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Reservoir Characterization of Low-Permeability FACHA Formation in Hakim Field Using ECRIN Well Test Analysis

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KEYWORDS

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Well Test;
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ABSTRACT

This study presents the Pressure Transient Analysis (PTA) of two wells in the Hakim field using pressure build-up test data. An Excel-based analysis model was developed to estimate the main reservoir parameters and was validated by comparison with results obtained from ECRIN (Saphir), the industry-standard software for pressure transient analysis. The comparison showed a close agreement between the Excel model and ECRIN results, demonstrating that the developed Excel model provides reliable estimates of reservoir properties. The studied wells, producing from the FACHA Formation, are characterized by low permeability, with permeability values ranging from 3.9 to 10.9 mD. The skin factor ranges from −3.38 to −0.60 for all wells except well A4, which exhibits a positive skin factor of 6.33 due to formation damage. The estimated average reservoir pressure in the Hakim field is approximately 2517 psi.

توصيف مكامن تكوين فاشا ذي النفاذية المنخفضة في حقل حكيم باستخدام تحليل اختبار الآبار ECRIN

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الكلمات المفتاحية

تحليل الضغط
اختبار البئر
ECRIN
المكمن ذو النفاذية المنخفضة

الملخص

هذه الدراسة تلخص تحليلًا لتغيرات الضغط العابرة (PTA) لبئرين في حقل حكيم باستخدام بيانات اختبار تراكم الضغط. تم تطوير نموذج تحليل قائم على برنامج Excel لتقدير معلمات المكمن الرئيسية، وتم التحقق من صحته بمقارنته مع النتائج المُستقاة من برنامج ECRIN (Saphir)، وهو البرنامج القياسي في هذا المجال لتحليل تغيرات الضغط العابرة. أظهرت المقارنة توافقًا كبيرًا بين نموذج Excel ونتائج ECRIN، مما يدل على أن نموذج Excel المُطور يوفر تقديرات موثوقة لخصائص المكمن. تتميز الآبار المدروسة، المنتجة من تكوين فاشا، بنفاذية منخفضة، حيث تتراوح قيم النفاذية من 3.9 إلى 10.9 ملي دارسي. يتراوح عامل التلف من -3.38 إلى -0.60 لجميع الآبار باستثناء البئر A4، الذي يُظهر عامل تلف موجبًا قدره 6.33 نتيجة لتلف التكوين. يُقدر متوسط ضغط المكمن في حقل حكيم بحوالي 2517 رطل لكل بوصة مربعة.

Introduction

Oil well test analysis is a branch of reservoir engineering, Information gathered from flow and pressure transient tests plays a crucial role in understanding in situ reservoir conditions, which are essential for assessing the reservoir's productive capacity [1]. Pressure transient analysis also yields estimates of the average reservoir pressure. The reservoir engineer must have sufficient information about the condition and characteristics of reservoir/well to adequately analyze reservoir performance and to forecast future production under various modes of operation [2]. The production engineer needs to understand the status of both production and injection wells to achieve optimal performance from the reservoir [3]. Among all types of data, pressure measurements are the most critical and valuable in reservoir engineering. They play a pivotal role, either directly or indirectly, in every aspect of reservoir engineering calculation [4].

The purpose of well testing is mainly to determine the ability of a formation to produce fluids, and to provide information about the reservoir needed in many aspects of reservoir and production engineering calculations [3]. A properly designed well test can provide information about the reservoir permeability, the extent of well bore damage or improvement, the reservoir pressure and in some cases information about the reservoir pore volume or boundaries [5]. Such information is important in many phases of petroleum engineering. The petroleum engineer must have sufficient information about the reservoir to adequately analyze current performance and be able to predict and optimize future performance [6].

Data derived from the many types of production testing are a basic part of reservoir calculations as well as production engineering design calculations, such as artificial lift and stimulation program [7].

Pressure buildup testing is one of the most widely recognized transient well-testing techniques and has been extensively applied in the petroleum industry. Basically, the test is

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conducted by producing a well at constant rate for some time, shutting the well in (usually at the surface), allowing the pressure to build up in the wellbore, and recording the down-hole pressure in the wellbore as a function of time. From these data, it is possible to estimate the formation permeability and current drainage area pressure, and to characterize damage or stimulation and reservoir heterogeneity or boundaries frequently.

Knowledge of surface and subsurface mechanical conditions is important in build-up test data interpretation. It is advisable to determine factors such as testing and casing sizes, well depth, and packer condition before initiating data interpretation. Usually, short-time pressure observations are necessary for the complete delineation of wellbore storage effects. During the initial few minutes of certain build-up tests, data may need to be collected at intervals as short as 15 seconds. As the test advances, however, the data collection interval can be extended [6].

Objectives of Study

The main aims and objectives of this study can be summarizing as following:

1.To analysis the build-up test for two vertical wells from Hakim, by using methods to estimate the average reservoir pressure and the main reservoir parameters such as permeability, skin factor, pressure drop due to skin, radius of investigation and flow efficiency.

2.To build an analysis model to analyse build-up tests on ECRIN software to calculate the reservoir parameters.

3.To compare the average reservoirs pressure and the reservoir parameter's results from the ECRIN model with the average reservoirs pressure reservoir parameter's results using EXCEL sheet to validate the results.

Cases of Study

Area of study: Hakim Field

The Hakim field is one of Libya's important oil fields: it was discovered in 1978. It is located in the southwestern Sirte Basin, within Block 74A [8], as shown in Fig. 1.

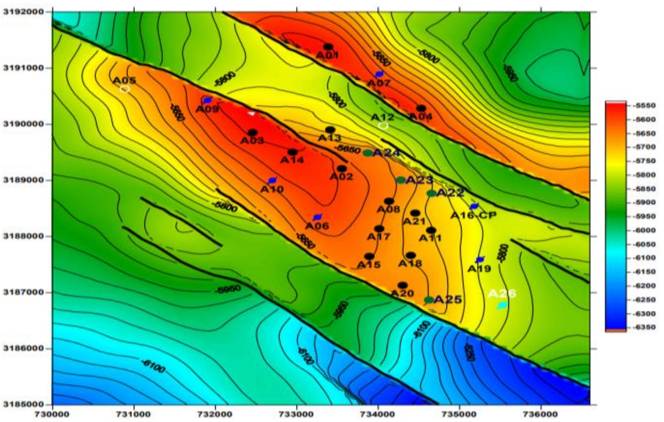


Figure 1: Hakim Oil Field

Block 74A is operated by Zueitina Oil Company, a joint venture between the National Oil Corporation (NOC) of Libya and international partners, including OMV. The wells investigated in this study produce from the FACHA Formation, an Upper Cretaceous carbonate reservoir in the Sirte Basin. Although the FACHA Formation exhibits variable reservoir quality across the basin, the interval analysed in this study is characterized by low permeability, as confirmed by the pressure transient analysis results [9]. Sirte Basin is widely recognized as the "oil basket of Libya," containing more than 80% of the country's proven oil reserves. The Hakeem Field is one of the producing fields operated by Zueitina Oil Company, which currently produces approximately 30,000 barrels of oil per day (BOPD). Of this production, approximately 7,000 BOPD represent the foreign company's share from joint operations. These production activities highlight the strategic importance of the Hakeem Field within Libya's petroleum sector [10].

Analyze the buildup test for two vertical wells from wells from Hakim oil field these wells are (A3-A4) and all these wells producing from FACHA formation [10]. The reservoir parameter and production test for the wells that will be study are following, as shown in tables 1 and 2.

Table 1: Fluid and rock properties data for well A3

Parameter	Value	Parameter	Value
B_o (bbl/STB)	1.55	r_w (ft)	**0.262**
Φ (%)	0.20	q (stb/d)	**865**
μ_o (cp)	0.40	t_p (hr)	**184**
C_t (1/psia)	30×10^{-6}	P_{wf} (psi) at Dt=0	**1904**
H (ft)	64		

Table 2: Fluid and rock properties data for well A4

Parameter	Value	Parameter	Value
B_o (bbl/STB)	1.84	r_w (ft)	**0.261**
Φ (%)	0.179	q (stb/d)	**1301**
μ_o (cp)	0.15	t_p (hr)	**39.5**
C_t (1/psia)	30×10^{-6}	P_{wf} (psi) at Dt=0	**1036**

ECRIN Software overview

ECRIN software has been the industry's leading well test analysis program for more than 20 years, as shown in fig. 2.

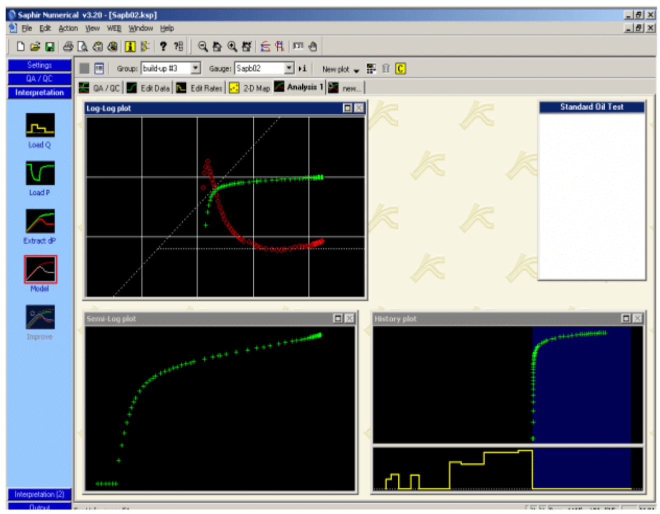


Figure 2: ECRIN main Windows

A pressure transient well test offers a distinctive capability to gather valuable insights from the reservoir area surrounding the well. Appropriate testing techniques provide a wealth of data:

- Permeability of the near-wellbore region and the reservoir at large
- Vertical permeability, vertical communication in layered systems
- Completion efficiency, effective open interval size (over life of well)
- Well performance (over life of well)
- Reservoir structure (boundaries, heterogeneities)
- Reservoir pressure
- Nature of pressure support

• Connected pore volume and initial hydrocarbons in place
• Deliverability and production forecasts

Calculations and results

Build-up analysis for well A03 (Hakim Field):

Ecrin analysis:

Start by insert the pressure and production data into ECRIN then analysis perform to identify the model that matched the data as shown in fig. 3.

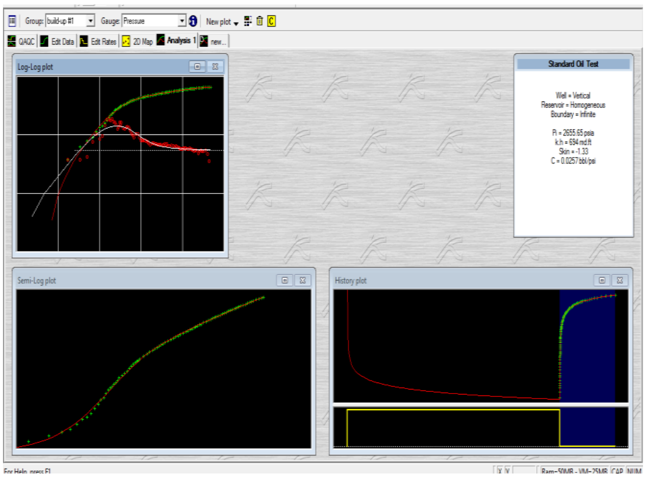


Figure 3: ECRIN Analysis (Well A03)

Insert the build-up test data and run the model, then the screen appears with pressure derivative and pressure drop on log-log plot.

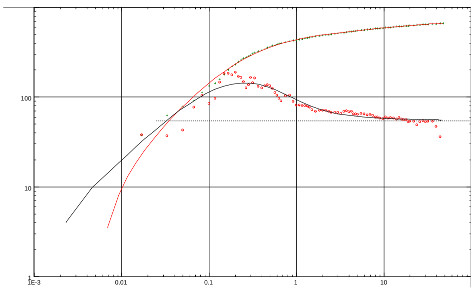


Figure 4: Pressure derivative and pressure drop versus equivalent time (Ecrin) (Well A03)

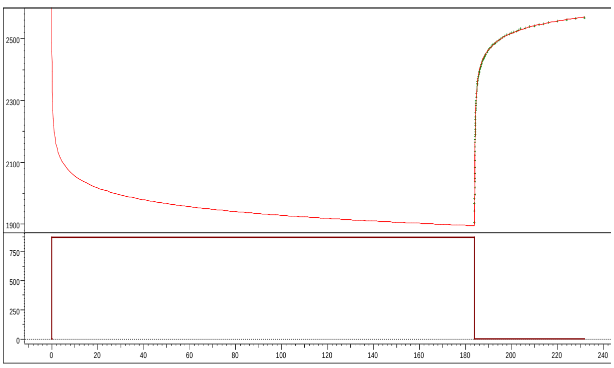


Figure 5: Test plot (Ecrin) (Well A03)

The Ecrin has ability to select the radial flow using pressure derivative method as shown in Fig. 4 and then Horner plot to estimate the slop and calculate the parameters as shown in Fig. 5 and Table 3 shows the calculated reservoir parameter for well A03 using Ecrin.

Table 3: calculated reservoir parameter for well A03 (Ecrin)

Name	Value	Unit
Selected Model		
Model Option	Standard Model	
Well	Vertical	
Reservoir	Homogeneous	
Boundary	Infinite	
Main Model Parameters		
TMatch	20	[hr]-1
PMatch	0.00917	[psia]-1
C	0.0257	bbl/psi
Total Skin	-1.33	--
k.h, total	694	md.ft
k, average	10.8	md
Pi	2655.65	psia
Model Parameters		
Well & Wellbore parameters (Tested well)		
C	0.0257	bbl/psi
Skin	-1.33	--

Name	Value	Unit
Total Skin	-1.33	--
k.h, total	694	md.ft
k, average	10.8	md
Pi	2655.65	psia
Model Parameters		
Well & Wellbore parameters (Tested well)		
C	0.0257	bbl/psi
Skin	-1.33	--
Reservoir & Boundary parameters		
Pi	2655.65	psia
k.h	694	md.ft
k	10.8	md
Derived & Secondary Parameters		
Rinv	648	ft
Test. Vol.	0.0169034	bcf
Delta P (Total	-145.287	psi
Delta P Ratio (	-0.215147	Fraction

The results of test shows that the well A03 has negative skin factor that's due to stimulation (Acidizing) job, that's increase the flow efficiency of well, with permeability 10.8 mD.

EXCEL Analysis

Starting the programming with Excel sheet and input the properties and the build-up test data. The fig. 6 shows the log-log plot of pressure drop and pressure derivative versus equivalent time on EXCEL model, then select the zero-slop period to investigate the radial fl.

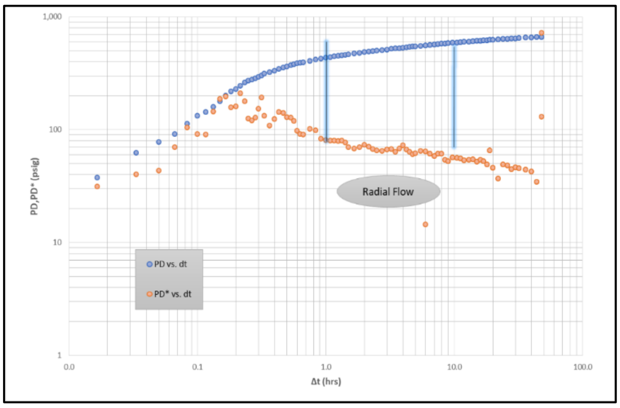


Figure 6: Pressure derivative and pressure drop versus equivalent time (EXCEL) (Well A03)

After select the radial flow region the plot of shut-in pressure versus Horner and MDH time to estimate the slop to calculate the reservoir parameters, as shown in Fig. 7 and 8.

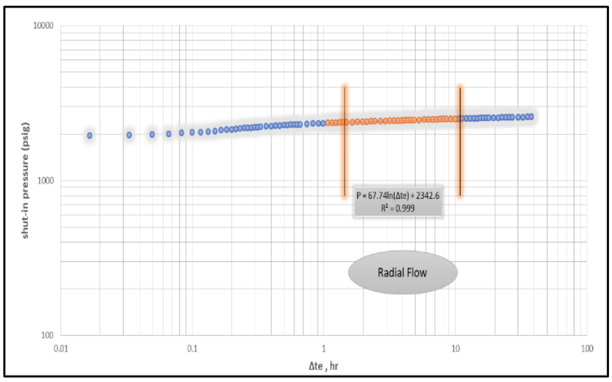


Figure 7: MDH plot (EXCEL) (Well A03)

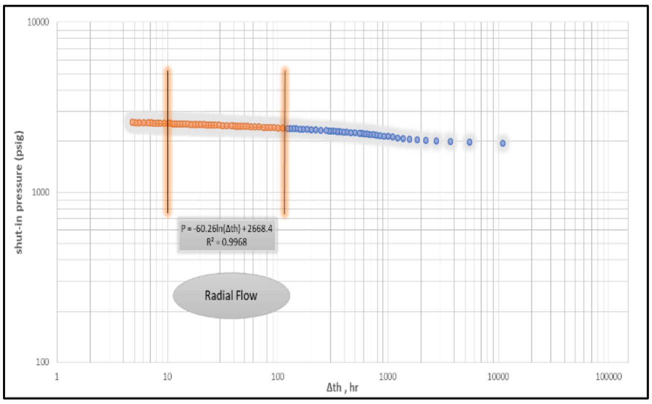


Figure 8: Hornor plot (EXCEL) (Well A03)

The following two figures is used to determine the average reservoir pressure using Arps Smith method, which is by calculating the pressure using the Hornor time then with the MDH time as shown in fig. 9 and 10.

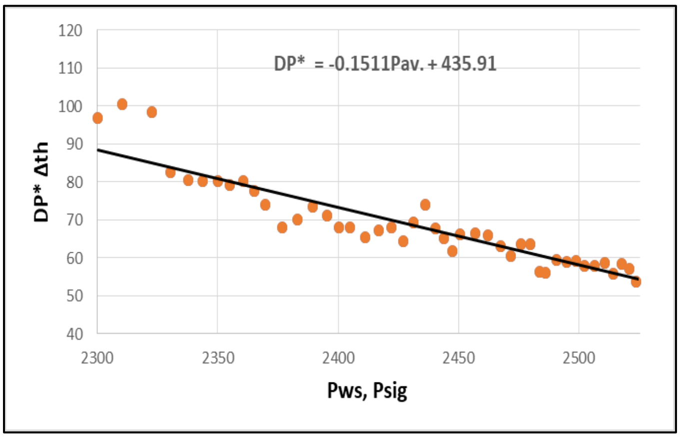


Figure 9: dp_{ws}/dth versus dp_{ws} plot (EXCEL) (Well A03)

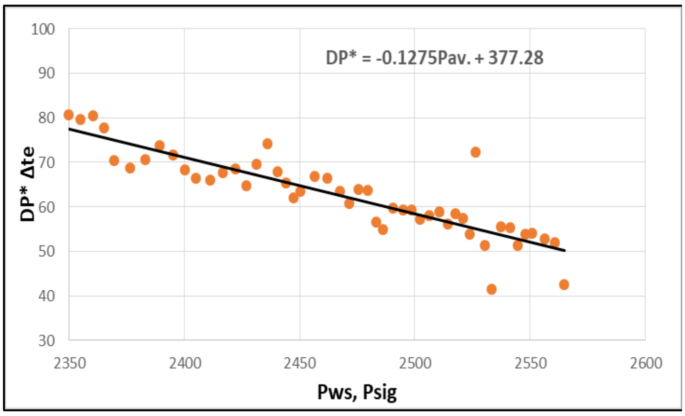


Figure 10: dp_{ws}/dte versus dp_{ws} plot (EXCEL) (Well A03)

As complete the analysis using ECRIN and Excel sheet comparison between the results needs to validate the results as shown in table 4 and 5. The pressure using the ECRIN software is found to be 2655 Psia.

Build-up analysis for well A04 (Hakim Field)

Ecrin analysis

Start by insert the pressure and production data into ECRIN then analysis perform to identify the model that matched the data as shown in fig. 11.

Table 4: Comparing Results using ECRIN and EXCEL model (Well A03)

Parameters	ECRIN	EXCEL (MDH)	EXCEL (Hornor)
Permeability (md)	10.81	8.73	9.82
Flow capacity (md.ft)	694	627	597
Flow efficiency	1.356	1.295	1.265
Δ Pskin (psia)	-243	-253.9	-209
Skin factor	-1.332	-1.437	-1.65

Table 5: Comparing Pressure Results using ECRIN and EXCEL model (Well A03)

Pressure estimating method	MDH	Horner
Deitz	1552	2721
MBH	2603	2666
Ramey Cobb	2421	2590
Arps smith	2959	2885

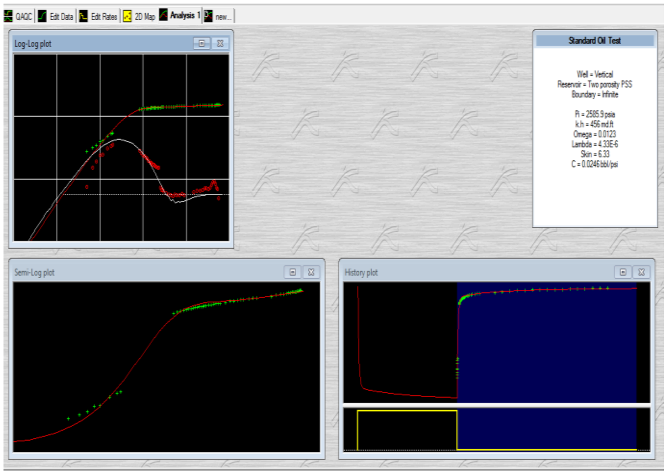


Figure 11: ECRIN Analysis (Well A04)

Insert the build-up test data and run the model, then the screen appears with pressure derivative and pressure drop on log-log plot. The *Ecrin* has ability to select the radial flow using pressure derivative method as shown in Fig. 12 and then Horner plot to estimate the slop and calculate the parameters as shown in Fig 13 the table 6 shows the calculated reservoir parameter for well A04 using *Ecrin*

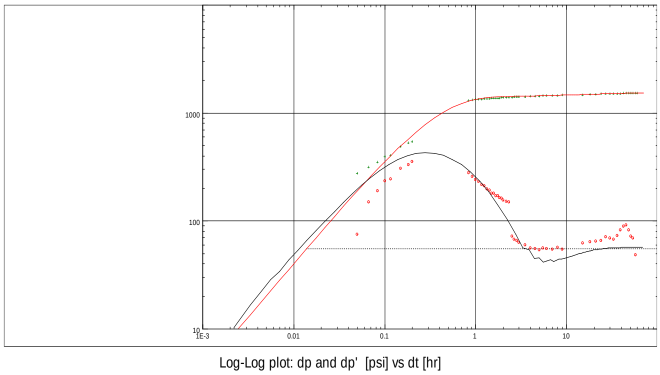


Figure 12: Pressure derivative and pressure drop versus equivalent time (Ecrin) (Well A04)

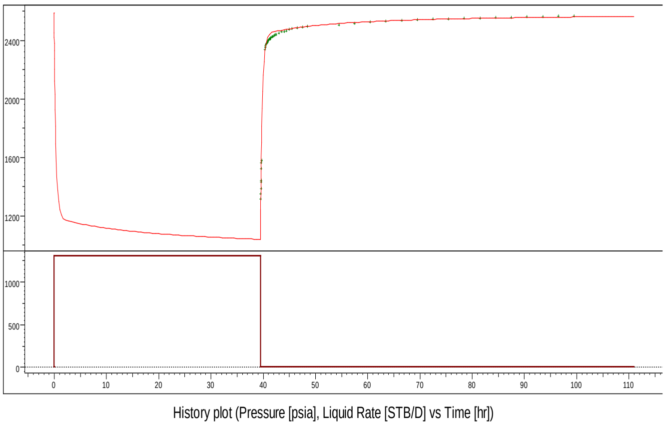
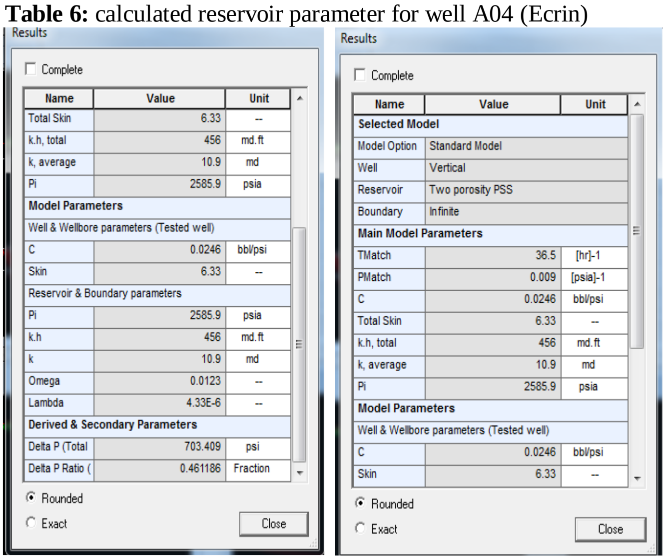


Figure 13: Test plot (Ecrin) (Well A04)

. **Table 6:** calculated reservoir parameter for well A04 (Ecrin)



Results

Name	Value	Unit
Total Skin	6.33	--
k.h, total	456	md.ft
k, average	10.9	md
Pi	2585.9	psia
Model Parameters		
Well & Wellbore parameters (Tested well)		
C	0.0246	bbl/psi
Skin	6.33	--
Reservoir & Boundary parameters		
Pi	2585.9	psia
k.h	456	md.ft
k	10.9	md
Omega	0.0123	--
Lambda	4.33E-6	--
Derived & Secondary Parameters		
Delta P (Total	703.409	psi
Delta P Ratio (	0.461186	Fraction

Results

Name	Value	Unit
Selected Model		
Model Option	Standard Model	
Well	Vertical	
Reservoir	Two porosity PSS	
Boundary	Infinite	
Main Model Parameters		
TMatch	36.5	[hr]-1
PMatch	0.009	[psia]-1
C	0.0246	bbl/psi
Total Skin	6.33	--
k.h, total	456	md.ft
k, average	10.9	md
Pi	2585.9	psia
Model Parameters		
Well & Wellbore parameters (Tested well)		
C	0.0246	bbl/psi
Skin	6.33	--

The results of test shows that the well A04 has positive skin factor that's due to formation damage near the wellbore, that's decrease the flow efficiency of well, with permeability 10.9 mD.

The pressure derivative response of well A4 indicates a dual-porosity reservoir behaviour, as identified by the ECRIN model. The estimated dual-porosity parameters are ω = 0.0123 and λ = 4.33 × 10^{-6}. The low value of the stativity ratio (ω) indicates that the secondary porosity system contributes a relatively small fraction of the total reservoir storage capacity. Meanwhile, the low interporosity flow parameter (λ) suggests limited and delayed fluid exchange between the two porosity systems. This response reflects the heterogeneous nature of the FACHA carbonate reservoir and indicates the presence of matrix–secondary porosity interaction affecting the pressure transient response. The identification of this behaviour is important for improving reservoir characterization and understanding the production performance of low-permeability carbonate reservoirs.

EXCEL Analysis

Starting the programming with Excel sheet and input the properties and the build-up test data. The fig. 14 shows the log-log plot of pressure drop and pressure derivative versus equivalent time on EXCEL model, then select the zero-slop period to investigate the radial flow.

After select the radial flow region the plot of shut-in pressure versus Horner and MDH time to estimate the slop to calculate the reservoir parameters, as shown in Fig. 15 and 16.

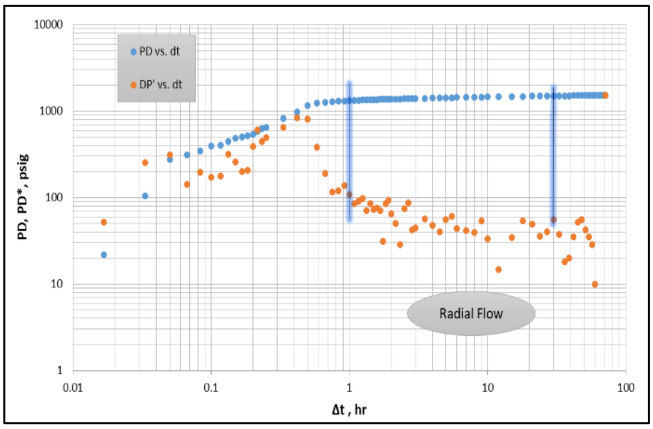


Figure 14: Pressure derivative and pressure drop versus equivalent time (EXCEL) (Well A04)

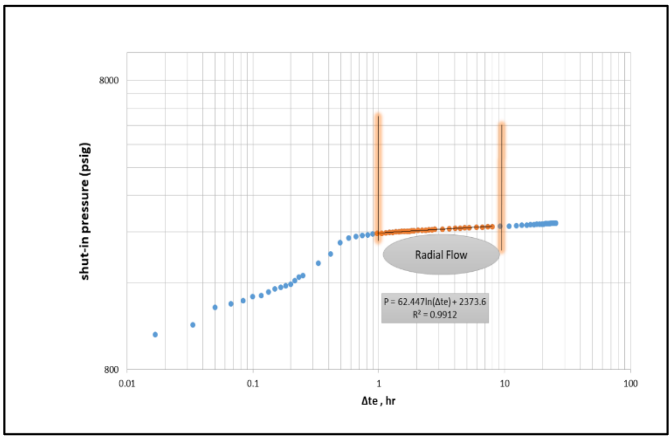


Figure 15: MDH plot (EXCEL) (Well A04)

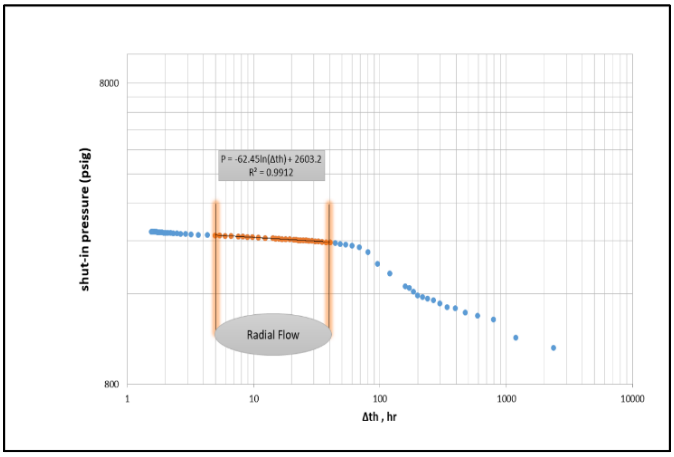


Figure 16: Hornor plot (EXCEL) (Well A04))

The following two figures is used to determine the average reservoir pressure using Arps Smith method, which is by calculating the pressure using the Hornor time then with the MDH time as shown in fig. 17 and 18.

Comparing between results

As complete the analysis using ECRIN and Excel sheet comparison between the results needs to validate the results as shown in table 7 and 8.

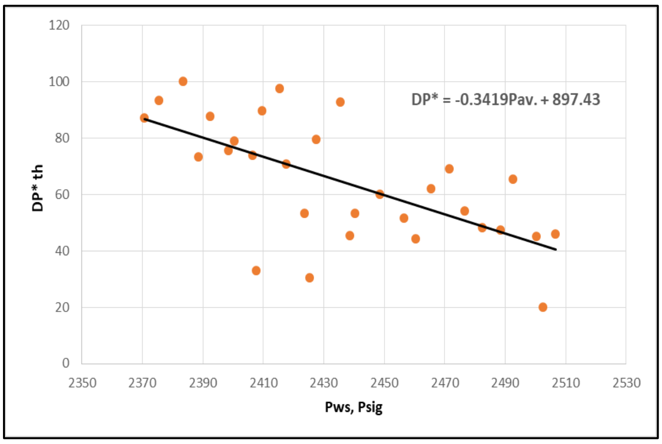


Figure 17: dp_{ws}/dth versus dp_{ws} plot (EXCEL) (Well A04)

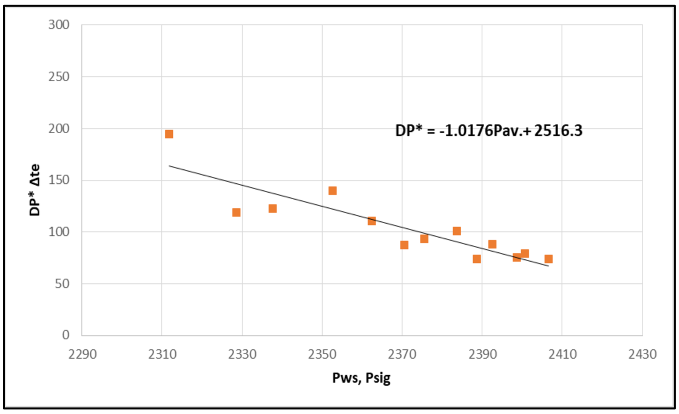


Figure 18: dp_{ws}/dte versus dp_{ws} plot (EXCEL) (Well A04)

Table 7: Comparing Results using ECRIN and EXCEL model (Well A04)

Parameters	ECRIN	EXCEL (MDH)	EXCEL (Hornor)
Permeability (md)	10.91	9.666	9.667
Flow capacity (md.ft)	456	459	459
Flow efficiency	0.50	0.54	0.54
ΔP_{skin} (psia)	702	709	710
Skin factor	6.33	6.85	4.99

Table 8: Comparing Results using ECRIN and EXCEL model (Well A04)

Pressure estimating method	MDH	Horner
Deitz	2296	2681
MBH	2372	2601
Ramey Cobb	2426	2550
Arps smith	2472	2642

Conclusions

1. The ECRIN software is an effective tool for analyzing pressure buildup tests to estimate the most important reservoir parameters. The resulting Excel file is also useful in providing a model for analyzing these tests. After comparing the results, our model proved to be a high-quality model for estimating reservoir parameters through well tests.The pressure using the ECRIN software is found to be 2586 Psia.
2. Only well tests provide information about the dynamic behavior of the well and/or reservoir as a function of oil production, water content, and average reservoir pressure.
3. To obtain accurate interpretations of the transient pressure test, the derivative (diagnostic) method should be used as a fundamental step in analyzing the transient pressure during the radial flow period.
4. Using the derivative diagram makes the results obtained from the Excel file calculations almost identical to those obtained from the ECRIN software.
5. All the wells used in this study are characterized by low reservoir permeability near the bottom of the well in both fields, because these two wells are produced from the FACH formation.

Recommendations

Based on the results obtained from the pressure transient analysis of wells A3 and A4 in the Hakim field, the following recommendations are proposed:

1. Additional pressure transient tests are recommended for other wells in the Hakim field to improve reservoir characterization and evaluate the lateral and vertical variation of the FACHA Formation properties.
2. Integration of PTA results with geological, petrophysical, and production data is recommended to obtain a more comprehensive understanding of reservoir heterogeneity, particularly in low-permeability carbonate reservoirs.
3. Further investigation of dual-porosity behavior is suggested, especially for well A4, where the estimated parameters ($\omega = 0.0123$ and $\lambda = 4.33 \times 10^{-6}$) indicate matrix–secondary porosity interaction. Additional geological studies and imaging logs could help confirm the presence and distribution of secondary porosity features.
4. Well stimulation optimization studies are recommended for wells exhibiting positive skin factors, such as well A4, to evaluate suitable stimulation strategies for reducing near-wellbore damage and improving productivity.
5. The developed Excel-based PTA model can be further enhanced by incorporating additional reservoir models, automated diagnostic procedures, and uncertainty analysis to provide a more comprehensive alternative for preliminary well-test interpretation.
6. Future studies should consider numerical reservoir simulation using the obtained pressure transient parameters to improve production forecasting and support reservoir management decisions.

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Conflicts of Interest: “The authors declare no conflict of interest."

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List of Symbols and Abbreviations

Symbol/Abbreviation	Description	Unit
PTA	Pressure Transient Analysis	–
ECRIN	Well Test Analysis Software	–
MDH	Miller–Dyes–Hutchinson method	–
BHP	Bottom Hole Pressure	psi
Pwf	Flowing Well Pressure	psi
Pi	Initial Reservoir Pressure	psi
Pavg	Average Reservoir Pressure	psi
k	Reservoir Permeability	md
h	Reservoir Thickness	ft
φ	Porosity	%
μo	Oil Viscosity	cp
Bo	Oil Formation Volume Factor	bbl/STB
Ct	Total Compressibility	1/psi
rw	Wellbore Radius	ft
S	Skin Factor	–
ΔPskin	Pressure Loss Due to Skin	psi
ω	Storativity Ratio (Dual Porosity Parameter)	–
λ	Interporosity Flow Parameter	–
q	Oil Production Rate	STB/day