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Review Article

Characterization of a Stratified Reservoir with Cross Flow Using Tiab's Direct Synthesis (TDS) Technique

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Abstract

This paper presents a comprehensive characterization of a stratified reservoir employing hydrocarbon well test interpretation through the Tiab's Direct Synthesis (TDS) Technique. The reservoir system in question exhibits cross flow phenomena and is separated by a low-permeability layer. Our mathematical model takes into account the interplay between formations, with an observation well situated in one stratum and an active well in another. To analyze the system, we generated multiple pressure and pressure derivative curves in dimensionless form. These curves were systematically integrated to unveil distinctive features, subsequently leading to the derivation of analytical equations. These equations are designed for easy, precise, and practical use. They facilitate the calculation of various essential parameters, including: total transmissibility, transmissibility in the support layer, transmissibility in the producing layer, dimensionless storage coefficient, interlayer flow parameter, capacity ratio, total and vertical flow ratio, dimensionless cross, the support layer and the semipermeable layer, among others. The developed expressions have undergone rigorous testing with both field and synthetic data, consistently yielding outstanding results. This study contributes valuable insights into the characterization of complex stratified reservoirs, offering practical solutions for reservoir engineers and geoscientists.

Introduction

Stratified reservoirs are defined by the presence of multiple production zones characterized by varying petrophysical properties and flow dynamics, often leading to the occurrence of cross-flow. Cross-flow is the phenomenon where unwanted fluid movement takes place vertically through distinct lithological layers within the reservoir. To diagnose and quantify cross-flow, vertical interference testing emerges as a versatile and indispensable tool. However, characterizing reservoirs experiencing cross-flow from a supporting layer to a producing layer often relies on type-curve matching. This approach, although widely used, can yield inconsistent results due to its trial-and-error nature. Bremer, Winston & Vela [1] introduced a mathematical model for analyzing vertical interference tests across low-permeability zones. Burns [2-5] et al. proposed methods to determine vertical permeability in stratified reservoirs. Earlougher [6] contributed with practical considerations and comparisons of these various methods. Additionally, he took into account the effects of wellbore storage, communication behind the casing, and vertical flow through low-permeability barriers. Streltsova-Adams [7] presented semi-analytical solutions for reservoirs comprising two layers separated by semipermeable shale barriers, considering assumptions controlled by both permeability and diffusivity. Ogbe and Dehghani (1989) introduced an interference test model for multi-layer systems and a solution for two-layer reservoirs, where the contiguous narrow layer provides support to the more permeable producing layer. Their interference test model for stratified systems encompasses both well storage and skin effects in active and observation wells. Hatzignatiou & Ogbe [8] developed a model to describe vertical interference pressure behavior in stratified cross-flow reservoirs with differing petrophysical characteristics and dynamic flow in the support and production layers. Their model incorporates wellbore storage and skin effects.

The domain configuration and reservoir geometry are illustrated in Figure 1. Tiab (1995) introduced the Tiab's Direct Synthesis (TDS) Technique for well-test interpretation. This method revolves around identifying characteristic points in the log-log plot of pressure and pressure derivative against time, leading to the derivation of analytical equations based on these 'fingerprints.' In the context of horizontal interference testing using the TDS Technique, the pioneering work was carried out by Ouandlous [9]. He successfully validated his equations using a combination of field and synthetic well-test data. Building upon Ouandlous's innovation, Escobar, et al. [10] employed the TDS Technique to estimate horizontal reservoir anisotropy, utilizing an active well and three observation wells. They also extended this methodology, albeit with slightly reduced accuracy, to cases where only two observation wells were considered. Eligh-Economides & Ayoub [11] presented an enhanced version of the model initially introduced by Bremer et al. [1]. Their model incorporates distinct properties in the two permeable layers, as well as accounting for wellbore storage and skin effects. They employed type-curve matching as their interpretation technique.

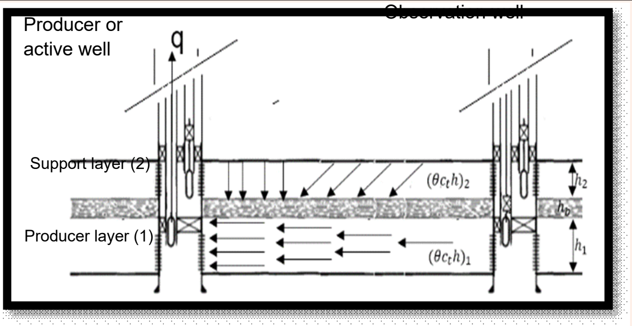

Figure 1: Test model of vertical interference of two wells through a narrow layer. Taken from Bremer et al. [1].

More recently, Escobar, et al. [12] effectively applied the TDS Technique to develop an analytical interpretation method for interference tests in naturally fractured formations. Their equations yielded excellent results when applied to synthetic data. In this study, we combine the model proposed by Hatzignatiou & Ogbe [8] with the TDS Technique to introduce an interpretation method for vertical interference pressure tests. This approach facilitates practical and accurate reservoir characterization. The proposed technique has been rigorously validated using both real-world and synthetic data.

Mathematical Model

Hatzignatiou & Ogbe [8] provided a Laplacian analytical solution to account for vertical interference in the system described in Figure 1, for a stratified reservoir with different properties and separated by a low permeability layer and considering wellbore storage and skin effects.

Active well

$$P_{wD1} = \frac{1}{\Delta}\{[\ell C_{OD}[K_0(\xi) + s_{o1}\xi K_1(\xi)] + (1-\sigma)\xi K_1(\xi)]$$

$$[K_0(\xi) + s_{a1}\xi K_1(\xi)] - \ell C_{oD} K_0(\xi r_{Db}) K_0(\xi r_{Db})\} \quad (1)$$

Observation well

$$P_{D1} = \frac{(1-\sigma)\xi K_1(\xi) K_0(\xi r_{Db})}{\Delta} \quad (2)$$

$$\Delta = \ell\{[\ell C_{oD}[K_0(\xi) + s_{01}\xi K_1(\xi)] + (1-\sigma)\xi K_1(\xi)] \\ [\ell C_{aD}[K_0(\xi) + s_{a1}\xi K_1(\xi)] + (1-\sigma)\xi K_1(\xi)] + \\ -C_{aD} C_{OD}[\ell K_0(\xi r_{Db})]^2\} \quad (3)$$

Being parameter ξ given by:

$$\xi = \sqrt{\frac{\omega}{1-\sigma}\ell + f} \quad (4)$$

Plus the below definitions:

$$T_j = \frac{k_j h_j}{\mu}, \text{ j = (1, 2)} \quad (5)$$

$$S_j = (\theta c_t h)_j; \text{ j = (1, 2)} \quad (6)$$

$$T_t = \frac{\sum_{j=1}^{n} k_j h_j}{\mu} \quad (7)$$

$$S_t = \sum_{j=1}^{n} (\theta c_t h)_j \quad (8)$$

$$\omega = \frac{(\theta c_t h)_1}{(\theta c_t h)_1 + (\theta c_t h)_2} \quad (9)$$

$$\gamma = \frac{r_w}{b}\sqrt{\frac{\sigma}{1-\sigma}} = \frac{r_w}{b}\sqrt{\frac{T_2}{T_1}} \quad (10)$$

$$s = \frac{kh}{141.2 q\mu B_0}\Delta P_s \quad (11)$$

$$\sigma = \frac{k_2 h_2}{k_2 h_2 + k_1 h_1} \quad (12)$$

The capacity ratio, equation (13), expressed as the fraction of the product of the thicknesses times the permeability of each of the layers provides cross-flow information, which is related to the ratio of the total flow to the cross flow.

$$\frac{q_v}{q} = 1 - \frac{k_2 h_2}{k_2 h_2 + k_1 h_1} \quad (13)$$

$$\lambda = \frac{b}{r_w}\sqrt{\frac{1-\omega}{\sigma}} \quad (14)$$

$$\tau = \frac{k_2 h_b}{k_b h_2} \quad (15)$$

The dimensionless quantities are provided as follows:

$$P_{Dj} = \frac{T_t \Delta P_j}{141.2 qB}; \text{ j = (1, 2)} \quad (16)$$

$$t_D * P_D' = \frac{kh(t*\Delta P')}{141.2 q\mu B} \quad (17)$$

$$t_D = \frac{2.637\times10^{-4} T_t t}{s_t r_w^2} \quad (18)$$

$$C_{mD} = \frac{5.615 C_m}{2\pi \sum_{j=1}(\theta c_t h)_j r_w^2} \quad (19)$$

$$r_D = \frac{r_b}{r_w} \quad (20)$$

TDS Technique

The model given by Equations (1) and (29) were used to generate synthetic pressure and pressure derivative curves. For the development of analytical expressions from characteristic points and lines found on the dimensionless pressure and dimensionless pressure derivative vs time log-log plot, it is necessary to normalize the dimensionless pressure and pressure derivative curves by manipulating the variable that causes the curves to diverge. These characteristic values or combination of these will allow the determination of the parameters of the reservoir in stratified formations with crossed flow. A systematic approach will be described step by step and field and synthetic examples will be made to facilitate the understanding of the method and demonstrate the accuracy of the results.

Figure 2 displays the dimensionless pressure and pressure derivative behavior versus dimensionless time as a function of the dimensionless radius between wells. The first characteristic aspect was already introduced by Tiab (1995) which consists of a flat straight line of the dimensionless pressure derivative during the radial flow period which allowed to develop an expression for the calculation of reservoir permeability, Tiab (1995). This equation resulted from the dimensionless pressure derivative during radial flow regime which a horizontal straight-line with an intercept od 0.5; t_D*P_D' = 0.5, Tiab (1995):

$$k = \frac{70.6 q\mu B}{h(t*\Delta P')_r} \quad (21)$$

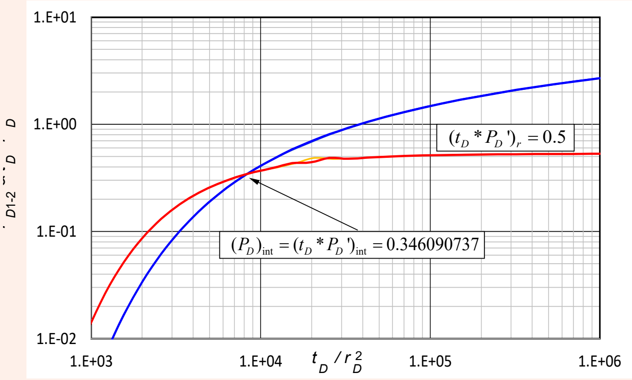

Figure 2: Dimensionless pressure and pressure derivative versus dimensionless time log-log plot for the producing and support layers for different radii between wells.

Figure 3 presents the behavior of pressure and derivative of dimensionless pressure versus dimensionless time, normalized by dividing dimensionless time by the squared dimensionless radius between wells. To obtain the equation of total transmissibility, T_t, the pressure and pressure derivative curves were normalized by multiplying them by the inverse of the squared dimensionless radius providing a unique intersection point between the pressure and pressure derivative curve. This point equals equation (17) and then clears the transmissibility:

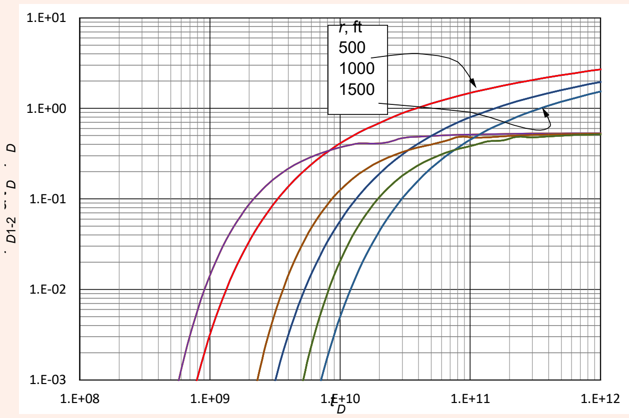

Figure 3: Dimensionless normalized behavior of pressure and pressure derivative versus time for different values of dimensionless radius.

Transmissibility of the production layer, T_1, results from equation (21);

$$T_1 = \frac{70.6qB}{(t*\Delta P')_r} \quad (23)$$

Total transmissibility in a multilayer system is defined as the sum of the transmissibilities of each of the layers that make up the medium, indicating that total transmissibility is the sum of the transmissibility of the support layer and the transmissibility of the production layer defined by equation (7). The difference of total transmissibility, Equation (22), and transmissibility in the producing layer, Equation (23), provides the transmissibility of the support layer.

$$T_2 = T_t - T_1 \quad (24)$$

Replacing equation (22) and (23) into equation (24) by factoring yields equation (25),

$$T_2 = qB\left(\frac{48.983692}{(t*\Delta P')_{int}\frac{70.6}{(t*\Delta P')_r}}()\right) \quad (25)$$

The capacity ratio in the low permeability zone, τ, is a parameter that was calculated by normalizing the pressure and pressure derivative curves which were multiplied by the inverse thickness of the support layer h_2 and $\tau^{6/5}$ and combined with equation (21) to yield;

$$\tau = \left(\frac{2983384qB}{T_t h_2 (t*\Delta P')_{int}}()^{5/6}\right) \quad (26)$$

The estimation of the total storage capacity, S_t, was obtained from the normalization of the pressure and pressure derivative curves by multiplying by the square root of the S_t. This results in:

$$S_t = \left(\frac{T_t (t*\Delta P')_r}{2226.5178qB}\right)^2 \quad (27)$$

The dimensionless storativity ratio, ω, was obtained by normalizing the pressure and pressure derivative curves by multiplying them by the dimensionless storativity ratio raised to 13/20, from which it is obtained:

$$\omega = \left(\frac{68.011471qB}{T_t (t*\Delta P')_r}\right)^{20/13} \quad (28)$$

Streltsova-Adams [7] concluded that reservoir permeability can be overestimated when interference test pressure data are obtained using conventional methods on a stratified system that is producing through the most permeable layer with cross-flow from the support layer to the producing layer. Stewart & Wittman [13] pointed out that it is difficult to obtain a good estimate of the k_2/k_1 ratio because this relationship does not significantly affect the technique of fitting by standard type-curve matching, based on the above, the capacity relationship, , equation 27 is proposed (27). The value of the dimensionless pressure derivative during infinite-acting radial flow regime for a system with cross-flow is subject to the flow capacity as shown in Figure 4.

$$\kappa = \frac{k_2 h_2}{k_1 h_1} \quad (29)$$

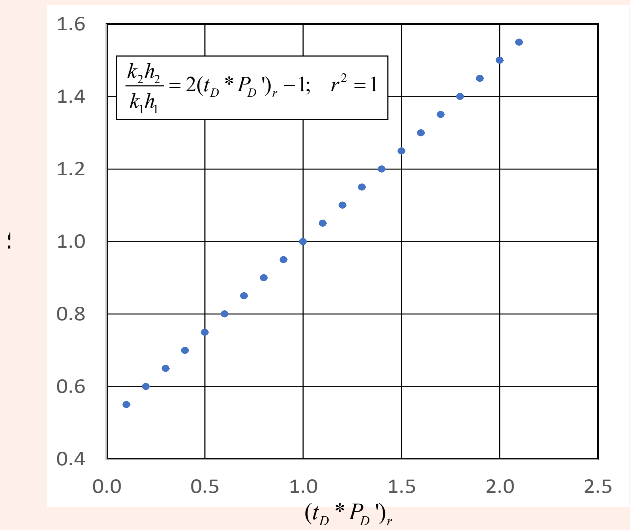

Figure 4: Pressure derivative behavior versus capacity ratio cartesian plot during radial flow.

The parameters calculated below were obtained by mathematical transformations taking into account the flow capacity equation and pressure derivative during radial flow.

$$\gamma = \frac{r_w}{h_2}\sqrt{\frac{T_t (t*\Delta P')_r}{70.6qB} - 1} \quad (30)$$

$$\sigma = 1 - \frac{70.6qB}{T_t (t*\Delta P')_r} \quad (31)$$

$$q_v = q(1-\sigma) \quad (32)$$

Examples

Field example

Figure 5 presents pressure and pressure derivative data digitized from Ehlig-Economides [11]. Other well, fluid and rock properties are given below:

q = 8614 STB/D	θ_{1-2} =20 %
r_w = 0.315 ft	B = 1.0 bbl/STB
μ = 1.0 cp	h_2 = 71 ft
k_2 = 2120 md	h_b = 103 ft
k_v = 3.7 md	h_1 = 92 ft
θ_2 = 20%	c_t = 0.00001 psi-1

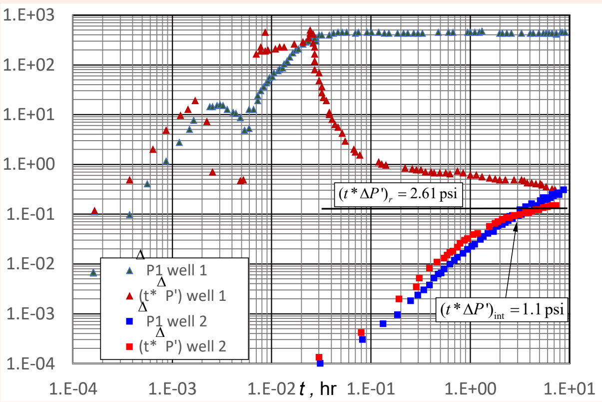

Figure 5: Digitized pressure and pressure derivative versus time for an interference test reported by Ehlig-Economides [11].

The characteristic points read from Figure 5 are:

$(t^*\Delta P')_{int}$ =1.1 psi $(t^*\Delta P)_r \approx$ 2.61 psi

Transmissibilities were estimated with Equations (22), (23) and (24), respectively.

$$T_t = \frac{48.983692(8614)(1.0)}{1.1} = 383586.84\frac{\text{md-ft}}{\text{cp}}$$

$$T_1 = \frac{70.6(8614)(1.0)}{(2.61)_r} = 233007.05\frac{\text{md-ft}}{\text{cp}}$$

$$T_2 = 8614(1.0)\left(\frac{48.983692}{1.1} - \frac{70.6}{2.61}\right) = 150579.79\frac{\text{md-ft}}{\text{cp}}$$

Find σ, q_v, γ, τ, ω and S_t using Equations 31, 32, 30, 28 and 27, respectively.

$$\sigma = 1 - \frac{70.6(8614)(1.0)}{383586.84(2.61)_r} = 0.39256$$

$$\gamma = \frac{0.315}{71}\sqrt{\frac{383586.84(2.61)_r}{70.6(8614)(1.0)}} - 1 = 0.00357$$

$$\tau = \left(\frac{2983384(8614)(1.0)}{383586.84(71)(1.1)_{int}}\right)^{5/6} = 278.2911$$

$$\omega = \left(\frac{68.011471(8614)(1.0)}{383586(2.61)_r}\right)^{20/13} = 0.4385$$

$$S_t = \left(\frac{383586.84(2.6)}{2226.5178(8614)(1.0)}\right)^2 = 0.00027$$

Ehlig-Economides [11] reported permeability values of the Support layer and the permeability of the low permeability layer are k_2 = 2120 md and k_v = 3.7 md. The values obtained on this study are:

$$\frac{T_2\mu}{h_2} = k_2 = 2120.84 \text{ md}$$

$$\frac{k_2 h_b}{\tau h_2} = k_b = 11.055 \text{ md}$$

$$\frac{\omega S_t}{c_t h_1} = \theta_1 = 0.1278 \approx 13\ \%$$

$$\frac{S_t - S_1}{c_t h_1} = \theta_2 = 0.212 = 21\%$$

The properties calculated by means of the equations proposed in this study present an excellent approximation to those developed by Ehlig-Economides [11]. This confirms once more that the TDS technique is a precise method, practical and easy-to-use method (Table 1).

Table 1: Comparison of results.

Reservoir Properties	Ehlig-Economides [11]	This Study
Total trasmisibility, T_t		383586.84
Producer layer trasmisibility, T_1		23007.05
Support layer trasmisibility, T_2	150520	150579.79
Storativity coefficient, ω		0.4385
Interlayer flow, γ		0.00357
Total capacity ratio, σ		0.39254
Low permeability total capacity ratio, τ		278.29
Total storativity capacity, S_t	0.000326	0.00027

Synthetic example 1

Input data to simulate this test are given below:

q = 220 STB/D	θ_1 = 40 %		
rw = 0.5 ft	B = 1.24 bbl/STB		
ct = 0.000023 psi-1	Sa = 30		
μ = 3.2 cp	Co = 0		
re = 1000 ft	h_2 = 70 ft		
k_2 = 90 md	hb = 25 ft		
kb = 0.14 md	h_1 = 200 ft		
k_1 = 150 md	S_1 = 0.01840	S2 = 0.000336	St = 0.002176
T_1 = 9375	T_2 = 1968.75	Tt = 11343.75	ω = 0.84556
σ = 0.148	γ = 0.00188		
τ = 271.42	λ = 174.151		
θ_2 = 40 %			

The following data points were read from Figure 6,

$(t^*\Delta P')_{int}$ = 1.177983 psi $(t^*\Delta P')_r$ = 2.05435 psi

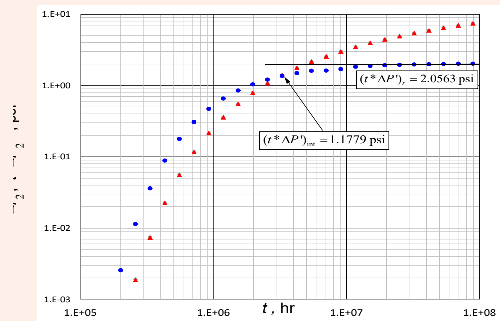

Figure 6: Pressure and pressure derivative versus time log-log plot for example 1.

Use Equations (22), (23), and (25) to estimate the transmissibilities,

$$T_t = \frac{48.983692(220)(1.24)}{1.17798} = 11343.75\frac{\text{md-ft}}{\text{cp}}$$

$$T_1 = \frac{70.6(220)(1.24)}{(2.05435)_r} = 9375.07\frac{\text{md-ft}}{\text{cp}}$$

$$T_2 = (200)(1.24)\left(\frac{48.983692}{(1.17798)_{int}} - \frac{70.6}{(2.05435)_r} 0\right)$$

Obtain ω, τ, S_t, σ, γ, and q_v using Equations 28, 26, 27, 31, 30 and 32, respectively.

$$\omega = \left(\frac{68.011471(220)(1.24)}{11343.75(2.05)}\right)^{20/13} = 0.71$$

$$\tau = \left(\frac{2983384(220)(1.24)}{(11343.75)(90)(1.17)}\right)^{5/6} = 228.39$$

$$S_t = \left(\frac{11343.75(2.05)}{2226.5178(220)(1.24)}\right)^2 = 0.00145$$

$$\sigma = 1 - \frac{70.6(220)(1.24)}{(11343.75)(2.05435)_r} = 0.17355$$

$$\gamma = \frac{0.5}{70}\sqrt{\frac{(11343.75)(2.0543)_r}{70.6(220)(1.24)} - 1} = 0.00327$$

$$q_v = (220)\left(1 - \frac{70.6(220)(1.24)}{(11343.75)(2.0543)}\right) = 38.18 \text{ STB/D}$$

A comparison of the input data for simulating and those obtained by means of the TDS technique is reported in Table 2. Small differences are observed.

Table 2: Comparison of calculated data versus data used for simulation in both synthetic examples.

	Synthetic Example 1		Synthetic Example 2	
Parameter	**Input Data**	**Results**	**Input Data**	**Results**
T_t	11343.75	11343.75	14687.5	14687.5
T_1	9375.0	9375.07	12500	12500
T_2	1968.75	1968.67	2187.5	2187.5
ω	0.8423	0.710	0.8423	0.7367
γ	0.0022	0.0021	0.0018	0.0018
σ	0.1735	0.1735	0.1489	0.1489
τ	229.59	228.39	271.43	281.6
S_t	0.00218	0.00146	0.00149	0.001388

Synthetic example 2

Data used for simulation are provided below:

q = 220 STB/D θ_1 = 25 %
θ_2 =12 %   B = 1.24 bbl/STB
c_{t1} = 0.000023 psi-1 S_a = 30
μ = 3.2 cp c_{t2} = 0.0000123 psi^{-1}
C_o = 0 h_2 = 70 ft k_2 = 100 md h_b = 19 ft
K_b = 0.1 md h_1 = 200 ft
k_1 = 200 md S_1 = 0.00115 S_2 = 0.000344 S_t = 0.0014944
T_1 = 12500
γ =0.030 T_2 = 2187.5 T_t = 14687.5   ω = 0.7695   σ = 0.14894
τ = 271.43   λ = 174.151
r_w = 0.5 ft r_e = 1000 ft

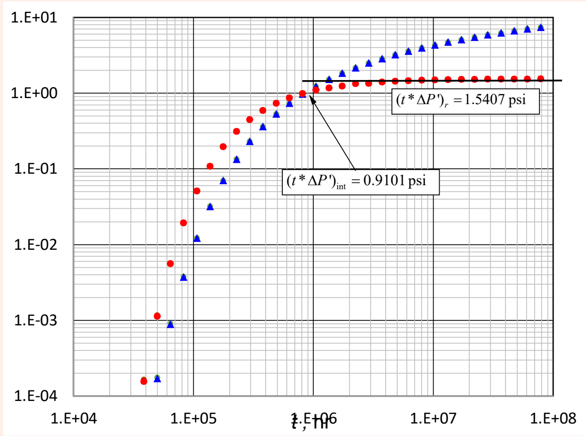

Figure 7: Pressure and pressure derivative versus time log-log plot for example 2.

Use Equations (22), (23), and (25) to estimate the transmissibilities and parameters ω, τ, S_t, σ, γ, and q_v were obtained using Equations 28, 26, 27, 31, 30 and 32, respectively. Calculations are reported in Table 2, along with results for synthetic example 2. Good agreement, with a deviation errors less than half percent, is obtained between the simulated and the calculated values.

Conclusion

In this study, we employ the TDS method to offer a robust means of interpreting well tests in stratified cross-flow formations. The equations, derived from dimensionless pressure and pressure derivative graphs using the mathematical model by Bremer et al. [1], prove to be a highly effective and straightforward solution for calculating the reservoir's characteristics. To facilitate the derivation of the equations used in the TDS Technique, we normalize the generated curves of both dimensionless pressure and dimensionless pressure derivative by dividing or multiplying them with key reservoir characteristic parameters. This normalization process enables the creation of unified graphs, streamlining the application of the equations.

The equations developed in this study exhibit a remarkable level of accuracy, with an error margin of less than 0.5% in comparison to the actual data entered into the simulator. This level of precision is noteworthy and strongly supports the practicality of both the TDS technique and the equations established for reservoir characterization. It is worth noting, as a recommendation, that the precision of the developed equations in this study is particularly high when the transmissibility of the supporting layer is lower than that of the production layer [14,15].

Author Contributions ASM

conceptualization (equal), investigation (lead), writing – original draft (lead); writing – review & editing (lead) MMM: formal analysis (equal), methodology (equal), writing – review & editing (supporting) FHE: conceptualization (equal), investigation (supporting), writing – review & editing (supporting).

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Competing Interests

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data Availability

All data generated or analyzed during this study are included in this published article (and its supplementary information files).

References

1. Bremer RE, Winston H, Vela S (1985) Analytical model for vertical interference tests across low-permeability zones. Society of Petroleum Engineers Journal 25(3): 407-418.
2. Burns WA (1969) New single-well test for determining vertical permeability. Journal of Petroleum Technology 21(6): 743-752.
3. Prats M (1970) A method for determining the net vertical permeability near a well from in-situ measurements. Journal of Petroleum Technology 22(5): 637-643.
4. Falade GK, Brigham WE (1974) The dynamics of vertical pulse testing in a slab reservoir. Presented at the Fall Meeting of the Society of Petroleum Engineers of AIME p. SPE-5055-A.
5. Hirasaki GJ (1974) Pulse tests and other early transient pressure analyses for in-situ estimation of vertical permeability. Society of Petroleum Engineers Journal 14(1): 75-90.
6. Earlougher RC (1980) Analysis and design methods for vertical well testing. Journal of Petroleum Technology 32(3): 505-514.
7. Streltsova-Adams TD (1988) Well testing in heterogeneous formations. John Wiley & Sons, New York, NY, USA.
8. Hatzignatiou DG, Ogbe DO (1993) Interference pressure behavior in stratified reservoirs. Presented at the SPE Western Regional Meeting p. SPE-26051-MS.
9. Ouandlous A (1999) Interpretation of Interference Tests by Tiab's Direct Synthesis Technique. M Sc Thesis, The University of Oklahoma, Norman, USA.
10. Escobar FH, Cubillos J, Montealegre MM (2008) Estimation of horizontal reservoir anisotropy without type-curve matching. Journal of Petroleum Science and Engineering 60(1): 31-38.
11. Ehlig-Economides C, Ayoub JA (1986) Vertical interference testing across a low-permeability zone. SPE Formation Evaluation 1(5): 497-700.
12. Escobar FH, Torregrosa CA, Olaya-Marin G (2020) Interference test interpretation in naturally fractured reservoirs. DYNA 87(214): 121-128.
13. Stewart G, Wittman M (1982) The interpretation of distributed pressure and flow measurements in produced reservoirs, paper EUR 272 presented at the 1982 European Petroleum Conference, London, UK, pp. 25-28.
14. Streltsova TD (1984) Buildup analysis for interference tests in stratified formations. Journal of Petroleum Technology 36(2): 301-310.
15. Tiab D (1993) Analysis of pressure and pressure derivatives without type-curve matching: I-skin and wellbore storage. Presented at the SPE Production Operations Symposium, p. SPE-25426-MS.

Nomenclature

B = Oil volumen factor, bb/STB.

h_2 = Thickness of the support layer, ft

C = Wellbore storage coefficient, bbl/psi

C_{aD} = Dimensionless wellbore storage coefficient of the active well

C_{oD} = Dimensionless wellbore storage coefficient of the observation well

c_t = Total comprenssibility, psi^{-1}

h_2 = Support layer thickness, ft

h_1 = Production layer thickness, ft

P_{D2} = Dimensionless pressure at the observation well

P_{D1} = Dimensionless pressure at the produced well

q = Production flow rate, STB/D

q_v = Cross-flow rate STB/D

r = Radial distance, ft

r_b = Radial distance to observation well, ft

r_D = Dimensionless radial distance

r_w = Wellbore radius, ft ft

s = skin factor

t = Time, hr

t_D = Dimensionless time

T_t = Total transmissibility, kh/p, md-ft/cp

T_1 = Production layer transmissibility, md-ft/cp

T_2 = Support layer transmissibility, md-ft/cp

γ = Interlayer Flow parameter

ℓ = Laplace parameter

λ = Dimensionless cross-flow coefficient zado.

μ = Viscosity, cp

θ_1 = Producer layer porosity, %

θ_2 = Support layer porosity,

σ = Capacity ratio

τ = Capacity ratio at the low permeability zone

S_t = Total storativity capacity

ω = Dimensionless storativity ratio

ΔP = Pressure change, psi

t*ΔP' = Pressure derivative, psi

$(t^*\Delta P)_r$ = Pressure derivative during radial flow regime, psi

$(t^*\Delta P')_{int}$ = Interceptión point between the pressure and pressure derivative curves, psi