Maximizing well productivity through cased hole logging

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Objectives

Maximize Rate $Q_{\text{max}}$

Current well performance

Shut-offs
Tubing/casing Clean up
Acid jobs
Conformance treatments
Fractures
Artificial Lift

Well productivity

Reservoir

Lift
Inflow Performance

\[ q = \frac{k \cdot h \cdot (\bar{p} - p_{wf})}{141.2 \cdot B \cdot \mu \cdot (\ln \frac{r_e}{r_w} + S)} \]

- \( q \): Oil Rate
- \( k \): Permeability
- \( h \): Thickness
- \( B \): Oil volume factor
- \( \bar{p} \): Average reservoir pressure
- \( p_{wf} \): Bottomhole flowing Pressure
- \( r_e \): External radius (drainage)
- \( r_w \): Wellbore radius
- \( S \): Skin
Pressure drop in Pipes

\[ \Delta P = \rho_m \Delta z \ g + \frac{2 f_f \rho_m u^2 L}{D} + \rho_m \Delta u^2 \]
Well Deliverability

- Increased production
- Water shut-off
- Scale removal
- Tubing sizing
- Acid, fracture
- Perforating
Selective Inflow Performance

Q_g = 15 mmscf/d

Layer 1
5 MMscf/d

Layer 2
10 MMscf/d

PLT: 3 rates + Shut-in passes

Q_g \sim c (P_{res}^2 - BHFP^2)^n

Obtain Pressure & Productivity layerwise
Very good understanding of well behaviour

© READ Cased Hole
Production Logging Tools

Minimum data required for interpretation:

Single Phase Flow:
- Velocity

2 Phase Flow:
- Velocity
- Density/Hold-up

3 Phase Flow
- Velocity
- Density
- Hold-up

Water: Full Bore Inline Continuous Diverter
Gas: Gradio Electrical Nuclear Tuning Fork
Nuclear Optical
Deviated/Horizontal Wells

Flow structure not simple any more

- Monophasic water at the bottom
- Dispersed/Monophasic Oil in the middle
- Monophasic Gas at the top

Conventional PL Tools may miss the oil, or gas, flowing on the high side, or water on the low side of the well
Deviated/Horizontal Wells

Need for Distributed measurements across the well cross section

Domain of Multiple Probe Tools (MPT)
MAPS

CAT

SAT

RAT
FAST

Ultra-compact production logging tool (3 ft) delivering typical PL measurements and array measurements.
Case Study 1

- >85% Wcut
- PLT to determine water entry points
- Water increases Pwf
- How much oil are we losing?

3 Zones producing only water

Water drive reservoir
Case Study 1

\[ \Delta P_h = \rho_m \Delta z g \]

\[ \rho_m = \rho_w Y_w + \rho_o Y_o \]

1600 BBL/D Incremental  
110000 $/D (@70 $/B)

2300 BBL/D Incremental  
160000 $/D (@70 $/B)
Case Study 2: Pre shift SSD

Oil hold-up was not measured accurately using centreline tool.
Oil production start from Z4, mostly from Z5 – Z8. Z1 – Z3 produce mostly water only.
Case Study 2: Post SSD Shift

Improvement in oil production after closing Z2, the increment (~1500 bopd) sustained for more than 5 months. Water cut reduced further after a week.
Case study 3: Scale

Unknown condition

Moderate condition with ~30% max penetrations

\[ \Delta P_F = \frac{2 f_f \rho_m u^2 L}{D} \]

1700 B/D
Case study 3: Scale removal

Tubing revealed to be in poor condition.

Full wall penetration revealed

1900 B/D
Multifinger caliper

- 24, 40, 60 and 80 fingers
- SRO or Memory
- Combinable with any other Ultrawire product
- 40 fingers HPHT READ proprietary development (220 degC & 20ksi)

Scale
Leak detection
Deformation / integrity issues
SSD status
Magnetic Thickness

- 12 Sensors and AC transmitter
- 150 degC, 15000 psi
- 2 – 7” pipe range
- Ultrawire toolbus standard
- Inner and outer corrosion
Case Study 4: Flow behind casing

Well producing above the WOC

Surface measurements indicate water (400 BPD)

Water channelling behind casing
NTO

- Based on hydrophone sensor sealed in an oil filled chamber
- Frequency range from 0 – 12.8 kHz
- Combinable with all sondex tools, memory or SRO
- Performs a FFT downhole by digitising data into 128 x 100hz wide, 16 bit frequency bins
RBT

- Electronics
- Transmitter
- 3ft Radial / Amplitude Receiver
- 5ft Receiver For VDL

Intermediate omnidirectional amplitude
Casing arrival time seen
Casing arrival seen
Non uniform amplitudes of segments
Channel on Cement Map
Pulsed Neutron: Waterflow Log

Operator is keen to find out the path of water injection. WFL indicates the injected water flow exits from a leak above packer and flow upward in annulus. Spinner data confirm the injection water exit from the leak.
Illustration of Pulsed Neutron Activity

- The neutrons are travelling and colliding with other atoms like Carbon and Oxygen.
- Eventually, the neutrons collide with hydrogen atoms, causing inelastic gamma rays with energy levels characteristic of the collision atom.
- These inelastic events only occur while the neutrons are epithermal (traveling fast). They tend to be relatively near the borehole and early in time as compared to capture events.
- The typical measurement during this period is the Carbon/Oxygen ratio.
Case Study 5: Identify Bypassed Oil

Carbon/Oxygen and Sigma are useful techniques to identify bypassed oil. C/O in particular is useful for low resistivity environment.

In this example, the C/O data confirm presence of bypassed oil in the 13.375” casing section.

The burst ratio (RNLB/RNFB) indicate changes of borehole environment.
Increasing Net pay

\[ q = \frac{k h}{141.2 B \mu} \frac{(\bar{p} - p_{wf})}{(\ln \frac{r_e}{r_w} + S)} \]

Note: Zones may have different petrophysical properties and be at different pressures
Pulsed neutron capture (sigma) is a versatile tool to identify gas in the formation. Recent tool with multi-detector allow increased sensitivity.

- Gas-oil contact could be useful in well planning.
- Gas-water contact typically useful for water-shut-off.
- Opening gas-cap could be an option for natural gas-lift.

\[ \Delta P_h = \rho_m \Delta z g \]
Summary

Unparalleled safety and operational record

Fast, accurate answers

Concentrated logging experience

Innovative and flexible commercial approach

Aligning products and services with customer specific needs
Thank you