Available online at www.elixirpublishers.com (Elixir International Journal)

Earth Science

Elixir Earth Science 161 (2021) 55905-55909

ISSN: 2229-712X

Estimation of Well and Formation Properties in a Niger Delta Oil Well Using Pressure Drawdown Test-Data

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ARTICLE INFO

Article history:
Received: 18 November 2021;
Received in revised form:
21 December 2021;
Accepted: 31 December 2021;

Keywords
Akata Formation,
Permeability,
Pore Volume,
Pressure Drawdown,
Skin Factor,
Storage Effect.

ABSTRACT

This research estimated the Well and Formation parameters of a Niger Delta Oil Well using pressure draw- down data. The well is located at longitude 05^0 $53^{'}$ $19^{''}$ and latitude 04^0 $20^{'}$ $24^{''}$. The time to end strong wellbore storage effect (t*) was obtained to be 0.0025hrs and the time for the wellbore effect to end completely (50t*) was also determined as 0.125hrs. The wellbore storage constant (C_S) value was obtained as $9.3x10^{-3}$ rb/psi, while the skin factor (S) was also obtained to be 23.4. The permeability to oil value (K) was obtained to be 954.4md and the Reservoir Pore Volume (V_p) value of 8.45 x 10^6 res bbl was also obtained.

Introduction

A reservoir is a subsurface rock that has effective porosity and permeability which usually contains commercially exploitable quantity of hydrocarbon. Reservoir characterization is undertaken to determine its capability to both store and transmit fluid. Permeability is the capacity of a reservoir rock to permit fluid flow. It is a function of interconnectivity of the pore volume; therefore, a rock is permeable if it has an effective porosity. The fluid saturation is the proportion of the pore space that is occupied by the particular fluid. A reservoir can either be water saturated (Sw) or hydrocarbon saturated (1-Sw) depending on the type of fluid it contains. Saturation is a relative measurement and commonly expressed in decimal/fractional units or else as a percentage. A good reservoir is one that is commercially productive; it produces enough oil or gas to pay back its investors for the cost of drilling and leaves a profit.

A pressure drawdown test is simply a series of bottom-hole pressure measurements made during a period of flow at constant production rate. Usually the well is closed prior to the flow test for a period of time sufficient to allow the pressure to stabilize throughout the formation, i.e., to reach static pressure. The objectives of a drawdown test usually included estimates of permeability, skin factor, and, occasion, reservoir volume. These tests are particularly applicable to (1) new wells (2) wells that have been shut in sufficiently long to allow the pressure to stabilize, (3) wells in which loss of revenue incurred in a Buildup test would be difficult to accept. Exploratory wells are frequent candidates for lengthy drawdown tests, with a common objective of determining minimum or total volume being drained by the well (Lee *et al*, 2003).

Geology of the study area

The Niger Delta is situated in the Gulf of Guinea (Figure 1) and extends throughout the Niger Delta Province. From Eocene to the present, the delta has prograded southwestward, forming depobelts that represent the most active portion of the delta at each stage of its development (Doust and Omatsola, 1990). These depobelts form one of the largest regressive deltas in the world with an area of some 300,000 km^2 (Kulke, 1995), a sediment volume of 500,000 km^3 (Hospers, 1965), and a sediment thickness of over 10 km in the basin depocenters, (Kaplan *et al*,1994**)**.

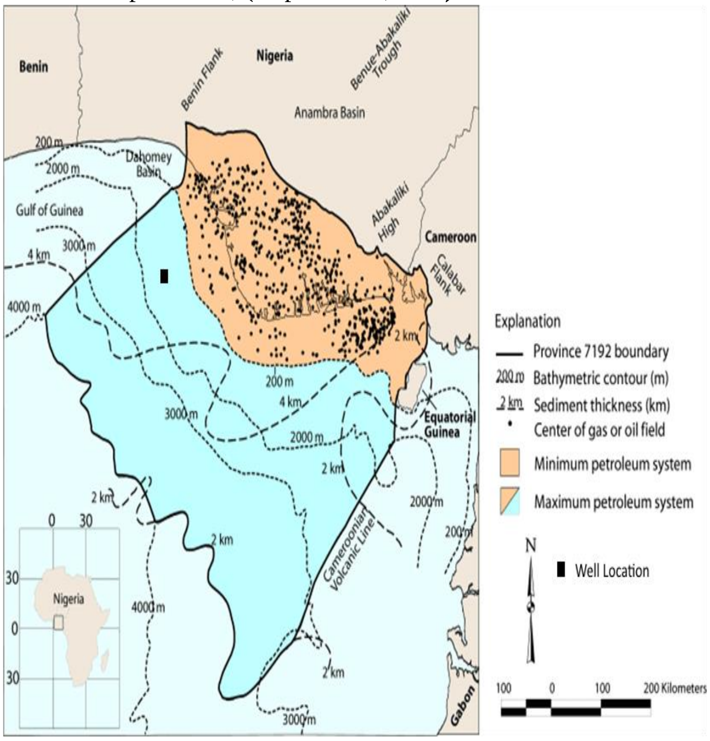

Figure 1. Index Map of Niger Delta Showing Well location (Adaeze *et al*, 2012).

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The onshore portion of the Niger Delta Province is delineated by the geology of southern Nigeria and southwestern Cameroon. The northern boundary is the Benin Flank an east-northeast trending hinge line south of the West Africa basement massif. The northeastern boundary is defined by outcrops of the Cretaceous on the Abakaliki High and further east-south-east by the Calabar Flank - a hinge line bordering the adjacent Precambrian.

The offshore boundary of the province is defined by the Cameroon volcanic line to the east, the eastern boundary of the Dahomey Basin (the eastern-most West African transform-fault passive margin) to the west, and the two-kilometer sediment thickness contour or the 4000-meter bathymetric contour in areas where sediment thickness is greater than two kilometers to the south and southwest. The province covers 300,000Km^2 and includes the geologic extent of the Tertiary Niger Delta (Akata-Agbada) Petroleum System.

Hydrocarbon Source

Much discussion has been made about the source rock for petroleum in the Niger Delta. Possibilities include variable contributions from the marine shale interbedded with paralic sandstone in the Agbada Formation and the marine Akata shale. Based on organic matter content and type, (Evamy, 1978]) proposed that both the marine shale (Akata Formation) and the shale interbedded with paralic sandstone (Lower Agbada Formation) were the source rocks for the Niger Delta oils. However, (Stacher, 1995) proposes that the Akata Formation is the only source rock volumetrically significant and whose depth of burial is consistent with the depth of the oil window.

Reservoir Rock

Petroleum in the Niger Delta is produced from sandstone and unconsolidated sands predominantly in the Agbada Formation. Characteristics of the reservoirs in the Agbada Formation are controlled by depositional environment and by depth of burial. Known reservoir rocks are Eocene to Pliocene in age, and are often stacked. Based on reservoir geometry and quality, (Kulke, 1995) describes the most important reservoir types as point bars of distributary channels and coastal barrier bars intermittently cut by sand-filled channels. The grain size of the reservoir sandstone is highly variable with fluvial sandstones tending to be coarser than their delta front counterparts; point bars fine upward, and barrier bars tend to have the best grain sorting. Much of this sandstone is nearly unconsolidated, some with a minor component of argillo-silicic cement. Porosity only slowly decreases with depth because of the young age of the sediment and the coolness of the delta complex.

Theoretical Background and Materials

In a constant-rate drawdown test, the well is initially shut in, and the reservoir is at uniform pressure. The well is produced at constant rate q, and the flowing bottom hole pressure pwf is measured as a function of time as the pressure draws down. The pressure response for a well producing at constant rate from an infinite-acting reservoir may be written as

$$p_{wf}(t) = p_i - \frac{162.6 qB\mu}{kh}\left[\log t + \log\left(\frac{k}{\phi\mu c_t r_w^{\ 2}}\right) - 3.23 + 0.869s\right] \quad \textbf{(1)}$$

Comparing equation (1) with the equation of a straight line, $y = mx + b$, suggests that a graph of $pwf\,(t)$ vs. $\log(t)$ for drawdown data exhibiting Infinite Acting Reservoir Flow (IARF) will be a straight line with slope m given by

$$m = -\frac{162.6 qB\mu}{kh} \quad (2)$$

$$b = p_{1hr} = p_i - \frac{162.6 qB\mu}{kh}\left[\log\left(\frac{k}{\phi\mu c_t r_w^{\ 2}}\right) - 3.23 + 0.869s\right] \quad (3)$$

Because the independent variable is log(t), the y-intercept is read from the y-axis, where log(t) = 0, corresponding to a time of 1 hour. Thus, the intercept b is usually written as $p1hr$ for a drawdown test. Figure 2 shows a graph of pressure vs. time for a drawdown test, showing the straight line through the data in IARF, the slope m, and the intercept $p1hr$.

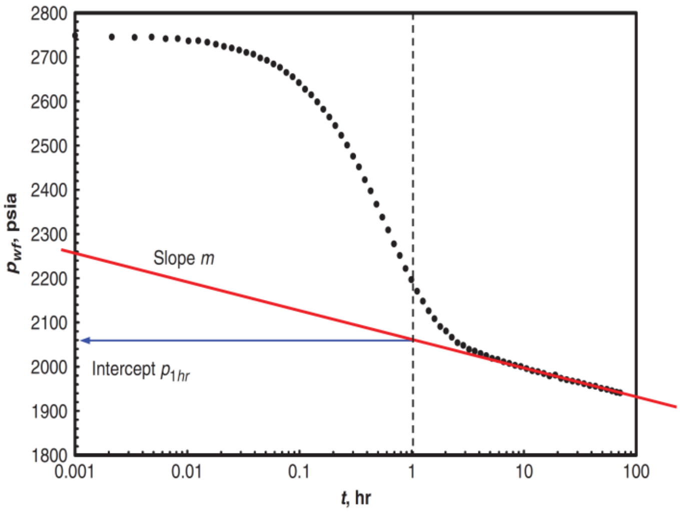

Figure 2. Semilog analysis for drawdown test (Spivey and Lee, 2013).

Calculate the skin factor s from the slope m and the intercept $p1hr$ as

$$s = 1.151\left\{\frac{p_i - p_{1hr}}{|m|} - \log\left(\frac{k}{\phi\mu c_t r_w^{\ 2}}\right) + 3.23\right\}. \quad (4)$$

Then calculate the radius of investigation at the beginning and end of the apparent semilog straight line (if needed) using the expression:

$$r_i = \sqrt{\frac{kt}{948\phi\mu c_t}}. \quad (5)$$

Another use of Drawdown tests is to estimate reservoir pore volume V_p. This is possible when the radius of investigation reaches all the boundaries during a test so that pseudosteady state is achieved. V_p is derived from;

$$\boldsymbol{V_p} = \frac{-0.234qB}{c_t\left(\frac{\partial p_{wf}}{\partial t}\right)} \quad (6)$$

Where $\left(\frac{\partial p_{wf}}{\partial t}\right)$ is the slope of straight line $\boldsymbol{p_{wf}}$ versus t plot on ordinary Cartesian graph paper.

The following Parameters where estimated in this study;

t* = the time at which strong wellbore storage effect ends.

50t* = the time at which wellbore storage effect ends and test results enters transient phase of the reservoir thereby yielding reservoir information.

C_s = Wellbore storage constant

k = Permeability; this is a measure of the inter connectivity of the pores in the formation.

S = Skin factor; this is used to evaluate the wellbore functionality.

V_p = Reservoir pore volume

The above method is basically known as Horner method after (Horner, 1951) and is strictly used for IARF. Alternative method as suggested by Miller-Dyes- Hutchinson (MDH) is often used interchangeably although it is usually recommended for finite-acting reservoirs. This study therefore involves both methods intentionally applied to validate results obtained; the Horner method was applied conventionally while the MDH method was done with the aid of Kappa Saphir software.

Data Analysis and Results

Table 1 is the table of pressure drawdown data from the study Well with additional reservoir parameters given as stated below;

r_w(Well radius) = 0.5ft

C_t(Totall compressibility) = 20 x10^{-6} psi^{-1}

q (Flow rate)= 1000 STB/D

h (Reservoir Thickness) = 50ft,

Bo (oil volume factor) = 1.125

μ (Oil viscosity) = 0.6cp ,

Φ (Porosity) = 0.25

An analysis table of (P_i - P_{wf}) and time was also generated from table1 from which the plots where raised. Figure 3 is a log – log plot for determining t*, 50t*, and C_s. It is evident that strong Well storage effect ended at about **0.0025hrs** and so Well bore storage effect would end completely at about 50t* which is

50 x 0.0025hrs = **1.25hrs**

Wellbore storage constant C_s is computed from;

$$Cs = \frac{qBt}{24\Delta p} \quad (7)$$

t/Δp is the t and Δp values from the unit slope line.

Thus from unit slope line in fig.3, ΔP_{wf} = 4.005 when t = 0.0008

Therefore , $Cs = \frac{1000\frac{STB}{D}\times 1.125\times 0.008hr}{24\times 4.005psi} = 9.3\times 10^{-3}$rb/psi

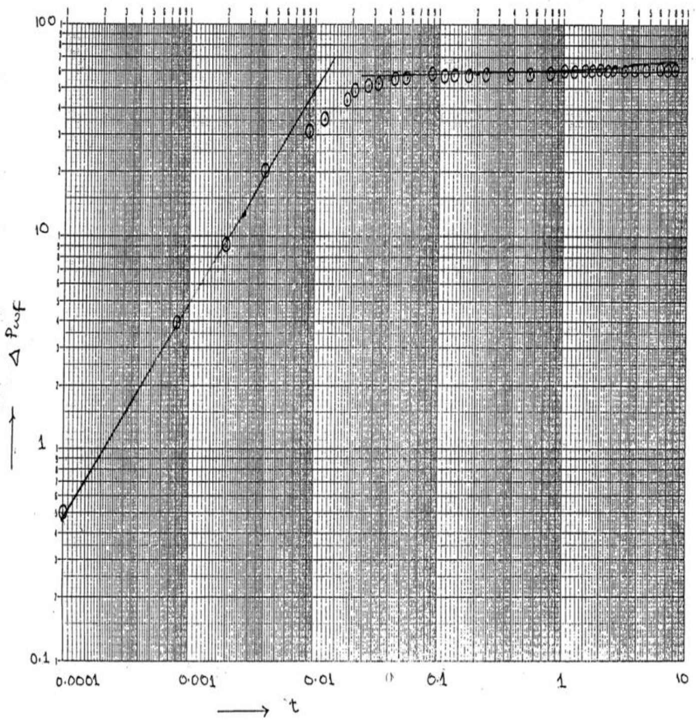

Figure 3. Conventional Log-Log plot.

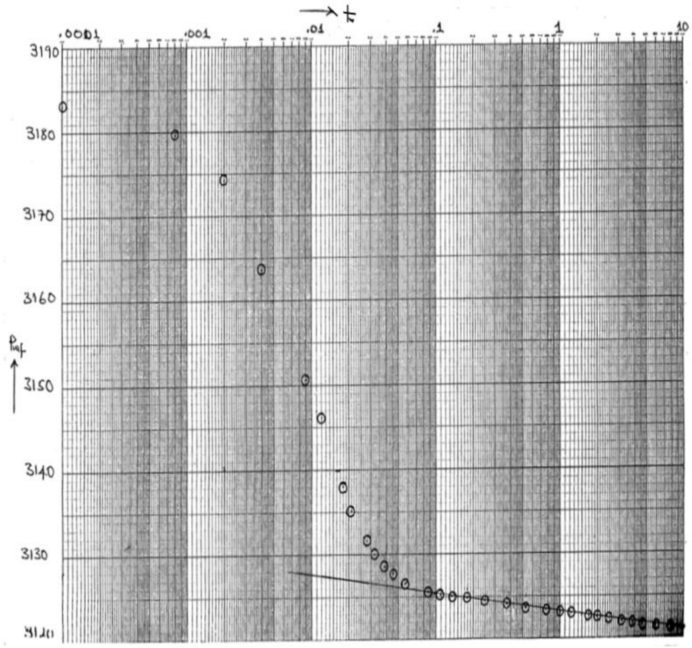

Figure 4. Conventional Semi-Log plot.

From figure 4, $m = \frac{3121.2-3123.5}{1\ cycle} = -\ 0.235$ psi /cycle

Therefore using equation (2),

$$k = \frac{-\ 162.6\ X\ 1000\frac{STB}{D} X\ 1.125\ X\ 0.6}{-0.235\ X\ 50ft}$$

k = 954.4 md

From Figure 4, P_{1hr} = 312.5 psi

P_i = 3183.763 (Initial Bottom Hole Pressure from table 1)

Applying equation (4) to find s;

$$s = 1.1513\left[\frac{3183.763-312.5}{-0.235} - log\frac{954.4}{0.25\ X\ 0.6\ X\ 20\ X10^{-6}\ X\ 0.5^2} + 3.23\right]$$

s = 23.4

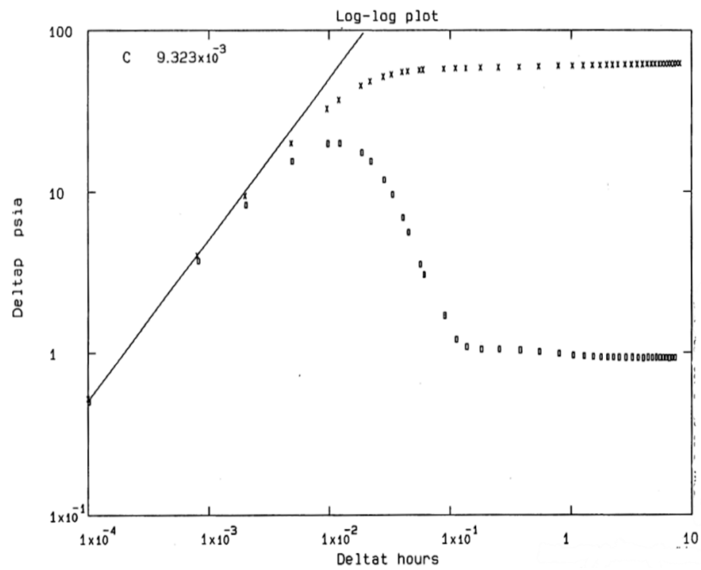

Figure 5. Computer Log-Log plot .

Figure 5 highlights a Cs value of $\mathbf{9.323X10^{-3}}$rb/psiwhile figure 6 depicts k and s values of 991.2md and 24.72 respectively. The table below summarizes the results obtained so far;

Table 1. Pressure Drawdown Data

Time.hr	Flowing Pressure.psi
.00000000E+00	3183.763
.10000000E-03	3183.245
.80000000E-03	3179.758
.20000000E-02	3174.302
.48000000E-02	3163.727
.96000000E-02	3150.896
.12000000E-01	3146.317
.18240000E-01	3138.186
.21600000E-01	3135.356
.27840000E-01	3131.839
.32400000E-01	3130.196
.39600000E-01	3128.530
.44400000E-01	3127.814
.55680000E-01	3126.796
.60000000E-01	3126.553
.88800010E-01	3125.731
.11040000E+00	3125.446
.13440000E+00	3125.224
.17760000E+00	3124.928
.24960000E+00	3124.572
.37440000E+00	3124.154
.53670000E+00	3123.788
.77760000E+00	3123.421
.10176000E+01	3123.157
.12576000E+01	3122.951
.14976000E+01	3122.781
.17376000E+01	3122.638
.19776000E+01	3122.513
.22176000E+01	3122.402
.24576000E+01	3122.303
.28176000E+01	3122.172
.31776000E+01	3122.056
.35376000E+01	3121.953
.38976000E+01	3121.860
.42576000E+01	3121.776
.46176000E+01	3121.698
.49776010E+01	3121.626
.53376010E+01	3121.559
.56976000E+01	3121.496
.60576000E+01	3121.438
.64176000E+01	3121.383
.67776000E+01	3121.330
.71376000E+01	3121.281
.74976000E+01	3121.234
.79536000E+01	3121.177

Table 2. Result Summary

Parameter	Conventional Method	Computer Method
Cs	9.3×10^{-3}rb/psi	$\mathbf{9.323X10^{-3}}$rb/psi
k	954.4 md	991.2md
s	23.4	24.72

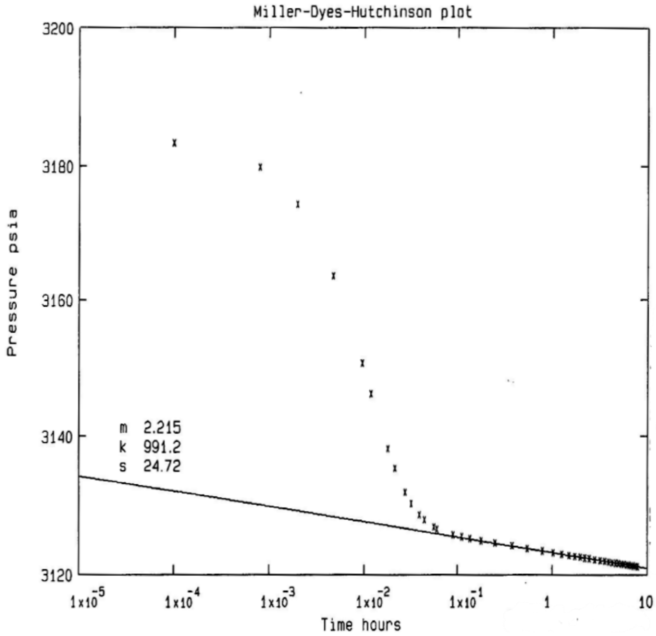

Figure 6. Computer Semi-Log plot (MDH).

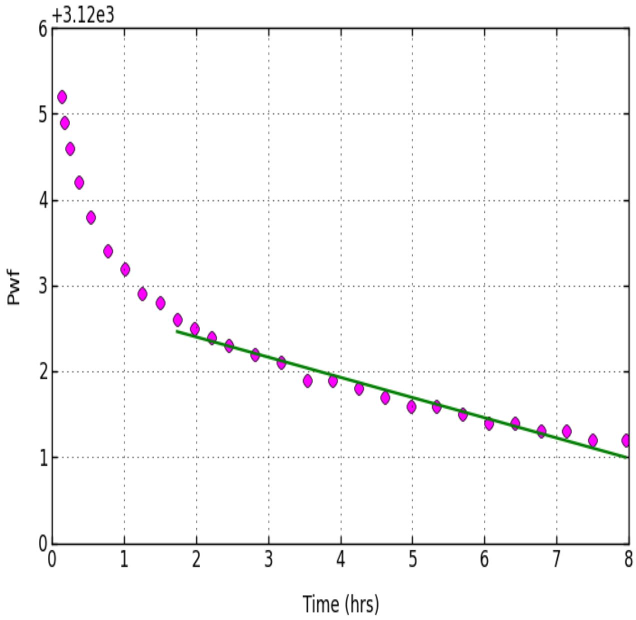

Figure 7. Cartesian plot for V_p computation.

Vp can be computed using the slope of the straight portion of fig. 7 and equation (6);

$$Vp = \frac{-0.234 \text{ x } 1000 \text{ x } 1.125}{20\text{x}10^{-6}\text{x } (-0.235)}$$

Vp = 56.01 x 10^6 cu ft or **8.45 x 10^6 res bbl**

Conclusion

The major advantage of conventional method is to be able to obtain t* and 50t* (a rule of thumb practice) which helps to obtain the time the wellbore storage effect dies out completely thereby heralding the beginning of the transient phase of the reservoir which carries information about the reservoir; this time is very helpful in making other computations about the Well and Reservoir.

Drawdown tests are mostly applied in exploratory wells because they yield reliable information about permeability (k) - a fit Well log Analysis may not level with; they also furnish Geophysicists with Pore volume Vp which helps in computations of reserve in place. Production Engineers are very interested in the value of skin (s) because it gives idea on the quality of Completion work done on the Well and further reveals whether stimulation is required. A positive skin value indicates some damage or influences that are impairing Well productivity.

The test analysis was used to obtain parameters like C_s, k, s and V_p efficiently but the s value of 24.72 means that flow in the Well is severely impaired.

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