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Two-rate drawdown test analysis to determine reservoir characteristics for the well (6J9-E59) in North Gialo field

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Abstract

The North Gialo field was discovered at the beginning of 2002. The first well that yielded commercial quantities of oil is well 6J-1. This paper applies the Russell and Pinson methods to assess reservoir characteristics through a two-rate drawdown test analysis for well 6J9-E59 in the North Gialo field, which was selected for this test due to its unstable production rate. The main objectives include estimating permeability, skin factor, and flow efficiency, as well as determining average reservoir pressure. Results reveal that the estimated value of reservoir permeability is 0.0354 md and the average skin factor is -1.021, indicating that the well has been treated successfully. The well flow efficiency is 133.83%, reflecting the improvement in well performance due to the treatment, and an average reservoir pressure of 9217.56 psi is determined using the Mathews, Bronze, and Hasbrouck (MBH) method. The investigation radius of 21.031 ft obtained from the test duration is relatively shallow, indicating limited influence around the well. This can have several implications: a shallow investigation radius suggests that the well may be encountering a confined area of the reservoir, potentially limiting overall drainage and recovery efficiency. To obtain a more comprehensive understanding of the reservoir, additional testing or longer-duration tests may be needed. This can help in assessing the flow characteristics over a broader area. Test duration of 225,048.9 hours is required to reach the reservoir boundary. Moreover, fluctuations in production rate do influence the accuracy of the study results. Results show favourable conditions for production optimization, with significant flow efficiency and a negative skin factor, have been obtained. These findings will inform future strategies for well completion and reservoir management.

Keywords: North Gialo field, Russell and Pinson methods, Reservoir Characteristics, Two-Rate Drawdown Test, MBH Method.

تحديد خصائص المكمن وضغطه الحالي باستخدام تحليل اختبار هبوط الضغط ثنائي التدفق للبئر 6J9–E59 بحقل شمال جالو

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الخلاصة

تم اكتشاف حقل شمال جالو في بداية عام 2002. أول بئر ينتج كميات تجارية من النفط هو البئر **6J1**. تم تطبيق طرق راسل وبينسون في هذه الورقة لتقييم خصائص الخزان النفطي من خلال تحليل إختبار تدفق ثنائي المعدل للبئر **6J9–E59** في حقل شمال جالو، والذي تم إختياره لهذا الاختبار بسبب معدل الإنتاج غير المستقر به. وتشمل الأهداف الرئيسية لهذه الدراسة تقدير النفاذية، وعامل تضرر الطبقة، وكفاءة التدفق، بالإضافة إلى تحديد متوسط ضغط الخزان. وتكشف النتائج أن القيمة التقديرية لنفاذية الخزان هي 0.0354 م ومتوسط عامل التضرر هو −1.021، مما يشير إلى أن البئر قد تم تحسينه بالمعالجة بنجاح. كفاءة تدفق البئر هي 133.83٪، مما يعكس التحسن في أداء البئر بسبب المعالجة، ومتوسط ضغط الخزان 9217.56 رطل لكل بوصة مربعة تم تحديده باستخدام طريقة ماثيوز وبرونز وهاسبروك (**MBH**). نصف قطر التحقق يساوي21.031 قدم والذي تم الحصول عليه من مدة الاختبار سطحي نسبيا، مما يشير إلى تأثير التحقق محدود حول البئر. قد يكون لهذا عدة آثار: يشير قطر التحقق الضحل

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إلى أن البئر قد يكون ضمن منطقة محصورة من الخزان، مما قد يحد من كفاءة التصريف والإسترداد بشكل عام. للحصول على فهم أكثر شمولا للخزان، قد تكون هناك حاجة إلى إختبارات إضافية أو إختبارات ذات زمن أطول حيث يمكن أن يساعد ذلك في تقييم خصائص التدفق على مساحة أوسع. مدة اختبار 225،048.9 ساعة مطلوبة للوصول إلى حد الخزان. بالإضافة الى ان التغير المفاجئ في معدل الإنتاج تؤثر على دقة نتائج الدراسة بشكل عام. وتم الحصول على ظروف مواتية لتحسين الإنتاج، مع كفاءة تدفق كبيرة ومعامل تضرر سلبي. وستُسهم هذه النتائج من خلال استراتيجيات مستقبلية لإكمال الآبار بشكل جيد وحُسن إدارة للمكامن النفطية.

الكلمات المفتاحية: حقل شمال جالو، طرق راسل وبينسون، خصائص المكمن النفطي، إختبار التدفق ثنائي المعدل، طريقة ماثيوس و برونز وهانزبروك.

1. Introduction

Although the basic theory of variable-rate pressure behavior in wells was developed many years ago, important contributions since that time have extended the original applicability to a much wider variety of situations. Reservoir engineers must have sufficient information about the condition and characteristics of the reservoir/well to adequately analyze reservoir performance and to forecast future production under various modes of operation. Production engineers must know the condition of production and injection wells to obtain the best possible performance from the reservoir pressure is the most valuable and useful data in reservoir engineering. Directly or indirectly, they enter into all phases of reservoir engineering calculations. Therefore, accurate determination of reservoir parameters is crucial.

A brief review of pressure transient analysis explains why advances in technology have had such a significant impact on well testing: At the start of production, pressure in the wellbore drops sharply and fluid near the well expands and moves toward the area of lower pressure. This movement is retarded by friction against the pore walls and the fluid's own inertia and viscosity. As the fluid moves, however, it in turn creates a pressure imbalance that induces neighboring fluid to move toward the well. The process continues until the drop in pressure that was created by the start of production is dissipated throughout the reservoir [1].

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Well testing is the technique and method for the evaluation of well conditions and reservoir characteristics, it involves producing a well at a constant rate or series of rates, some of which may be zero (well closed in), while simultaneously taking a continuous recording of the changing pressure in the well bore using some form of pressure recording device.

1.1.Two-rate testing

A two-rate test is a method used in the oil and gas industry to evaluate the productivity of a well. During this test, the flow rate of the well is first set at a lower rate, and then increased to a higher rate after a period of time. By monitoring the pressure and flow rates during this test, engineers are able to gather valuable data on the well's performance and characteristics. This information is crucial for determining the optimal production strategy and maximizing the overall output of the well. The primary objectives of a two-rate test in petroleum engineering revolve around providing an evaluation of reservoir properties and well performance. The test aims to obtain detailed insights into reservoir characteristics, such as permeability, skin factor, and average reservoir pressure through the analysis of pressure transient data obtained during the test. Additionally, it seeks to evaluate the effectiveness of well completion and stimulation techniques by assessing the productivity of the well. Moreover, the test aims to optimize reservoir management strategies by identifying potential reservoir heterogeneities and other factors that may impact production performance [1,2].
Pressure buildup analysis requires a long shut-in period and four times longer producing time for actual reservoir response. This is uneconomical for high production wells and tight formations due to income loss. Drawdown tests require long shut-in and constant flow rate, difficult to achieve in practice. To overcome these drawbacks, a multi-rate flow test should be run, yielding the same results as a single test, reducing income loss, minimizing phase redistribution effects and being less affected by wellbore storage due to less flow rate difference. The main disadvantage of any multi-rate test is the difficulty of maintaining a constant flow rate; high fluctuations in flow rates could lead to inaccurate interpretation.
This paper focuses on assessing the reservoir characteristics by a two-rate test analysis. That is achieved by estimating permeability, skin factor, flow efficiency and average reservoir pressure by

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applying both Russel and Pinson methods by using hand calculations.

The North Gialo field was discovered at the beginning of 2002. The first well on this one the locality whose testing yielded commercial quantities of oil is well 6J-1. During the period from 2002-2004, the well occasionally produced for 129 days cumulatively yielded 338.348 MSTB of oil, with an average production of 2623 STB of oil per day.

2. Previous studies

The two-rate test has been a critical method for assessing the productivity and characteristics of oil and gas wells. In recent years, numerous studies have been conducted to investigate the effectiveness of this test and its implications for well performance. This literature review aims to provide a comprehensive overview of the research conducted on the two-rate test, utilizing a descending chronological approach to summarize the key findings and methodologies employed in previous studies. By examining the evolution of research in this field, this review seeks to identify gaps in current knowledge and contribute to a deeper understanding of the factors influencing well productivity and optimization strategies, below is a comprehensive summary of the most important research papers related to the topic.

Wang et al. (2020) conducted a comprehensive research on the application of the Two-Rate Flow Test method in the petroleum industry for determining reservoir parameters was conducted and focused on the practical challenges encountered in the field operations of hundreds of wells in the Changqing Oilfield, China. The common practice of lacking pressure data before the production-rate change period during the Two-Rate Flow Test, which is essential for accurate interpretation results, was highlighted by the authors. The absence of this data was noted to potentially lead to unreasonable interpretations.

An extension of the conventional three-rate flow test was proposed by the authors in this review, involving the incorporation of the Gringarten-Bourdet type curve analysis method instead of a specialized plot to analyze testing pressure behavior. This modification, termed the modified two-rate flow (MTRF) technique, involved measuring a brief period of pressure data at an additional production rate, typically returning to the initial stabilized condition to minimize production losses, following the conventional two-rate flow test approach.

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It was demonstrated by the study that the total measurement time for the MTRF test was comparable or slightly longer than the conventional two-rate flow test, yet significantly shorter than a three-rate flow test.

Mathematical justifications of the Gringarten-Bourdet type curve applied in the MTRF test were re-derived, and well test designs for horizontal and multi-fractured horizontal wells were conducted by the authors to validate the applicability of the MTRF method.

It was indicated by the results that while the outcomes of conventional two-rate flow tests heavily relied on the initial parameters set, the values obtained through the MTRF method closely approximated the correct values even with varying initial parameters. Retaining the advantages of the two-rate method, this novel technique minimized result non-uniqueness by introducing an additional pressure history, thereby offering a double-check of crucial parameters such as permeability and reservoir pressure. (Wang et al., 2020) [3].

A. Mongi and Dr. Tiab, SPE, 2000, presented a novel approach for analyzing variable rate tests in oil reservoirs to address the challenges faced during pressure drawdown tests was proposed by the authors. Maintaining a constant rate for a sufficient duration can be problematic during a pressure drawdown test, potentially leading to inaccurate results if rate changes are not properly considered. Furthermore, limitations for pressure drawdown tests posed by sand-producing wells, while pressure buildup tests in high-production wells are deemed uneconomical due to income losses.

In response to these challenges, the conducting of multi-rate tests instead of buildup or constant rate drawdown tests is advocated for by the authors. Traditional analysis of multi-rate tests necessitates a type curve matching technique, typically involving a trial-and-error process.

Their proposed methodology, known as Tiab's Direct Synthesis, introduces a systematic approach that leverages the intersection points and slopes of straight lines derived from a log-log plot of pressure and pressure derivative data. By utilizing exact analytical solutions, the Direct Synthesis technique facilitates the determination of reservoir parameters. Additionally, the concept of pressure derivatives is introduced to enhance the interpretation of multi-rate tests, the Direct Synthesis technique is designed to accommodate the interpretation of continuously changing flowrate tests or a sequence of constant rate tests, offering a more efficient

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and accurate alternative to conventional methods. (A. Mongi and Tiab, 2000) [4].

Farida Chairul, SPE, 1984, conducted a research on the utilization of the Two-Rate Flow Test method in the Langkat Field Pertamina Unit EP–1 to estimate average reservoir pressure, formation permeability, and skin-factor. The necessary pressure data were obtained by observing transient bottom-hole pressure behavior following a change in the well's stabilized producing rate to a lower rate. The parameters required for the Two-Rate Flow Test analysis were similar to those used for conventional pressure build-up analysis.

The advantage of eliminating extended shut-in periods experienced with conventional build-ups due to long, low-rate production periods was offered by the application of this method. In 1983, 17 Two-Rate Flow Test measurements were conducted in the Langkat Field, potentially preventing a total production loss of about 1264 STB.

A consistent value of P* (P extrapolation) compared to pressure build-up tests was yielded by the analysis of flowing bottom-hole pressure data, except in oil-producing wells with a high water cut (water cut >50%). Additionally, it was found by the study that the effect of a fault could be indicated by the application of the Two-Rate Flow Test. (Farida Chairul, 1984) [5].

Jesus Rivera-R and Henry Ramey, Jr., SPE, 1977, discussed the utilization of established pressure transient analysis methods to determine geothermal reservoir parameters. Of the various pressure transient techniques available, those related to two-rate flow testing were chosen to be investigated by the authors. The implementation of a two-rate test has the potential to acquire data while minimizing disruptions to power generation processes. While two-rate techniques have been successfully employed in oil and gas reservoirs, there is a lack of published information, to the authors' knowledge, regarding the application of this approach in liquid-dominated geothermal reservoirs. Data from a single test conducted at a well in the Cerro Prieto Geothermal Field was presented by the authors.

Analysis of the field data was carried out using four distinct models, of which three produced consistent results while the fourth exhibited data discrepancies. (Rivera-R and Ramey, Jr., 1977) [6].

Odeh, A.S., Jones, L.G., SPE, 1974, presented a paper on the elimination of the disadvantages of the two-rate flow test and

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maintaining its advantages by removing the constant-rate requirement during the second flow period was discussed, thus making the test easier to run, and accounting for any fluctuation in rate in the calculations. The two-rate flow test, in the variable-rate case, is suited to wells that have been flowing at stable rates for a period that is relatively long compared with the second flow period. It is also suitable when semi-steady state flow occurs during the first flow period. This requirement is usually met by pumping and gas-lift wells, which are prime candidates for the test. In particular, the after-flow periods of buildup on these wells are readily analyzed with this approach. (Odeh et al., 1974) [7].

Earlougher, SPE, 1973, conducted a research on Pinzon's method when he does not indicate how long the initial flow period must be before the simplified analysis method provides valid results. A method for estimating the error obtained in transmissibility and skin factor when the simplified analysis technique is used for a two-rate flow test is presented in this note. This error can be used to decide which analysis technique to use. By combining the complete flow equations (2.1) and (2.2), the error in calculated transmissibility when the simplified simplified analysis technique is used can be obtained. (Earlougher, 1973) [8].

$$Et = \left[\frac{\left(\frac{\mathrm{kh}}{\mu}\right)' - \left(\frac{\mathrm{kh}}{\mu}\right) actual}{\left(\frac{\mathrm{kh}}{\mu}\right) actual}\right] = \frac{q1}{q1(T^* - 1) - q2T^*} \qquad (2.1)$$

Where

$$T^* = \frac{\log \Delta \mathrm{t}}{log\left(1 + \frac{\Delta \mathrm{t}}{t}\right)} \qquad (2.2)$$

The error in the calculated skin factor can be estimated from

$$Es = s' - S_{actual} = \frac{-1.151[P_{1hr} - P_{wf}(t)]}{m'} \times \left(\frac{q1}{q1 - q2}\right)\frac{1}{T^*} \quad (2.3)$$

Pinson A.E., SPE, September 1972, presented a technique for simplifying the analysis of two-rate transient flow tests was described by Pinson, where two simplifications that can often be used to make the analysis more convenient were pointed out. For rigorous analysis, a graph should be plotted with Pwf vs [log (t+Δt/Δt) + log Δt], which will have a straight-line section with slope

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m, related to the system transmissibility (kh/μ). It was suggested by Pinson that when the first flow rate, q1, acts over a long time, plotting Pwf vs log Δt should be done. This plot should have a straight-line portion whose slope, m", is related to the system transmissibility. (Pinson A.E., 1972) [9].
Selim, M.A., SPE, 1967, proposed a modification in order to eliminate some of the difficulties encountered in the two-rate test analysis. The modification consisted of following the rate reduction (second rate) with a rate increase. The modification still requires constant-rate flow and results in lengthening the test time. (Selim, M.A., 1967) [10].
Russell, D.G., SPE, 1963, presented a novel approach for examining flowing bottom-hole pressure data generated from two-rate flow tests conducted in oil or gas wells was discussed. The estimation of formation permeability, skin factor, and average reservoir pressure can be enabled by this method. By monitoring the transient bottom-hole pressure behavior following a change in the stabilized producing rate of the well, essential data can be extracted. Notably, identical results to those obtained through conventional pressure buildup analysis can be provided by this technique, but the necessity of well closure is eliminated. The complexity of analyzing a two-rate flow test is comparable to that of a conventional pressure buildup analysis and demands a similar amount of engineering time for application. Through field trials, the efficacy and cost-effectiveness of the two-rate flow test method have been validated, positioning it as a viable alternative to or in conjunction with traditional pressure buildup methodologies. (Russell, D.G., 1963) [11].

3. Methodology

3.1 Analysis Procedure for a two-rate test:

3.1.1 Two-rate test data for well 6J9-E59:

Table 3- 1 Well, Formation data and Fluid data

Formation porosity, Φ	5.19 %
Formation thickness, h	473 ft
Wellbore radius, ft	0.27
Oil viscosity, μ_o	0.183 cp
Oil formation volume factor, B_o	2.387 bbl/STB
Total compressibility, Ct	2.133E-05 1/psi

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(24/64) choke test data:

Table 3- 2 (24/64) choke test data

Initial flow rate, q1	442 STB/Day
Final flow rate, q2	620 STB/Day
Production time of the initial flow, t_{p1}	24 hr
Production time of the final flow rate, Δt	24 hr

(32/64) choke test data:

Table 3- 3 (32/64) choke test data

Initial flow rate, q1	620 STB/Day
Final flow rate, q2	724 STB/Day
Production time of the initial flow, t_{p1}	24 hr
Production time of the final flow rate, Δt	24.68 Hr

3.1.2 Procedure Analysis for Russel Method:

1. Plot p_{wf} vs. $\left[\log\left(\frac{t_{p1}+\Delta t}{\Delta t}\right) + \frac{q_2}{q_1}\log(\Delta t)\right]$

2. Determine the slope m from the plot and use it to calculate permeability, k, from the relationship

$$k = 162.6\frac{q_1 B\mu}{mh} \tag{3.1}$$

3. Calculate the skin factor, s, from the equation

$$S = 1.151\left[\frac{q_1}{(q_2 - q_1)}\left(\frac{p_{wf1} - p_{1\text{hr}}}{m}\right) - \log\left(\frac{\text{k}}{\emptyset\mu c_t r_w^2}\right) + 3.23\right] \tag{3.2}$$

Where:

$p_{1\text{hr}}$ is the flowing pressure at $\Delta t = 1$ hour on the MTR line and p_{wf1} is the flowing pressure at the time the rate is changed ($\Delta t = 0$).

4. Calculate the extra pressure drop due to skin using the equation

$$\Delta ps = 0.87\, ms \tag{3.3}$$

5. p_i (or, more generally, p^*) is obtained by solving for p_i (p^*) from the equation written to model conditions at the time of the rate change. (It is implied that s and m are known at this point.)

$$p^* = p_{int} - \frac{q_1}{q_1 - q_2}\left[p_{wf1} - p_{1\text{hr}}\right] \tag{3.4}$$

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6. Calculate the dimensionless production time of the system using the formula

$$t_{DA} = 0.000264 \frac{kt_{p1}}{\emptyset \mu c_t A} \qquad (3.5)$$

Where:
$t_{p1} =$ the producing time before rate change.
$A =$ Well's drainage area expressed in square feet.

7. Using the MBH average reservoir pressure calculation charts in appendix C, draw a straight line that goes upward starting from the horizontal axis at the exact value of the calculated t_{DA}, stop at the curve that matches the reservoir shape, draw another straight line that goes horizontally starting from the point of the vertical line intersection with the reservoir shape curve, stop drawing the line when it intersects with the vertical axis and read the value at the vertical axis which will be the dimensionless pressure of the system (P_{DMBH}).

By using the value of the dimensionless pressure of the system the average reservoir pressure can be calculated using the equation

$$\overline{P} = P^* - \frac{M}{2.303} \times P_{DMBH} \qquad (3.6)$$

Where:
$p^* =$ the extrapolated pressure at a HTR of unity
$\bar{p} =$ the current average pressure
$M =$ the slope of the MTR straight line on a Horner plot

8. Calculate the Flow Efficiency of the well using the equation

$$FE = \frac{\overline{P} - Pwf_1 - \Delta P_s}{\overline{P} - Pwf_1} \qquad (3.7)$$

9. Calculate the Radius of Investigation using the formula

$$r_{inv} = \sqrt{\frac{k\Delta t}{948 \times \emptyset \times \mu \times C_t}} \qquad (3.8)$$

10. Calculate the Stabilization Time using the formula

$$t_s = \frac{948 \times \emptyset \times \mu \times C_t \times r_e^2}{k} \qquad (3.9)$$

3.1.3 Procedure Analysis for Pinson Method:

1. Plot p_{wf} vs $\log(\Delta t)$.

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2. Determine the slope m from the plot and use it to calculate permeability, k, from the relationship

$$k = 162.6\frac{(q_2 - q_1)B\mu}{mh} \qquad (3.10)$$

3. Calculate the skin factor, s, from the equation

$$s = 1.151\left[\frac{(p_{wf1} - p_{1\text{hr}})}{m} - \log\left(\frac{\text{k}}{\emptyset\mu c_t\, r_w^2}\right) + 3.23\right] \qquad (3.11)$$

4. Calculate the extra pressure drop due to skin using the equation

$$\Delta ps = 0.87\, ms\left(\frac{q_1}{q_2 - q_1}\right) \qquad (3.12)$$

5. Calculate the value of p^* from the following relationship

$$p^* = p_{wf1} + m'\frac{q_1}{q_2 - q_1}\left[\log(t_{p1}) + \frac{p_{1\text{hr}} - p_{wf1}}{m'}\right] \qquad (3.13)$$

Where:
m': the slope of the straight line of the MTR in Russel semi-log plot.

6. Calculate the dimensionless production time of the system using the equation (3.5).

7. Using the MBH average reservoir pressure calculation charts in appendix C, draw a straight line that goes upward starting from the horizontal axis at the exact value of the calculated t_{DA}, stop at the curve that matches the reservoir shape, draw another straight line that goes horizontally starting from the point of the vertical line intersection with the reservoir shape curve, stop drawing the line when it intersects with the vertical axis and read the value at the vertical axis which will be the dimensionless pressure of the system (P_{DMBH}), By using the value of the dimensionless pressure of the system, the average reservoir pressure can be calculated using the equation (3.6).

8. Calculate the Flow Efficiency of the well using equation (3.7).

9. Calculate the Radius of Investigation using equation (3.8).

10. Calculate the stabilisation time using equation (3.9).

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4. Results and Discussion

4.1 Introduction

Two-rate test was conducted twice on the well 6J9- E59, based on the tests data Included in the appendixes, both the tests were interpreted using Russel method and Pinson method to estimate permeability, skin factor, average reservoir pressure, flow efficiency, radius of investigation and time of stabilization, by applying equations manifested on the methodology we get the following results.

4.2 (24/64) choke test results

The well has flowed at a constant rate of 420 STB Per Day for 24 hours then the choke size was increased to 24/64 resulting in an increase in flow rate (see figure 1), the well continued to flow by the new flow rate (620 STB Per Day) for 24 hours as the bottomhole pressure was monitored and recorded.

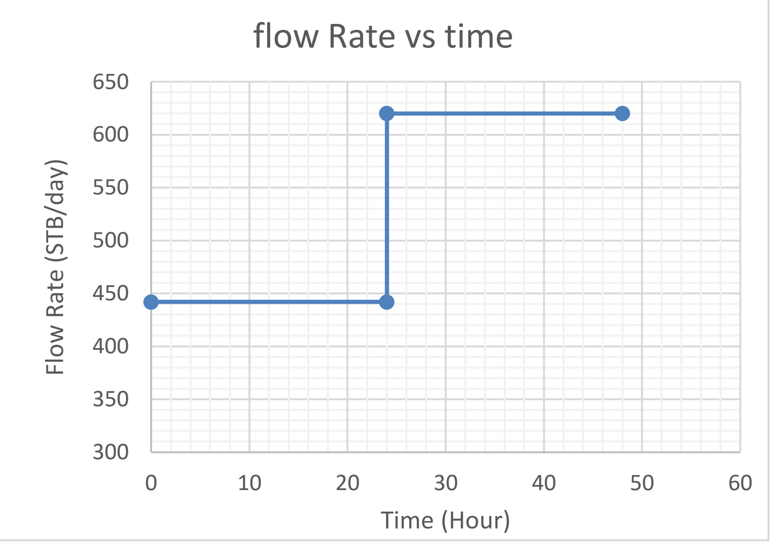

Figure 1. (24/64) test flow rate vs time

4.2.1 Russel Method Results:

Applying the methodology of Russel and pinson methods for choke size of (24/64), the following figure (2) semi-log plots are obtained:

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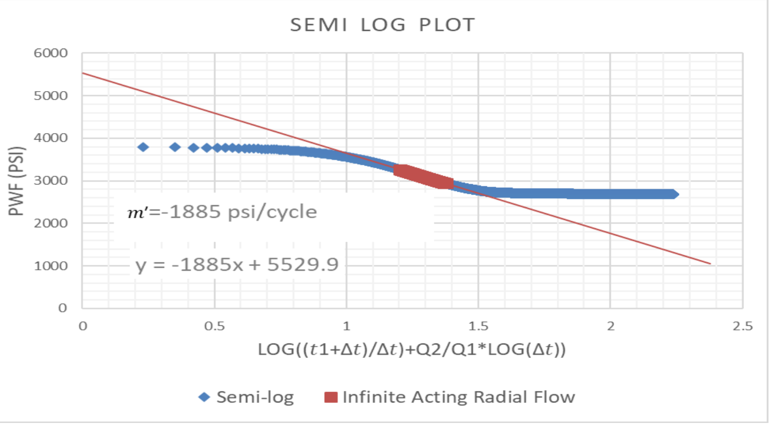

Figure 2. (24/64) test Russel semi-log plot

✓ **From figure (4-2)**, slope, m' = 1885 psi/cycle.

Let the equation of the X-axis in the semi-log plot be X and consider that Δt =1 hour and calculate X:

$$X = \log(\frac{t1 + \Delta t}{\Delta t}) + \frac{q2}{q1} \times \log(\Delta t)$$

$$X = log\left(\frac{24+1}{1}\right) + \frac{620}{442} \times \log(1)$$

$$X = 1.39794$$

From the straight-line equation of the semi-log plot (Figure 2) consider P1hr = Y and X=1.39794 and calculate for P1hr : $P_{1hr} = 2894.7831$ psi

✓ **False Reservoir Pressure Calculations**

$$p^* = p_{int} - \frac{q_1}{q_1 - q_2}[p_{wf1} - p_{1hr}]$$

$$p^* = 5529.9 - \frac{442}{442 - 620}[3794.45 - 2894.7831]$$

$$p^* \, 8663.571 \text{ psi}$$

✓ **Average reservoir pressure using MBH method**

$$t_{DA} = \frac{0.000264 \times k \times t_{p1}}{\emptyset \times \mu \times C_t \times A}$$

$$= \frac{0.000264 \times 0.0352 \times 24}{0.519 \times 0.183 * 2.133 \times 10^{-5} \times 13068000.78877}$$

$$= 8.424 \times 10^{-6}$$

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Since the value of the dimensionless production time of the system is extremely lowt_{DA}, the reservoir is considered infinite acting and the average reservoir pressure equals the false pressure, $\overline{P} = P^* = 8663.571\ psi$

Applying the above mentioned methodology of the Russel Method, all results of Russel method are shown in table (4-1) below.

4.2.2 Pinson Method Results:

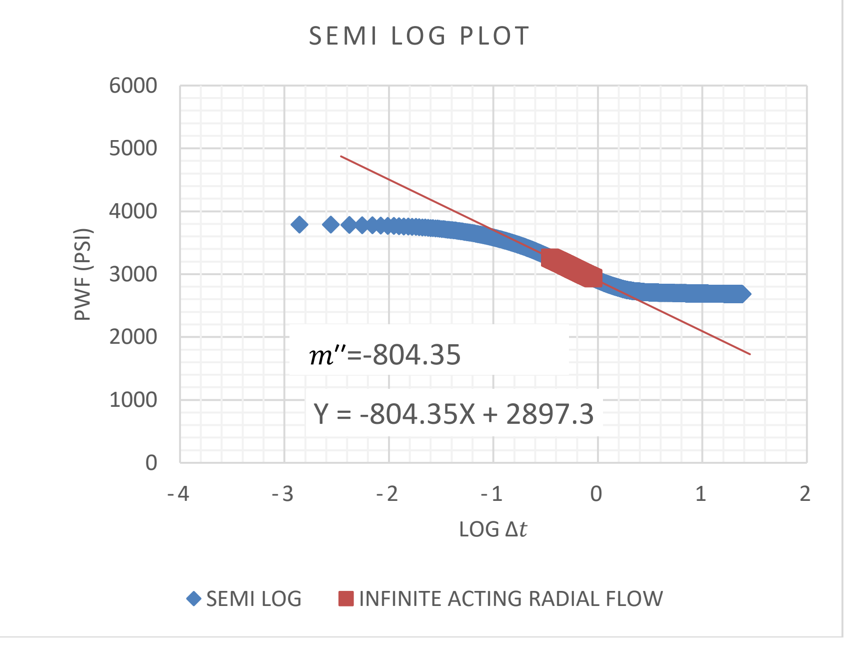

Figure 3. (24/64) test, Pinson method semi-log plot.

✓ **From figure (3),** slope, m'' = 804.35 psi/cycle.

Extrapolate the straight line in figure (3) to Δt =1 hour, (i.e.log (Δt) = 0), and read, P_{1hr}, P_{1hr} = *2897.3 psi*

✓ **False Reservoir Pressure Calculations**

$$p^* = p_{wf1} + m' \frac{q_1}{q_2 - q_1}\left[\log\left(t_{p1}\right) + \frac{p_{1hr} - p_{wf1}}{m'}\right]$$

$$p^* = 3794.45 + 1885 \frac{442}{620 - 442}\left[\log\left(24\right) + \frac{2897.3 - 3794.45}{1885}\right]$$

$$p^* = 8027.092\ psi$$

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✓ **Average reservoir pressure using MBH method**

$$t_{DA} = \frac{0.000264 \times k \times t_{p1}}{\emptyset \times \mu \times C_t \times A}$$

$$= \frac{0.000264 \times 0.0332 \times 24}{0.519 \times 0.183 \times 2.133 \times 10^{-5} \times 13068000.78877}$$

$$= 7.945 \times 10^{-6}$$

Since the value of the dimensionless production time of the system is extremely low t_{DA}, the reservoir is considered infinite acting and the average reservoir pressure equals the false pressure.

$\overline{P} = P^* = 8027.092\ psi$ psi

4.3 (32/64) choke test results

The well has flowed at a constant rate of 620 STB Per Day for 24 hours then the choke size was increased to 32/64 resulting in an increase in flow rate (see figure 4), the well continued to flow by the new flow rate (724 STB Per Day) for 24.068 hours as the bottomhole pressure was monitored and recorded.

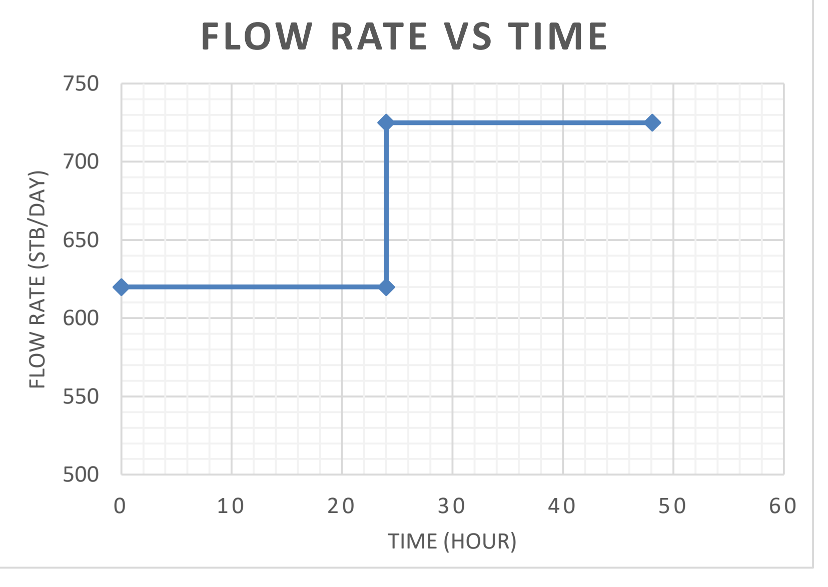

Figure 4. (32/64) test flow rate vs Time

4.3.1 Russel Method Results:

Applying the methodologies of Russel and pinson methods for (32/64) choke size, the following semi log plots are obtained (figure 5):

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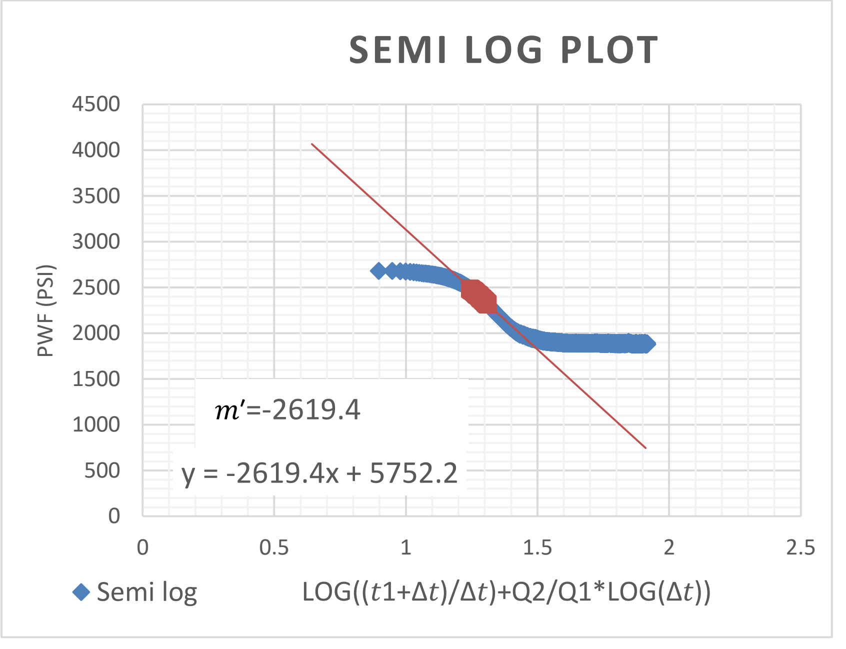

Figure 5. (32/64) Russel semi-log plot

✓ **From figure (5),** slope, m'= 2619.4 psi/cycle.

Let the equation of the X-axis in the semi-log plot be X and consider that Δt =1 hour and calculate X:

$$X = \log(\frac{t1 + \Delta t}{\Delta t}) + \frac{q2}{q1} \times \log(\Delta t)$$
$$X = log\left(\frac{24 + 1}{1}\right) + \frac{620}{442} \times \log(1)$$
$$X = 1.39794$$

X=1.39794 From the straight-line equation of the semi-log plot (Figure 2) consider P_{1hr} = Y and X=1.39794 and calculate for P_{1hr}, $P1hr = 2090.4359\ psi$

✓ **False Reservoir Pressure Calculations**

$$p^* = p_{int} - \frac{q_1}{q_1 - q_2}[p_{wf1} - p_{1\text{hr}}]$$
$$p^* = 5752.2 - \frac{725}{620 - 725}[2684.45 - 2090.4359]$$
$$p^* = 9852.345 \text{ psi}$$

✓ **Average reservoir pressure using MBH method**

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$$t_{DA} = \frac{0.000264 * k * t_{p1}}{\emptyset * \mu * C_t * A}$$
$$= \frac{0.000264 * 0.0355 * 24}{0.519 * 0.183 * 2.133 * 10^{-5} * 13068000.78877}$$
$$= 8.4962 * 10^{-6}$$

Since the value of the dimensionless production time of the system is extremely low t_{DA}, the reservoir is considered infinite acting and the average reservoir pressure equals the false pressure.

$$\overline{P} = P^* = 9852.345\, psi$$

4.3.2 Pinson Method Results:

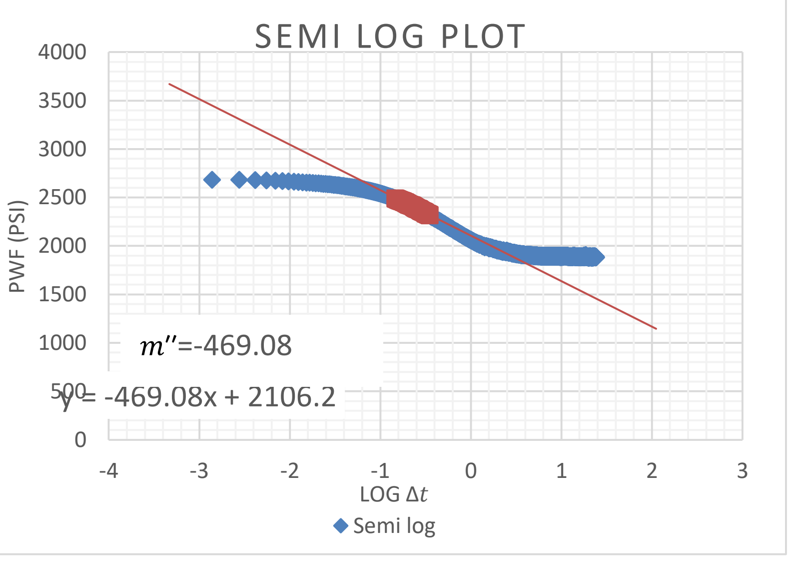

Figure 6. (32/64) Pinson semi-log plot

✓ **From figure (6),** slope, m"= 469.08 psi/cycle.

Extrapolate the straight line in figure (6) to Δt =1 hour, (i.e.log (Δt) = 0), and read, P1hr, P_{1hr} =2106.2 psi

✓ **False Reservoir Pressure Calculations**

$$p^* = p_{wf1} + m' \frac{q_1}{q_2 - q_1}\left[\log\left(t_{p1}\right) + \frac{p_{1hr} - p_{wf1}}{m'}\right]$$

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$$p^* = 2684.25 + 2619.4 \frac{620}{725 - 620}\left[\log(24) + \frac{2106.2 - 2684.25}{2619.4}\right]$$

$$p^* = 20618.637\ psi$$

✓ **Average reservoir pressure using MBH method**

$$t_{DA} = \frac{0.000264 \times k \times t_{p1}}{\emptyset \times \mu \times C_t \times A}$$

$$= \frac{0.000264 \times 0.0336 \times 24}{0.519 \times 0.183 \times 2.133 \times 10^{-5} \times 13068000.78877}$$

$$= 8.04148 \times 10^{-6}$$

Since the value of the dimensionless production time of the system is extremely low t_{DA}, the reservoir is considered infinite acting and the average reservoir pressure equals the false pressure.

$$\overline{P} = P^* = 20618.637psi$$

Results summary of both methods (Russel and Pension Methods) at the two choke sizes is shown in table (4-1) below.

Table 4- 1 Results summary

Parameters	**24/64 Choke size**		**32/64 choke size**	
	Method of analysis		**Method of analysis**	
	Russel	**Pinson**	**Russel**	**Pinson**
permeability, md	*0.0352*	0.0332	0.0355	0.0336
skin factor	*-1.1073*	-1.158	-0.935	-1.0298
false pressure ,psi	*8663.571*	8027.092	9852.345	20618.637
skin pressure drop ,psi	*-1815.91*	-2012.21	-2130.75	-2481.54
Average reservoir pressure, psi	*8663.571*	8027.092	9852.345	20618.63
Flow efficiency, %	*138.73*	147.53	129.72	113.83
Radius of investigation, ft	*20.97*	20.368	21.092	20.428
Time of stabilization, hr	*226003.84*	239618.52	224093.9	236675.9

From the result, it's obvious that the permeability is almost identical for both tests when analyzed by both methods, which was expected giving the fact that both tests were performed on the same well. Pinson method results were disproportionate which is reasonable giving that the production time of the initial rate t_{p1} is identical to

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the production time of the final rate Δt in the first test and it has a higher value in the second test.

5. Conclusion

Well testing is a good technique and method for the evaluation of well conditions and reservoir characteristics and to obtain accurate results, it is crucial to monitor carefully and regularly the changes in the wellhead pressure to ensure that there is no tubing leaking. Moreover, however the tests only lasted about 48 hours each, it was adequate to analyze and estimate well and reservoir properties, indicating that the two-rate test is an excellent alternative to conventional single rate tests, which would take way more time to conduct. The two-rate test saves a lot of money; test conducting expenses and avoiding the income loss resulting from the production stop. Test results manifest that reservoir permeability is very low, which requires a very long test time to conduct a full test with all boundaries despite the negative skin of (-1.021).

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