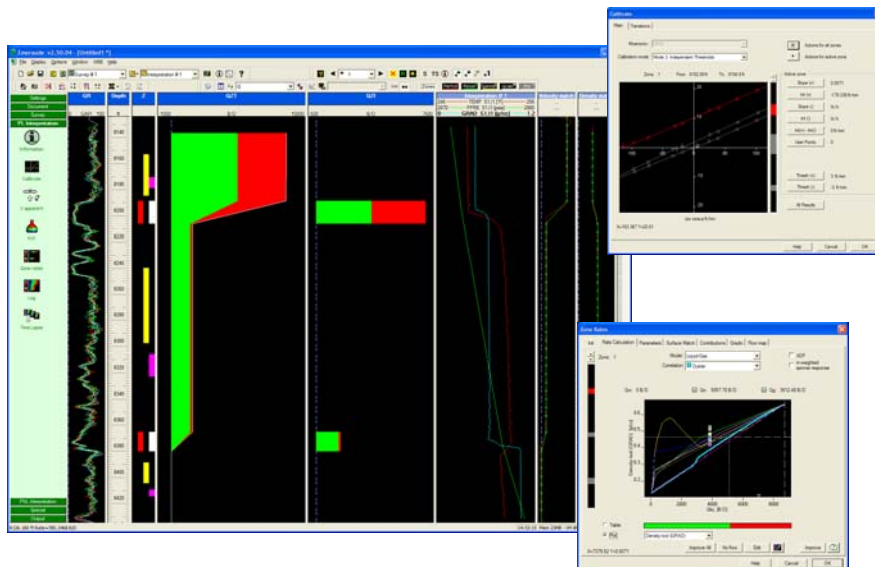


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PL data interpreted



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Stations

**Sensor data is usually independent of logging speed.
Data acquired from stations can be averaged and “merged” and used in exactly the same way as data from flowing passes.**

- If spinner calibration data is known, stations can give velocity information.
- Passes have better coverage than stations, as they span the total interval with continuous data.
- Some measurements require stations e.g. PVL, Radioactive tracer logging – velocity stations.
- Some sensors only achieve sufficient accuracy when logged for prolonged periods. E.g. Oxygen activation, WFL, Spectral Flow

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Stations

REASONS FOR STATIONS:-

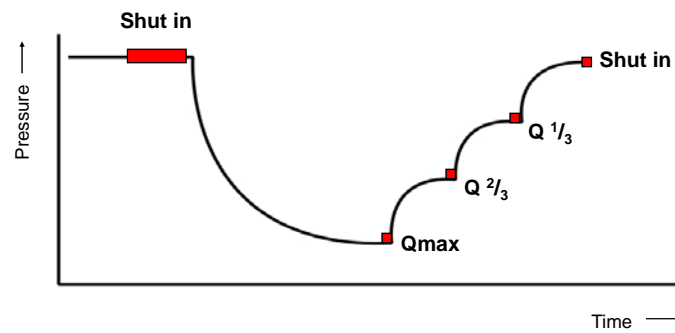
- Monitor stability of well
- Record stabilized pressure reading
- Record buildup or falloff for Pressure Transient analysis
- Evaluate for flow direction in low velocity areas (+/- spinner sign)
- Log vs time for flow regime evaluation
- Oxygen activation water velocity measurement
- Basket/Diverter Flowmeter
- Pressure Gradient stops
- Confirmation of log response observed on passes
- Density of fluids without friction effect caused by cable velocity
- Just because it is on the logging program.. ☺

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Multirate PL: MRPL



- The sequence of rates can be adjusted to suit operational & reservoir requirements.
- Many clients prefer to perform Q_{max} first, to ensure best clean out of well, and best chance of clean stable flow.
- For SIP analysis, stabilized flowing periods should be of similar durations.