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Pressure Distribution of Horizontal Wells in a Layered Reservoir with Simultaneous Gas Cap and Bottom Water Drives

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ABSTRACT : *A plot of dimensionless pressure versus dimensionless time on a log-log paper was done for the six sets of data to illustrate the pressure distribution of horizontal wells in a two layered reservoir with simultaneous gas cap and bottom water drive. From the graphs it was shown that dimensionless pressure increases with dimensionless time.We also observed that when there is crossflow, pressure distribution in such reservoir is the same as that of the homogeneous system. Pressure responses in crossflow reservoir are higher than that of without crossflow.*

We also observed that the following affects the pressure distribution:
Well location along x-axis,x_{wD} *,Wellbore radius* r_{wD}*,Interlayer fluid mobility ratio, time Normalization factor, dimensionless Well length* L_D *and dimensionless height* h_D*.*
It was also observed that the well location z_{wD} *along z-axis does not affect pressure distribution for two layered reservoir.Two-layer crossflow liner with Partial Isolations well completion would be recommended This method provides limited zone isolation, which can be used for stimulation or production control along the well length.*
Also two-layer reservoir without crossflow with cased hole completion is recommended because it provides a high degree of the wellbore control and reservoir management.Cased hole completions are excellent for reservoirs where the horizontal well is being drilled to minimize coning problems. Perforations may be selectively squeezed off to prevent the influx of unwanted fluid.

KEY WORDS: *Well, Pressure,Layer,Reservoir,Horizontal*

I. INTRODUCTION

Production of oil from horizontal well in a layered reservoir subject to simultaneous top gas-cap and bottom water drive poses very serious challenges. The presence of a gas-cap at initial condition indicates saturated oil in equilibrium with the gas. Hence production of gas should be minimised since gas acts as the driving force like the water behind oil production Another challenge is the problem of occasioned by a permeable (crossflow) interface. Isolating each layer through a test analysis is a challenge if the layers contain oil of different properties or layers contain oil and gas .Well completion strategy has to be specially designed to achieve optimal[1] individual layer production performance. For well test analysis of pressure data, it would be required that flow from each layer is adequately quantified and delineated.It is with a view to addressing these challenges that a model was developed by combining application of instantaneous source functions and Newman product methods. to obtain dimensionless pressure distribution of horizontal wells in a layered reservoir with simultaneous gas cap and bottom water drive for sex (6) different set of reservoir and well parameters.

All integrals was evaluated numerically.(GAUSS-LEGENDRE QUADRATURE).

II. METHODOLOGY

- Dimensionless variables for horizontal well was used with instantaneous source functions were obtained for each flow period.
- In this work we treated the effect of gas cap and bottom water drive as a constant pressure condition for both top and bottom boundaries.

- The combined application of instantaneous source functions and Newman product methods was used to obtain equation for dimensionless pressure.
- Determination of flow period (Goode and Thambynayam)[2]
- Determination of interlayer fluid Mobility ratio (M)
- Time normalization factor α ,specifying equivalent flow time in layer 2 for dimensionless flow t_D in layer 1 since the layers have different response time due to different in properties.
- Computation of A_1 and A_2 using numerical method (Gauss-Legendre Quadrature)
- Value of A_1 and A_2 are substituted into Equation for dimensionless pressure and evaluated at different value of t_D to obtain the pressure distribution for each layer .

  Note: All integrals was evaluated numerically.(GAUSS-LEGENDRE QUADRATURE)

To obtain dimensionless pressure distribution of horizontal wells in a layered reservoir with simultaneous gas cap and bottom water drive .Sex (6) different set of reservoir and well parameters were used. A physical description of the problem is illustrated in fig1.0,for horizontal well, the instantaneous source function is the product of three one-dimensional instantaneous source functions is represented by a line source horizontal well in a reservoir infinite in the x and y directions and bounded by the upper and lower boundaries in the z-direction[3].

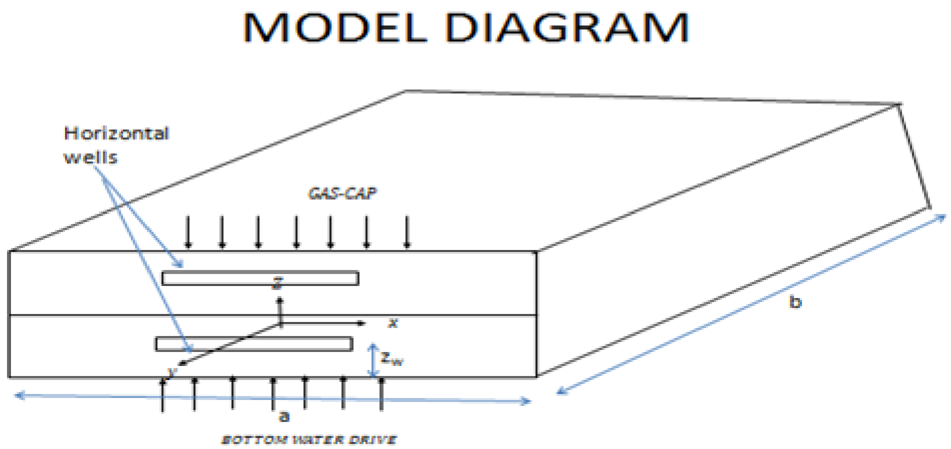

Fig.1.0 Model Diagram

Assumption

(i)Two layers reservoir (ii)Homogeneous reservoir (iii) Oil production

(iv) Negligible capillary (v) Unsteady flow of oil (vi)Slightly compressible oil production.

Dimensionless Variables

The following are dimensionless parameters used for this work.

(1)Dimensionless Pressure

$P_D = P - P(x,y,z,t)/(p - p_w)$ --1.0

(2)Dimensionless time

$$t_D = \frac{K}{\phi c_t \left(L/2\right)^2} \quad ------------------------------------ 2.0$$

(3)Dimensionless distance in the x-direction

$$x_D = \frac{2x}{L}\sqrt{\frac{K}{k_x}} \quad ------------------------------------ 3.0$$

(4) Dimensionless well width

$$x_y = \frac{2y}{L}\sqrt{\frac{K}{k_y}} \quad ------------------------------------ 4.0$$

(5)Dimensionless well length

$$L_D = \frac{L}{2h}\sqrt{\frac{k_z}{k_y}} ------------------------------------ 5.0$$

(6)Dimensionless effective well bore radius

$$r_{wD} = \frac{2rw}{L}\sqrt{\frac{K}{k_x}} + \sqrt{\frac{K}{k_y}} ------------------------------------ 6.0$$

(7) Dimensionless pay thickness

$$h_D = \frac{2h}{L}\sqrt{\frac{k}{k_z}} ------------------------------------ 7.0$$

(8) Dimensionless distance in z-direction

$$z_D = \frac{2z}{L}\sqrt{\frac{K}{k_z}} ------------------------------------ 8.0$$

PRESSURE DISTRIBUTION

A general expression for dimensionless pressure for horizontal well[4].

$$P_{Dj} = 2\pi h_D \int_0^{t_D} s(x_D,\tau), s(y_D,\tau), s(z_D,\tau), ----- 9.0$$

Mathematical Model For Layer 1

$$P_{D1} = -\frac{\beta}{4L_{D1}}\int_0^{tD}\frac{e^{-\frac{(y_D - y_{wD1})^2+(Z_D - Z_{wD1})^2}{4\tau}}}{\tau}d\tau + 2\pi h_{D1}A_1\int_{tDe}^{tDZ}\left[e^{-\frac{(y_{D1}-y_{wD1})^2}{4\tau}}\right] * \left[erf\frac{\left(\sqrt{\frac{K}{k_X}} - X_{D1}\right)}{2\sqrt{\tau}} + erf\frac{\left(\sqrt{\frac{K}{k_X}} - X_{D1}\right)}{2\sqrt{\tau}}\right] *$$

$$\left[1 + 2\sum_{n=1}^{\infty}\exp\left(\frac{n^2\pi^2\tau}{h_{D1}^2}\right)\cos n\pi\frac{Z_{D1}}{h_{D1}}\cos n\pi\frac{Z_{wD1}}{h_{D1}}\right]d\tau + 2\pi h_{D1}A_1\int_{tDZ}^{tD}\left[1 + \frac{4x_{eD1}}{\pi}\sum_{n=1}^{\infty}\frac{1}{m}\exp\left(\frac{-m^2\pi^2\tau}{x_{eD1}^2}\right)\sin\frac{\pi m}{2x_{eD1}}\cos\frac{m\pi x_{eD}}{x_{eD1}}\cos\frac{m\pi x_{D1}}{x_{eD1}}\right] *$$

$$\frac{1}{y_{eD1}}\left[1 + 2\sum_{n=1}^{\infty}\exp\left(\frac{-m^2\pi^2\tau}{y_{eD1}^2}\right)\cos\frac{m\pi y_{wD1}}{y_{eD1}}\cos\frac{m\pi y_{D1}}{y_{D1}} *\right] * \left[\frac{2}{h_{D1}}\sum_{n=1}^{\infty}\exp\frac{\left(-(2n+1)^2\right)\pi^2\tau}{4h_{D1}^2}\cos\frac{(2n+1)\pi z_{wD1}}{h_{D1}}\cos\frac{(2n+1)\pi z_{D1}}{h_{D1}}\right]d\tau -- 10.0.$$

Mathematical Model For Layer 2

$$P_{D2} = -\frac{\beta}{4L_{D2}}\int_0^{t_D}\frac{e^{-\frac{(y_{D2}-y_{wD2})^2+(z_{D2}-z_{wD2})^2}{4\tau\alpha}}}{\tau}d\tau + 2\pi h_{D2}A_2\int_{t_{De}}^{t_{DZ}}\left[e^{-\frac{(y_{D2}-y_{wD2})^2}{4\tau\alpha}}\right]*\left[erf\frac{\left(\sqrt{\frac{K}{k_x}}-x_{D2}\right)}{2\sqrt{\tau\alpha}}+erf\frac{\left(\sqrt{\frac{K}{k_x}}-x_{D2}\right)}{2\sqrt{\tau\alpha}}\right]*$$

$$\left[1+2\sum_{n=1}^{\infty}\exp\left(\frac{n^2\pi^2\tau\alpha}{h_{D2}^2}\right)\cos n\pi\frac{z_{D2}}{h_{D2}}\cos n\pi\frac{z_{wD2}}{h_{D2}}\right]d\tau + 2\pi h_{D2}A_2\int_{t_{DZ}}^{t_D}\left[1+\frac{4x_{eD2}}{\pi}\sum_{n=1}^{\infty}\frac{1}{m}\exp\left(\frac{-m^2\pi^2\tau\alpha}{x_{eD2}^2}\right)\sin\frac{\pi m}{2x_{eD2}}\cos\frac{m\pi x_{eD2}}{x_{eD2}}\cos\frac{m\pi x_{D2}}{x_{eD2}}\right]*$$

$$\frac{1}{y_{eD2}}\left[1+2\sum_{n=1}^{\infty}\exp\left(\frac{-m^2\pi^2\tau\alpha}{y_{eD2}^2}\right)\cos\frac{m\pi y_{wD2}}{y_{eD2}}\cos\frac{m\pi y_{D2}}{y_{D2}}\right]*\left[\frac{2}{h_{D2}}\sum_{n=1}^{\infty}\exp\frac{\left(-(2n+1)^2\right)\pi^2\tau\alpha}{4h_{D2}^2}\cos\frac{(2n+1)\pi z_{wD2}}{h_{D2}}\cos\frac{(2n+1)\pi z_{D2}}{h_{D2}}\right]d\tau \text{ --- } 11.0$$

Constants (A_1 and A_2) at the Interface

Multiplicative factors, A_1 and A_2 are introduced such that if obtained would compensate the assumption of a constant-pressure boundary and duplicate the influence of the interface more properly.

To obtain expression for the above constant (A1 and A2), boundary conditions come to play at the interface. That is,

$$P_{D1}=P_{D2}\text{--}12.0$$

$$\frac{\partial p_{D1}}{\partial z_D} = M\frac{\partial p_{D2}}{\partial z_D}\text{ ------------------------------ } 13.0$$

From equation 3.17 and 3.18

$$A_1 = \frac{M\ P_{2i}V + Vd\ P_{2i}}{M\ p_i + d\ P_i P_{2i}}\text{ ------------------------------ }14.0$$

$$A_2 = \frac{V\ A_1 d\ P_i}{Md\ P_{2i}}\text{ ------------------------------ }15.0$$

Where

$$P_{2i} = 2\pi h_{D2}\int_{t_{De}}^{t_{DZ}}\left[e^{-\frac{(y_{D2}-y_{wD2})^2}{4\tau}}\right]*\left[erf\frac{\left(\sqrt{\frac{K}{k_X}}-x_{D2}\right)}{2\sqrt{\tau\alpha}}+erf\frac{\left(\sqrt{\frac{K}{k_X}}-x_{D2}\right)}{2\sqrt{\tau\alpha}}\right]*$$

$$\left[1+2\sum_{n=1}^{\infty}\exp\left(\frac{n^2\pi^2\tau\alpha}{h_{D2}^2}\right)\cos n\pi\frac{z_{D2}}{h_{D2}}\cos n\pi\frac{z_{wD2}}{h_{D2}}\right]d\tau$$

$$V = \frac{\beta}{4L_{D2}}\int_0^{t_D}\frac{e^{-\frac{(Y_D-Y_{WD2})^2+(z_{D2}-z_{WD2})^2}{4\tau}}}{\tau}d\tau - \frac{\beta}{4L_{D1}}\int_0^{t_D}\frac{e^{-\frac{(Y_D-Y_{WD1})^2+(z_{D1}-z_{WD1})^2}{4\tau}}}{\tau}d\tau$$

$$P_i = \frac{}{2\pi h_{D1}} \int_{t_{De}}^{t_{DZ}} \left[e^{-\frac{(y_{D1} - y_{wD1})^2}{4\tau}} \right] * \left[erf \frac{\left(\sqrt{\frac{K}{k_X}} - X_{D1}\right)}{2\sqrt{\tau\alpha}} + erf \frac{\left(\sqrt{\frac{K}{k_X}} - X_{D1}\right)}{2\sqrt{\tau\alpha}} \right] *$$

$$\left[1 + 2 \sum_{n=1}^{\infty} \exp\left(\frac{n^2 \pi^2 \tau\alpha}{h_{D1}^2} \right) \cos n\pi \frac{Z_{D1}}{h_{D1}} \cos n\pi \frac{Z_{wD1}}{h_{D1}} \right] d\tau$$

$$dP_i = -\frac{\pi}{h_{D1}} \left[e^{-\frac{(Y_{D1} - Y_{WD1})^2}{4\tau}} \right] * \left[erf \frac{\left(\sqrt{\frac{K}{K_x}} - x_{D1}\right)}{2\sqrt{\tau}} + erf \frac{\left(\sqrt{\frac{K}{K_x}} - x_{D1}\right)}{2\sqrt{\tau}} \right] * \left[1 + 2 \sum_{n=1}^{\infty} \exp\left(\frac{n^2 \pi^2 \tau}{h_{D1}^2} \right) \sin\left(\frac{n\pi Z_{D1}}{h_{D1}} \right) Cos\left(\frac{n\pi Z_{WD1}}{h_{D1}} \right) \right] d\tau$$

$$dP_{2i} = -\frac{\pi}{h_{D2}} \left[e^{-\frac{(Y_{D1} - Y_{WD1})^2}{4\tau\alpha}} \right] * \left[erf \frac{\left(\sqrt{\frac{K}{K_x}} - x_{D2}\right)}{2\sqrt{\tau\alpha}} + erf \frac{\left(\sqrt{\frac{K}{K_x}} - x_{D2}\right)}{2\sqrt{\tau\alpha}} \right] * \left[1 + 2 \sum_{n=1}^{\infty} \exp\left(\frac{n^2 \pi^2 \tau\alpha}{h_{D1}^2} \right) \sin\left(\frac{n\pi Z_{D1}}{h_{D1}} \right) Cos\left(\frac{n\pi Z_{WD1}}{h_{D1}} \right) \right] d\tau$$

Interlayer Fluid Mobility Ratio:

$$M = \frac{K_1 h_1 \mu_1}{K_2 h_2 \mu_2} --16.0$$

(14) Time Normalization Factor

The term α is the time normalization factor to establish the same dimensionless time for flow in two layers of different flow behavior and is derived based on the definition of dimensionless flow times of the layers[5].The equation factor is given in equation 17.0

$$\alpha = \frac{\phi_1 c_{1t} \mu_{t1} L_1^2 K_1}{\phi_2 c_{t2} \mu_2 K_2} -------------------------------------17.($$

Note:

$$t_{D2} = \alpha t_{D1}$$

Dimensionless Time Used In Horizontal Well In Terms Of L/2

$$t_D = \frac{0.0002637 \, k \, t}{\phi\mu \, c_t \left(\frac{L}{2}\right)^2} ----------------------------------18.0$$

To apply flow period equation, we substitute any of flow period in t ,in equation 1.0 above .
For example
Early-Time Radial Flow. The early-time radial flow period ends at

$$t_{e1} = \frac{190\, d_z^{2.095}\, r_w^{-0.095}\, \phi\mu\, c_t}{k_v} ----------------------------------- 19.0$$

Equation 18.0 is now

$$t_D = \frac{0.0002637\, k\, t_{e1}}{\phi\mu\, c_t \left(\frac{L}{2}\right)^2} -- 20.0$$

Equation 20.0 will give dimensionless value of Early-Time Radial Flow value.
Also by substituting t_{e2} and t_{e3} in equation 1.0

$$t_{e2} = \frac{20.8\,\phi\mu\, c_t L^2}{k_v}$$

$$t_{e3} = \frac{1230.0\,\phi\mu\, c_t L^2}{k_v}$$

Dimensionless values of Intermediate-time linear flow and Pseudoradial Flow can be obtained[2].

Statistical test for null significal test

The statistical test for significant differences is the t-test for two means for the results[5].

$$\bar{\sigma}_{\bar{X}_1 - \bar{X}_4} = \sqrt{\frac{SS_1 + SS_4}{N_1 + N_4 - 2} * \frac{N_1 + N_4}{N_1 * N_4}} ------------------------------ 21.0$$

Calculation of t-ratio

$$t = \frac{\bar{x}_1 - \bar{x}_4}{\bar{\sigma}_{\bar{X}_1 - \bar{X}_4}} -- 22.0$$

Where
SS_1=Corrected sum of squares for sample 1, PD(clonts and Ramey),x1
SS_2=Corrected sum of squares for sample 2, **PD(Ozkan et al),x_2**
SS_3=Corrected sum of squares for sample 3, **PD(Malekzadeh t al)x_3**
SS_4=Corrected sum of squares for sample 4 **PD(Our Results)**,x_4
N_1=size of sample 1
N_1=size of sample 2
N_1=size of sample 3
N_1=size of sample 4
Sum of squares,SS=

$$SS_{tX} = \sum X^2 - \frac{\left(\sum X\right)^2}{N} ------------------------------------ 23.0$$

Hypothesis

Null hypothesis is stated: H_0: $\bar{x}_1 - \bar{x}_4 = 0$

III. RESULTS AND DISCUSSION

Table1.0: EXAMPLE 1, RESERVOIR AND WELL PROPERTIES

LD1	**LD2**	**ZWD1**	**ZWD2**	**ZD1**	**ZD2**	**DZ(ft)**
0.19764	0.194	0.995	0.788	0.005	0.004	2.5
h_{D1}	**h_{D2}**	**X_{wD1}**	**XwD2**	**YeD1**	**YeD2**	**DX(ft)**
4.785	2.5298	0.99244	0.795	0.0015	0.0215	2.00E+02
XeD2	**XeD1**	**K2(Md)**	**Kx2(Md)**	**k1(mD)**	**kx1(mD)**	**dy(ft)**
0.0215	0.14	10	10	8.94427	10	21
Ct_1(psi-1)	**ct_2(psi^{-1})**	**L1(ft)**	**L2(ft)**	**h1(ft)**	**h2(ft)**	
4.00E-06	3.00E-06	250	250	200	100	
YD1	**YD2**	**Ø1**	**Ø2**	**YWD1**	**YWD2**	
8.00E-03	6.00E-03	0.23	0.23	9.92E-01	8.94E-01	
XD1	**XD2**	**µ1(cp)**	**µ2(cp)**	**hD2**	**hd1**	
0.00757	0.0065	0.5	0.2	2.5298	4.785	

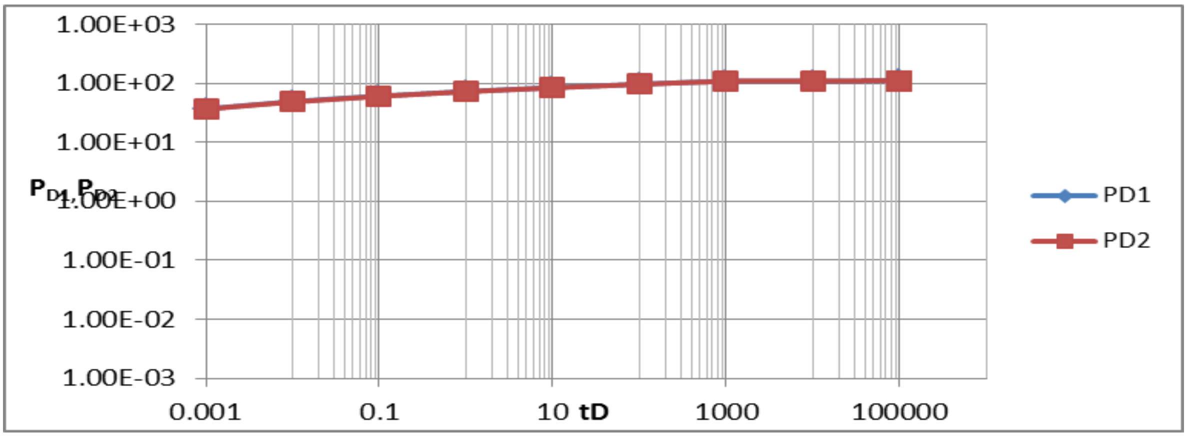

Fig. 1.0: Pressure Distribution for Two Layered Reservoir for Example 1

Pressure Distribution for Example 2: From Fig. 1.0 , it is observed that there is no significant difference between pressure response in Layer 1 and Layer 2. This could be as a result of both layers having equal permeability. In this case, possibility of having a crossflow between Layer1 and Layer 2 will not be there. Effect of layering is observed at early $t_{D,}$ and steady-state flow is observed at late $t_{D.}$ The steady-state behavior is as a result of subjection of the reservoir both up and down by a gas cap and bottom water drive.

Table2.0: EXAMPLE 2, RESERVOIR AND WELL PROPERTIES

LD1	**LD2**	**ZWD1**	**ZWD2**	**ZD1**	**ZD2**	**YD1**	**YD2**
0.1186	0.1001	0.995	0.788	0.1854	0.1793	5.93E-02	3.46E-02
hD1	**hD2**	**XwD1**	**XwD2**	**YeD1**	**YeD2**	**XD1**	**XD2**
7.495	6.43	0.992435	0.795	0.0015	0.0215	0.05925	0.04532
K_2(mD)	**K_{x2}(mD)**	**k_1(mD)**	**kx_1(mD)**	**$Ø_1$**	**$Ø_2$**	**$µ_1$(cp)**	**$µ_2$(cp)**
8	10	6.32	10	0.22	0.23	0.04	0.2
L_1(ft)	**L_2(ft)**	**h1(ft)**	**h2(ft)**	**YWD1**	**YWD2**	**XeD2**	**XeD1**
30	50	40	40	9.92E-01	8.94E-01	0.0215	0.14
r_{WD1}	**r_{WD2}**	D_x(ft)	Dx(ft)	**c_{t1}**	**c_{t2}**	k_v(mD)	D_z(ft)
0.0156	1.11×10^{-3}	20	8	5.00E-06	3.00E-06	0.8	30

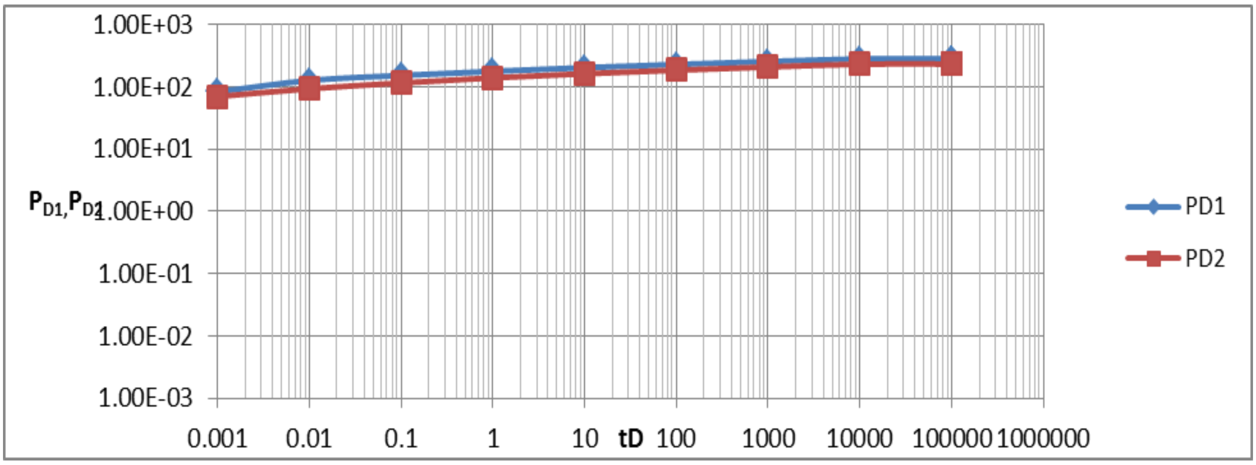

Fig. 2.0: Pressure Distribution for Two Layered Reservoir for Example 2

Pressure Distribution for Example 2 : Pressure Distribution for Two Layered Reservoir for Case Study 2 is shown in Fig. 2.0 above. The permeability of layer 2 is higher than that of layer 1 and the viscosity of Layer 1 is higher than that of Layer 2, as a result of this the pressure response in layer 2 is higher than that of Layer 1 as shown in Fig. 4.10 above. In this case study the value of α =1.51 and M=0.158. The degree of crossflow through the interface is higher toward Layer 2 as indicated by the value of M. Here completion should be carried out in Layer 2 where there is the possibility of have more recovery.

Table3.0: EXAMPLE 3, RESERVOIR AND WELL PROPERTIES

LD1	**LD2**	**ZWD1**	**ZWD2**	**ZD1**	**ZD2**	**YD1**	**YD2**
0.75293	0.7012	0.0995	0.0788	0.005	0.004	8.00E-03	6.00E-03
hD1	**hD2**	**XwD1**	**XwD2**	**K2(mD)**	**Kx2(mD)**	**k1(mD)**	**kx1(mD)**
1.32816	1.211	0.9924	0.795	10	10	10	10
YWD1	**YWD2**	**YeD1**	**YeD2**	**XD1**	**XD2**	**hd2**	**Hd1**
9.92E-01	8.94E-01	0.0015	0.0215	0.007565	0.0065	1.211	1.328157
Ø1	**Ø2**	**µ1**	**µ2**	**ct1**	**ct2**	**L1(ft)**	**L2(ft)**
0.2	0.23	1	0.2	4.00E-06	3.00E-06	1000	1500
dy(ft)	**dx(ft)**	**Dz(ft)**	**dy(ft)**	**rwD1**	**rwD2**	**XD1**	
21	200	8.05	21	0.004936	0.00221	0.008	
h2(ft)	**h1(ft)**	**XeD2**	**XeD1**	**kv(mD)**	**K_h(mD)**		
21	21	0.022	0.14	0.01	10		

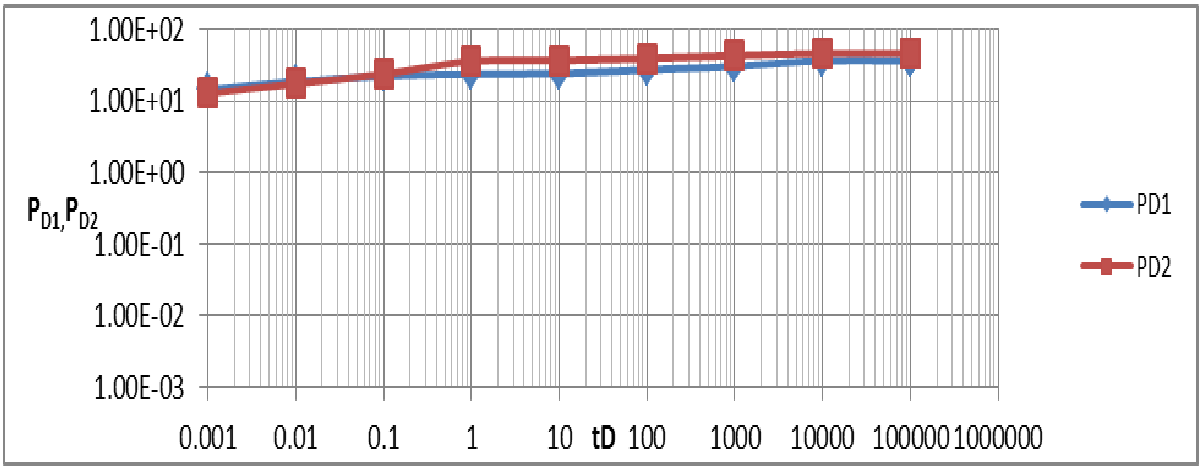

Fig. 3.0: Pressure Distribution for Two Layered Reservoir for Example 3

Pressure Distribution for Example 3 :
Pressure Distribution for Two Layered Reservoir for Case Study3 is shown in Fig.3.0 above. The permeability of the two layers equal but layer 2 has a higher porosity. This could have contributed to high productivity of Layer 2. In this case study the value of α =3.86 and M=5.0. The degree of crossflow through the interface is higher toward Layer 2 as indicated by the value of M. Here completion should be carried out in Layer 2 where there is the possibility of have more recovery.

Table4.0: EXAMPLE 4, Reservoir And Well Properties

LD1	**LD2**	**ZWD1**	**ZWD2**	**ZD1**	**ZD2**	**YD1**
0.2209	0.1109	0.995	0.788	0.005	0.004	8.00E-03
hD1	**hD2**	**XwD1**	**XwD2**	**ct2**	**L1(ft)**	**L2(ft)**
4.785	5.412	0.992435	0.795	3.00E-06	250	250
K2(mD)	**Kx2(mD)**	**k1(mD)**	**kx1(mD)**	**Ø1**	**Ø2**	**µ1(cp)**
10	10	8.94427	10	0.23	0.23	0.5
YeD1	**YeD2**	**XD1**	**XD2**	**hd2**	**Hd1**	**XeD2**
0.0015	0.0215	0.007565	0.0065	5.412	4.785	0.0215
dy(ft)	dx(ft)	YWD2	kv(mD)	dz(ft)	Dz(ft)	rwD1
21	200	8.94E-01	1	2	30	0.0160
Yw_{D1}	**ct1(psi^{-1})**	**h_1(ft)**	**h_2(ft)**	**µ2(cp)**	**XeD1**	**rwD2**
9.9E-1	5.00E-05	200	100	0.2	0.14	0.0591

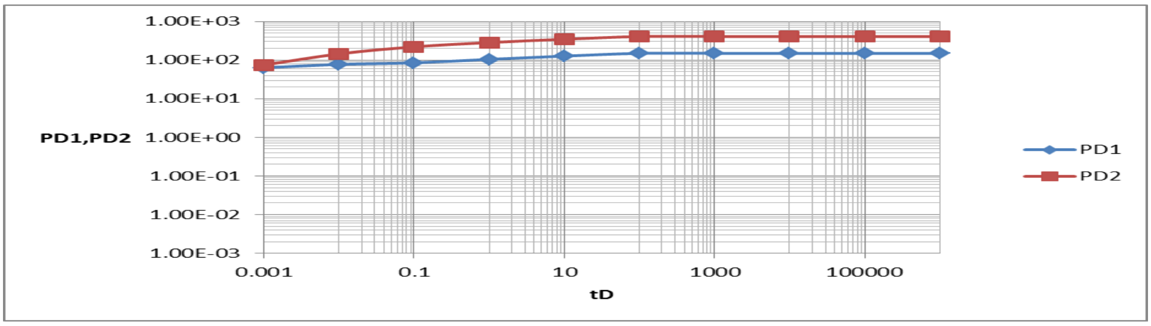

Fig. 4.0: Pressure Distribution for Two Layered Reservoir for Example 4

Pressure Distribution for Example 4
In this case study we have four numbers of flow periods . The value of time normalization factor α =37.3 and the interlayer mobility ratio M=4.47. Fig. 4.0 illustrate the pressure distribution in each layer. From the figure we observe that the pressure response is higher in Layer 2 than in Layer 1. Here the permeability is higher in Layer 2 than in Layer 1; and porosity and in both Layers are equal. The high pressure response in layer 2 could be as a result of high permeability of Layer 2 or as a result of gas cap being predominant. From the figure this reservoir experiences steady-state behavior at later $t_{D.}$

Table5.0: EXAMPLE 5, RESERVOIR AND WELL PROPERTIES

LD1	LD2	ZWD1	ZWD2	ZD1	ZD2	YD1	YD2
0.144	0.0812	0.056	0.0121	0.121	0.313	0.351	0.141
hD1	hD2	XwD1	XwD2	YeD1	YeD2	XD1	XD2
6.93	3.11	0.732	0.732	0.012	0.006	0.231	0.312
K2(mD)	Kx2(mD)	k1(mD)	kx1(mD)	Ø1	Ø2	µ1(cp)	µ2(cp)
1000	1000	1000	1000	0.2	0.21	0.3	0.3
YWD1	YWD2	XeD2	XeD1	L1(ft)	L2(ft)	h1(ft)	h2(ft)
0.00712	0.006	0.214	0.325	100	100	6	6
ct1(ft)	ct2(ft)	XD1	Dz(ft)	dx(ft)	dy(ft)	rwD1	rwD2
0.000004	0.000004	0.231	4	2	10	0.04	0.012

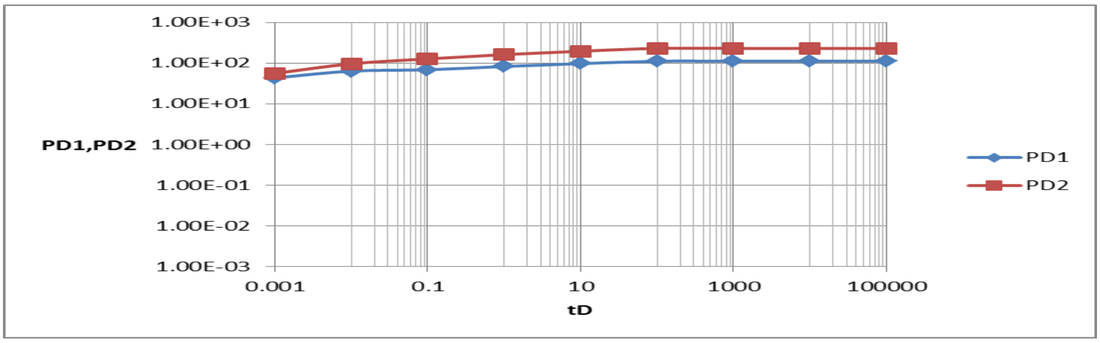

Fig. 5.0: Pressure Distribution for Two Layered Reservoir for Example 5

Pressure Distribution for Example5

In this case study we have two numbers of flow periods . The value of time normalization factor α =0.952 and interlayer mobility ratio M=1.0. Fig. 5.0 illustrates the pressure distribution of both layers. The pressure in Layer 2 is higher than that of layer 1. This could be as a result of higher porosity of Layer2 since both layers have the same permeability. It could also be as a result of as cap energy.

Table6.0: EXAMPLE 6, Reservoir and Well Properties

LD1	**LD2**	**ZWD1**	**ZWD2**	**ZD1**	**ZD2**
0.129764	6.03	0.995	0.788	0.005	0.004
hd2	**hd1**	**XwD1**	**XwD2**	**XD1**	**XD2**
4.785	2.5298	0.992435	0.795	0.007565	0.0065
K2(mD)	**Kx2(mD)**	**k1(mD)**	**kx1(mD)**	**Ø1**	**Ø2**
4	4	4	4	0.2	0.23
YWD1	**YWD2**	**YeD1**	**YeD2**	**Dz(**	**Dz(ft)**
9.92E-01	8.94E-01	0.0015	0.0215	2	0.3
XD1	**h1(ft)**	**h2(ft)**	**Dx(ft)**	**Dy(ft)**	**Dz(ft)**
0.00126	5	5	200	21	2.00E+00
rwD1	rwD2	**YD1**	**YD2**	**XeD2**	**XeD1**
$4\text{x}10^{-2}$	$1.2\text{x}10^{-2}$	8.00E-03	6.00E-03	0.0215	0.14
µ1(cp)	**µ2(cp**	**ct1psi^{-1}**	**ct2psi^{-1}**	**L1(ft)**	**L2(ft)**
0.03	0.2	4.00E-06	3.00E-06	2000	2500

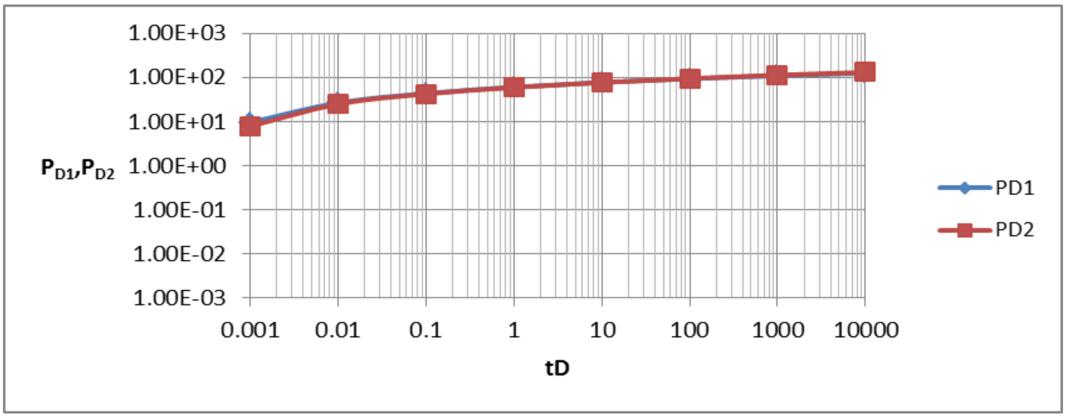

Fig. 6.0: Pressure Distribution for Two Layered Reservoir for Example 6

Pressure Distribution for Example 6

In this case study we have three numbers of flow periods . The value of time normalization factor α =0.139 and interlayered mobility ratio M=0.15. Fig. 6.0 illustrates the pressure distribution of the two Layers. Productivity is higher in Layer 1 at $t_D \leq 10$.

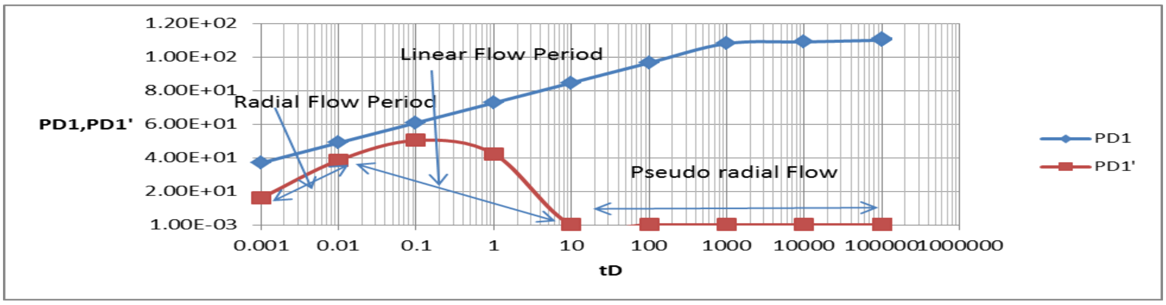

Fig. 7.0: Dimensionless Pressure and Dimensionless Pressure Derivative for Layer1 With Flow Period for Example 1.

Dimensionless Pressure and Dimensionless Pressure Derivative for Layer1 With Flow Period for Example 1.

Fig.7.0 shows pressure derivative distribution for example 1.With this figure we are able to identify the flow period. The pressure derivative enable us to identify flow period and also help in determine some Important parameters.

Table7.0:Comparison of Results

t_D	PD(clonts and Ramey),x1[6]	PD (Ozkan et al),x2[7]	PD Malekzadeh t al)x3[8]	Pd(Our Results)x4
0.000 1	0.17007	0.17	0.1126	0.11033271
0.001	0.22888	0.2288	0.17098	0.356560518
0.01	0.34956	0.3495	0.29164	0.576587549
0.1	0.66767	0.6675	0.60972	0.867461538
1	1.3763	1.376	1.31828	1.339233496

VALIDATION OF RESULTS

The results of an infinite-acting reservoir have been validated as presented in Table7.0 and Fig 8.0 and also from statistic test carried out below. This implies that the numerical method used was adequate.

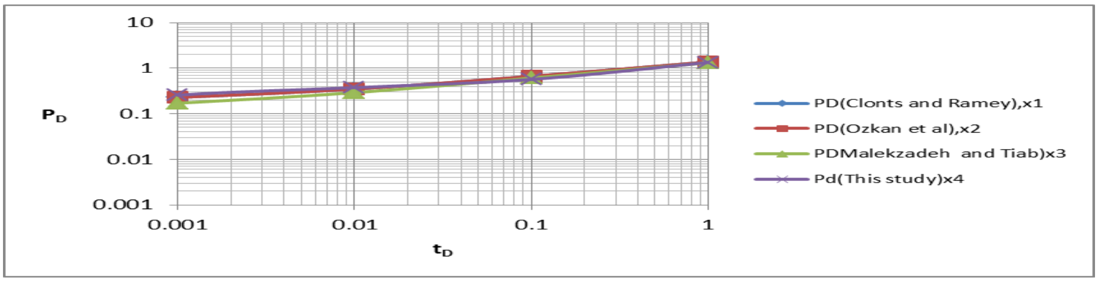

Fig 8.0: Comparison of Dimensionless Wellbore Pressure Results

From Table7.0 and equation 21.0

(i) t-Test for clonts and Ramey)x1

$$\sigma_{\bar{X}_1 - \bar{X}_4} = \sqrt{\frac{0.98389062 + 0.905}{8} * \frac{10}{25}} = 0.307324526$$

Also from equation 22.0

$$t = \frac{\bar{x}_1 - \bar{x}_4}{\sigma_{\bar{X}_1 - \bar{X}_4}} = \frac{0.558496 - 0.65}{0.307324526} = 0.297774389$$

=0.29777507

Similarly,
t-Test for PD(Ozkan et al),x2

t-Test for PDMalekzadeh t al)x3
=0.29778588
Degree of freedom=N_1+N_2-2=5+5-2=8
Choosing a significant level test H_O,α=0.05
Therefore, the tabled t-ratio(α=0.05) for 8 degree freedom is 2.306
Since our obtained t-ratio is less than that of the tabled value H_o accepted. The conclusion drawn from the t-test carried
out, therefore there is no significant difference between our results and other Authors considered.

IV. CONCLUSION

Haven presented the problems objectives, and results of study in the previous chapters, we arrived at the following conclusion:

[1] We have been able to show behavior of pressure distribution for two layered reservoir subjected simultaneously by a Gas-cap and bottom water derive both graphical and tabular form for six examples were considered.
[2] We have been able to determine the flow regime ;(i) Radial Flow (ii) Early Linear Flow Period.
[3] We have been able to compute the multiplication factor (A_1 and A_2)using numerical method (Gauss-Legendre Quadrature)
[4] This factor decreases with dimensionless time,t_D and become zero with increase in t_D And we have seen that the time interval at which the constants maintain a zero slope marks the end of infinite-acting flow and attainment of
[5] their final values irrespective of flow time.
[6] We have also compute the dimensionless pressure and dimensionless pressure derivative using numerical

Method (Gauss-Legendre Quadrature) .The results showed that dimensionless pressure increases with dimension

time.The results show that it is possible to analyzed each layers using the conventional methods and each

layer requires properties from other layer involved.

NOMENCLATURE

C_t	Total reservoir compressibility, Psi $^{-1}$
h	Formation thickness ft
h_D	Dimensionless height
L_D	Dimensionless length
P_D	Dimensionless Pressure
P_{wD}	Dimensionless wellbore pressure
p_D'	Dimensionless pressure derivative
S	Instantaneous source functions
t	Time,hrs
t_D	Dimensionless time
x,y,z	Space coordinates
x_D,y_D	Dimensionless distance in the x and y directions
x_f	Horizontal well half length
z_D	Dimension distance in the z director
k	Horizontal permeability and
k_y	Permeability in the y – direction, md
k_z	Permeability in the z direction , md
l	Horizontal well length, ft
r_D	Dimensionless radial distance in the horizontal plane
r_{wD}	Dimensionless wellbore radius
x_w	Well location in the x – direction, ft.
x_e	Distance to the boundary or reservoir length ft
x_{eD}	Dimensionless distance to the boundary
x_{WD}	Dimensionless well location in the x- direction
Z_w	Well location in the direction, ft.

z_{WD} Dimensionless well location in the Z direction
Y_w Well location in the y – direction, ft.
Dimensionless well location in the Y direction.

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