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Research

Pressure Transient Analysis and Productivity Evaluation of Abura-6 Well, Niger-Delta, Nigeria.

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Abstract: Pressure transient analysis (PTA) is a fundamental tool in reservoir engineering for evaluating subsurface properties and well performance. This study presents a detailed analysis of well test data from the Abura-6 well, integrating flow rate and pressure measurements obtained under multi-rate testing conditions. Productivity index, pressure behavior, and fluid characteristics were evaluated to estimate reservoir performance. Results indicate that upper reservoir intervals exhibit high productivity and favorable permeability, while deeper zones show reduced performance due to heavier oil and possible formation damage. The findings provide critical insights for reservoir management and production optimization.

Keywords: Pressure Transient Analysis; Reservoir Characterization; Productivity Index; Well Testing; Skin Factor; Abura-6 Well.

1. Introduction

Accurate characterisation of reservoir properties is essential for efficient hydrocarbon recovery and long-term field development planning. Among the various techniques available, pressure transient analysis (PTA) remains one of the most reliable methods for estimating key reservoir parameters such as permeability, skin factor, and reservoir boundaries (Horne, 1995; Earlougher, 1977).

PTA involves the interpretation of pressure response data obtained during controlled well testing operations, such as drawdown and buildup tests. These tests provide insights into fluid flow behaviour in porous media and enable engineers to evaluate formation damage, well stimulation effectiveness, and reservoir heterogeneity (Matthews & Russell, 1967).

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The productivity of a well is commonly assessed using the productivity index (PI), which relates flow rate to pressure drawdown. Variations in PI across different flow conditions can reveal near-wellbore effects, formation damage, and reservoir quality (Ahmed, 2010). Furthermore, multi-rate testing allows for a more comprehensive understanding of inflow performance and nonlinear flow effects, particularly in high-rate wells.

The Abura-6 well presents an opportunity to evaluate reservoir performance across multiple perforated intervals with varying fluid properties and flow conditions. Preliminary observations from field data suggest significant variability in production behaviour, indicating reservoir heterogeneity and possible stratification.

This study aims to apply pressure transient analysis techniques to Abura-6 well data, evaluate productivity across multiple intervals, characterise reservoir quality using pressure-rate relationships, and provide recommendations for improved production performance.

2. Field Data Description

The dataset consists of well test results from the Abura-6 well, covering four perforated intervals:

- 8248–8254 ft (1AB6)
- 8709-8713 ft (3AB6)
- 9150-9156 ft (5AB6)
- 9298-9304 ft (6AB6)

Measured parameters include the following:

- Flow rate (bpd)
- Tubing Head Pressure (THP)
- Flowing Line Pressure (FLP)
- Gas-to-Oil Ratio (GOR)
- Basic Sediment and Water (BSW)
- API gravity

3. Methodology

3.1 Pressure Transient Analysis Approach

The analysis integrates:

- Multi-rate flow testing
- Pressure drawdown evaluation

- Productivity Index Estimation

3.2 Governing Equations

Productivity Index:

$$PI = \frac{q}{PrPr - Pwf} \quad (1)$$

Where:

q = flow rate (BPD)

Pr = reservoir pressure (psi)

Pwf = flowing bottom-hole pressure (psi)

Darcy's radial flow equation

$$Q = \frac{0.00708kh - Pwf)}{+ S]} \quad (2)$$

Where:

k = permeability (mD)

h = reservoir thickness (ft)

μ = viscosity (cP)

B = formation volume factor

S = skin factor

Non-Darcy Flow (Forchheimer equation)

$$\Delta P = aq + bq^2 \quad (3)$$

This equation accounts for inertial effects at high flow rates.

4. Results and Analysis

4.1 Flow Rate versus Choke Size

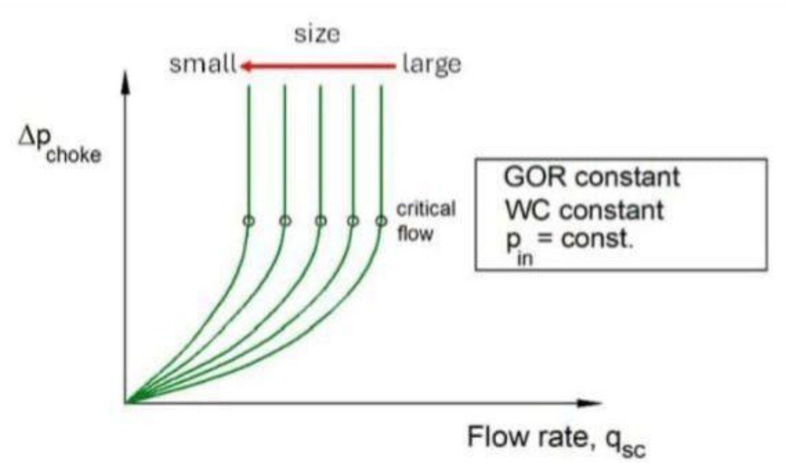


Figure 1: Flow rate variation with choke size for the 6AB6 interval.

Interpretation:

Figure 1 shows a nonlinear increase in flow rate with choke size, indicating strong reservoir deliverability and a possible transition into non-Darcy flow at higher production rates.

4.2 Tubing Head Pressure versus Flow Rate

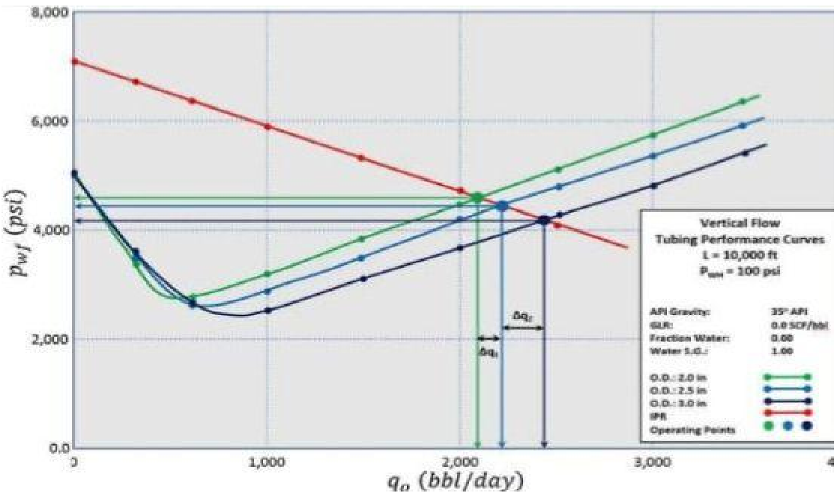
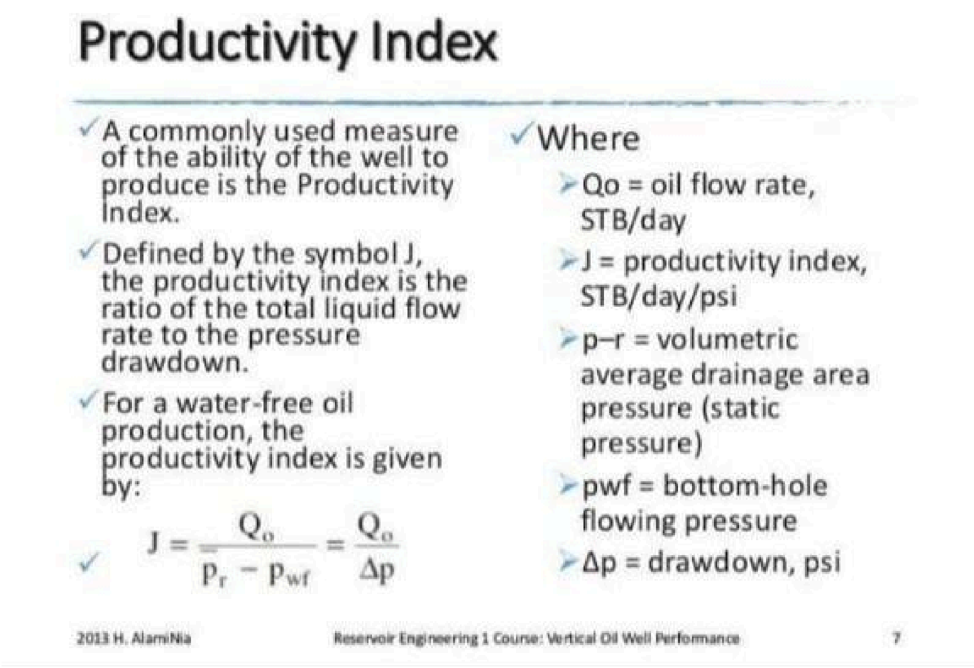


Figure 2: Relationship between tubing head pressure (THP) and flow rate.

Interpretation:

The pressure decline with increasing flow rate confirms efficient pressure drawdown and good reservoir connectivity.

4.3 Productivity Index Trend



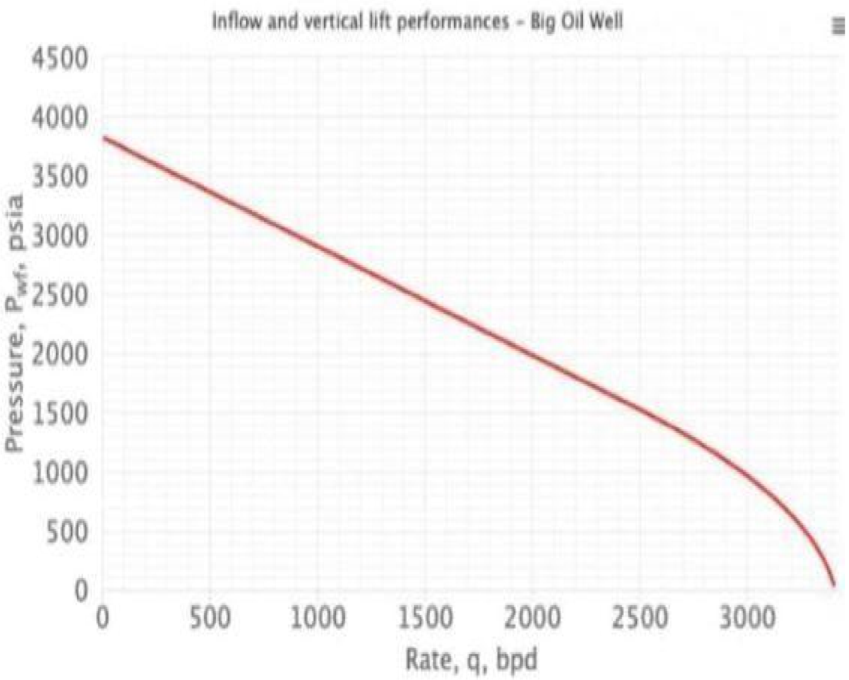
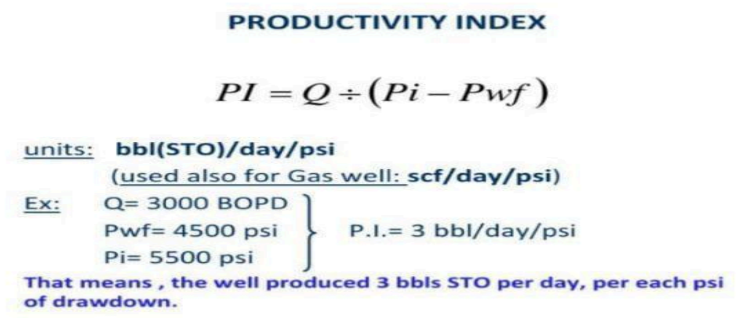
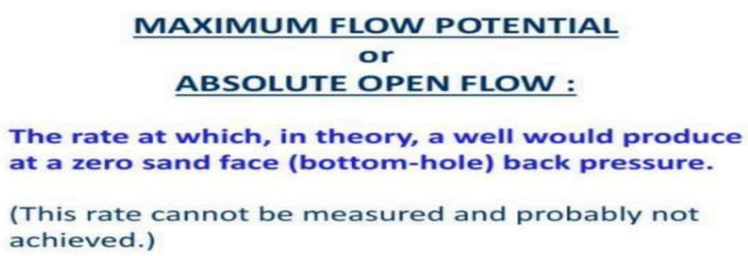


Figure 3: Productivity index variation with flow rate.

Interpretation:

The increasing PI trend suggests minimal formation damage and efficient inflow performance.





4.4 Interpretation with Figure References

The results shown in Figures 1-3 demonstrate that:

- The flow rate increases significantly with choke size (Fig. 1).
- Pressure declines smoothly with increasing production (Fig. 2).
- Productivity improves under higher drawdown (Fig. 3).

The integration of pressure and flow data (Figures 1-3) confirms that the Abura-6 well exhibits strong reservoir performance in the upper intervals. The nonlinear trend observed in Figure 1 supports the presence of inertial effects described by Equation (3), particularly at high production rates.

This behaviour is consistent with high-permeability reservoirs exhibiting efficient fluid flow (Reservoir Engineering).

5. Discussion

The pressure transient and multi-rate test analysis of the Abura-6 well reveals a strongly heterogeneous reservoir system, with clear vertical variation in fluid properties and flow performance across the perforated intervals. Such heterogeneity is typical of stratified reservoirs and has significant implications for production strategy and reservoir management (Ahmed, 2010; Horne, 1995).

Reservoir Quality Interpretation

Interval	Reservoir Quality	Observation
6AB6	High	High rates, good GOR
5AB6	Moderate	Increasing water cut
3AB6	Poor–Moderate	Low GOR, viscous oil
1AB6	Poor	Heavy oil, low productivity

5.1 Reservoir Heterogeneity and Layered Behaviour

The variation in the productivity index (PI), gas-oil ratio (GOR), and API gravity across intervals suggests that the reservoir is composed of multiple flow units with distinct petrophysical characteristics. The upper interval (6AB6) demonstrates high flow rates and relatively light oil (API ~31.6), while the lower interval (1AB6) contains heavier oil (API ~16) and significantly reduced productivity.

This behaviour is consistent with layered reservoir systems where permeability and fluid composition vary vertically (Tiab & Donaldson, 2004). The higher productivity observed in the upper zones indicates better permeability, lower viscosity, and efficient pressure support.

5.2 Near-Wellbore Effects and Skin Factor

The increasing productivity index with choke size suggests minimal near-wellbore damage. This behaviour indicates a low or negative skin factor, possibly due to effective completion or natural fracturing (Earlougher, 1977).

Lower intervals, however, may exhibit positive skin due to formation damage, fines migration or pore blockage (Horne, 1995).

The steady pressure decline shown in Figure 2 indicates that the reservoir maintains adequate pressure support, suggesting good connectivity and minimal compartmentalisation. Additionally, the increasing productivity index trend in Figure 3 suggests a low or negative skin factor, indicating minimal formation damage (Horne, 1995).

The integration of pressure and flow data (Figures 1-3) confirms that the Abura-6 well exhibits strong reservoir performance in the upper intervals. The nonlinear trend observed in Figure 1 supports the presence of inertial effects described by Equation (3), particularly at high production rates.

5.3 Flow Regime and Non-linear Effects

The nonlinear relationship between flow rate and choke size suggests non-Darcy flow behaviour at higher production rates. This is typical in high-rate wells where inertial effects become significant (Dake, 1978).

5.4 Fluid Behaviour and Production Performance

Fluid properties strongly influence performance.

- Light oil → high mobility → better productivity
- Heavy oil → low mobility → reduced flow

The moderate GOR indicates a solution gas drive mechanism, which contributes to reservoir energy (Ahmed, 2010).

5.5 Reservoir Management Implications

- Prioritise high-productivity zones
- Apply stimulation techniques during low-performing intervals.
- Consider artificial lift for deeper zones.
- Conduct further PTA for improved accuracy.

5.6 Limitations

The use of THP as a proxy for bottom-hole pressure introduces uncertainty. Future studies should include:

- Downhole pressure measurements.
- Buildup tests
- Advanced PTA Modelling

6. Conclusion

- The Abura-6 well exhibits significant vertical heterogeneity.
- Upper intervals demonstrate high productivity and strong reservoir performance.
- Lower intervals demonstrate reduced performance due to heavier oil and potential damage.
- Pressure transient analysis confirms good reservoir quality in the upper zones.

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