Alternative technology for pressure test application on mature fields

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Abstract*– An important factor in the viability of mature fields projects, is the application of alternative technology that helps to optimize the process; operating times is perhaps the most important factor to take into account when referring to a project for this type of field. Technology such as that provided by echometer with its Total Well Management (TWM) software makes it possible to apply well tests in a fast and efficient way, since for this process it is not necessary to carry out Workover jobs, thus avoiding production losses due to well intervention, this is because it is equipment that is installed on the surface and is connected to the wellhead. This equipment determines the fluid column and consequently the bottom hole pressure (BHP), as well as an approximation of the reservoir pressure, formation damage (skin damage) and permeability. The application of technological alternatives is a successful way of knowing the reservoir behavior.

Keywords*— Reservoir pressure, optimizing operation, skin damage.

I. Introduction

The Gustavo Galindo Velasco oil field was the first one discovered in the Republic of Ecuador. In 2011, this field reached 100 years of hydrocarbon exploitation activity, and year by year its productivity has decreased, so it can be classified as a mature field. A field can be considered as mature when it has had many years with productive activities. As consequence, investment in technology is complicated due to its low productivity, and the period of investment recovering is long. For these reasons, is vital to carry out studies that allow to extend/increase the productive life of this field, being economically profitable.

For studying the behavior of a reservoir, there are useful methods for analyzing the changes or factors that directly affect the productivity of the well. Here are included pressure tests, that allow to determine the present pressure of the reservoir, permeability, possible formation damages, among others. However, there are two techniques that allow to take pressure tests in wells: (i) the Drawdown test, that is recommended to apply in wells that were recently drilled with the purpose of knowing the productive potential of the well, and (ii) the Build-up tests, that is used for determining some additional properties unlike the Drawdown test. Within the techniques for taking pressure tests, there are methodologies that, according to it functionality and operation, are more feasible to apply in a mature field. These are: conventional method (memory gauge) and unconventional method (echometer system). The main difference between them is clearly based on the facility that each one has for its applicability and interpretation of the data.

Fig. 1, Well analyzer and computer
Source: Pacifpetrol S.A., 2018

With the application of the unconventional method in a mature field, it is possible to determine properties that allow characterizing and analyzing a reservoir; these properties are: formation damage, permeability and present reservoir pressure.

Fig. 2, Gas gun
Source: Pacifpetrol S.A., 2018

II. Methods and materials

The unconventional methodology consists of an equipment whose work does not require the input of any tool to bottom of well. The echometer system, it is the equipment that makes this process possible, due to its working modality requires only tools installed and monitored from the surface [1].

The components echometer system are:

- Gas gun (nitrogen or CO_2).
- Computer or Laptop with Total Well Management (TWM) software.

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- Well Analyzer or box that digitizes the shot draw.
- Gas supply.
- Batteries.
- Pressure transducer.
- Microphone and coaxial cable.

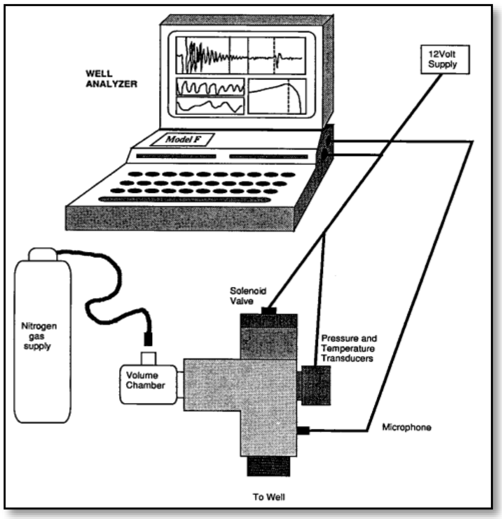

Fig. 3, Echometer system schematic diagram
Source: Pressure Transient Digital Data Acquisition and Analysis from Acoustic Echometric Survey in Pumping Wells [2]

This equipment works with a gas gun, which is responsible for executing, receiving, and transmitting the wave of the shot that is generated, through a microphone and a cable connected to the Well Analyzer. This component's main function is to analyze and convert acoustic signals into digital signals, to later be relayed to the computer where through the Total Well Management (TWM) software. It is possible to interpret the data obtained, by means of the casing pressure graphs, bottom pressure, acoustic velocity, among others, regarding the duration of the test, all this due to the dynamic interface present in the software.

The process and evaluation of the transient pressure test require an understanding of the methods that the echometer software uses. Among these methods, there are those that determine the initial reservoir pressure (pressure at which the hydrocarbon is confined and the pressure at which the reservoir was found) and those that determine the average reservoir pressure [3] [4].

Horner's method- This method uses P* to extrapolate the line from Horner graph.

$$\frac{kh(p_i - p_{ws})}{141.2 q\mu B} = \frac{1}{2}\ln\left(\frac{t+\Delta t}{\Delta t}\right) + p_D(t+\Delta t)_D - \frac{1}{2}[ln(t+\Delta t)_D + 0.80907] \quad (1)$$

Miller - Dyes - Hutchinson method (MDH)- The closure pressure versus logarithm of closure time results in a line with a slope proportional to kh (permeability thickness).

$$\frac{kh(\bar{p} - p_{ws})}{141.2 q\mu B} = p_D(t+\Delta t)_D - p_D(\Delta t)_D - 2\pi t_{DA} \quad (2)$$

III. PROCESS AND DESIGN FOR APPLICATION OF BUILDUP TEST

The process consists of three stages: 1. Well selection, data collection and calculations required for the software, 2. Site preparation and test application 3. test data analysis.

Stage 1

Candidate wells for a pressure test must meet the following characteristics:

Well selection:

- Present state of well (Productive).
- Cumulative production.
- Producing wells in the Santo Tomas or Atlanta formation. (only one formation).
- Artificial lift system: Sucker rod pump or Swab.
- Wells belonging to section 67, 68 and 73, due to only from these sections the PVT properties could be collected.
- The slotted casing must not be too extensive (max. 500 ft).

Data collection and calculations required:

- Review the file well of selected wells for PVT and pressure data collection [5][6].

Table 1. Data collection

Data collection	
rw (ft)	Bg
uo (cp)	Np
uw (cp)	Co
ug	Cw
ρo (lb/ft³)	Cg
Ø (frac)	Soi
k (md)	Sor
Boi	h (ft)
Bw	skin

Source: Balceca O., 2019 [9]

- Calculations required

Table 2. Calculations required

Calculations required	
re (m)	Ct
Ad (acre)	Cs
Aw (ft²)	Csd
dg	Twbs (hr)
Cf	Twbs (d)
C	

Source: Balceca O., 2019

Stage 2

Site preparation and test application.

- Check the tightness of wells.
- 2-inch diameter well valves must be free from corrosion or damage.
- Provide an electrical energy source for the equipment (batteries or vehicle).

- Perform an equipment test to verify operating conditions (cables, gas gun, laptop, well analyzer, gas supply, pressure transducer).
- Perform the installation and uninstallation of echometer system according to the TWM manual.
- Constant monitoring of the state well in order to prevent possible leaks.

Stage 3

Analysis and interpretation of the results

- Correction of data obtained.
- Analyze the respective graphs of TWM software.
    - Casing pressure versus Time.
    - BHP (Bottomhole Pressure) versus Time.
    - Liquid level versus Time.
    - Acoustic velocity versus Time.
    - Log Log Plot of Pressure variation versus Time variation.
    - MDH plot of BHP versus Time variation.
    - Horner plot of BHP versus (Tp + ΔT)/ ΔT.
- Interpretation of data obtained from TWM software.
    - Cs, storage coefficient.
    - Csd, Additional storage coefficient.
    - Pressure derived.
    - Formation damage.
    - Effective permeability of oil, water and gas.
    - Conductivity.
    - Reservoir pressure.

For the transient pressure test design, it is necessary to mention concepts and equations, which allow an efficient development and application of the test [7].

Dimensionless variables- The dimensionless variables and its use in the hydrocarbon industry, particularly in the process for a reservoir evaluation, facilitate the mathematical operations of the parameters that are handled, due to it does not present units. the equations on which it is based are:

Dimensionless Radius

$$r_D = \frac{r}{r_w} \qquad r_{eD} = \frac{r_e}{r_w} \tag{3}$$

r_w= Wellbore radius (ft).
r_e= Drainage area Radius (ft).

Dimensionless Time

$$t_D = \frac{0{,}0002637kt}{\emptyset \mu C_t r_w^2} \tag{4}$$

C_t = Total compressibility (psi^{-1}).
k = Permeability (md).
μ = Fluid viscosity in the well (cp).
$\emptyset$ = Porosity (%).
t = Time (hours).
r_w^2 = Wellbore radius (ft^2).

According to well geometry, dimensionless time is defined by the following equation.

$$t_{DA} = \frac{0{,}0002637kt}{\emptyset \mu C_t A} = t_D = \frac{r_w^2}{A} \tag{5}$$

C_t = Total compressibility (psi^{-1}).
k = Permeability (md).
μ = Fluid viscosity in the well (cp).
$\emptyset$ = Porosity (%).
t = Time (hours).
A = Drainage area (ft^2).

Dimensionless Pressure

$$P_D = \frac{kh}{141.2qB\mu}\left(pi - p_{wf}\right) \tag{6}$$

k = Permeability (md).
q = Well production rate (STB/d).
B = Volume factor (Vol res / Vol std).
μ = Fluid viscosity in the well (cp).
h = Thickness (ft).
pi = Reservoir initial pressure (psia).
p_{wf} = Flowing bottomhole pressure (psia).

Storage Coefficient- It is a parameter that facilitates the quantification of the so-called storage effect or Wellbore Storage and is defined with the following equation:

$$C_s = \frac{\Delta v}{\Delta p} = \frac{v_i - v_{(t)}}{p_i - p_{wf(t)}} \tag{7}$$

Δv = Differential volume.
Δp = Differential pressure.
v_i = Initial volume of fluid in the well before discharge.
$v_{(t)}$ = Volume variation in the well during the discharge of the fluid.
p_i = Initial pressure in the well before discharge.
$p_{wf(t)}$ = Pressure variation in the well during the discharge.
p_{wf} = Flowing bottomhole pressure (psia).

Regarding the storage coefficient, which is calculated in the process of preparing the pressure test, there are many formulas for calculating this parameter; for this article we work with the equation that involves two phases (liquid and gaseous) [8].

$$C_s = 25.65\frac{A_{wb}}{\rho_{wb}} \tag{8}$$

A_{wb} = Wellbore area (ft^2).
ρ_{wb} = Fluid density in the well (lb/ft^3).

Storage time- Time where the contribution from the reservoir to well fills the column with fluid.

$$t_{wbs} = \frac{(200000+12000s)C_s}{kh/\mu} \tag{9}$$

C_S = Storage Coefficient (bbl/psi).
s = Skin.
k = Permeability (md).

h = Thickness from Net Pay (ft).
μ = Fluid viscosity in the well (cp).

Radius of Investigation- Distance inside the formation at which the pressure wave has been determined, this as a function of time.

$$r_{inv} = \left(\frac{kt}{948 \emptyset \mu C_t}\right)^{1/2} \quad (10)$$

k = Permeability (md).
t = Time (hours).
$\emptyset$ = Porosity (%).
C_t = Total compressibility (psi^{-1}).
μ = Fluid viscosity in the well (cp).

Due to there are wells that were fractured in previous years, it is important to mention the types of fractures, in order to perform a correct analysis of the data and the graphs. There are 3 types of fractures, these are [9]:

1. Finite conductivity vertical fracture- It is a type of flat fracture, which generates a pressure falloff greater than zero during production.
2. Infinite conductivity vertical fracture- It is a type of flat fracture, which generates zero or negligible a pressure falloff during production.
3. Uniform flow vertical fracture- These types of fractures are similar to infinite conductivity fractures, but with the difference that the flow of the formation is linear.

IV. RESULTS

Once the necessary parameters had been established and obtained, only three wells met the optimal conditions. (see table 3).

Table 3. Candidate Wells table to TPT

	Sucker Rod Pump	SWAB	
	SOUTH - ST	SOUTH - ST	SOUTH - ST
	68	68	68
	PGWELL1	PGWELL3	PGWELL2
re (m)	63,784	50,074	37,328
Ad (acre)	3,157	1,946	1,081
rw (ft)	0,318	0,354	0,318
Aw (ft²)	0,317	0,394	0,317
uo (cp)	1,386	1,386	1,839
uw (cp)	0,761	0,761	0,757
Ug (cp)	0,011	0,011	0,010
ρo (lb/ft³)	51,066	51,066	51,933
dg	1,753	1,753	1,080
Ø (frac)	0,090	0,09	0,09
k (md)	6,000	6	6
Boi	1,140	1,140	1,140
Bw	1,003	1,003	1,004
Bg	0,033	0,033	0,053
Np	154866,080	43254,141	56417,672
Co	1,191E-05	1,191E-05	9,965E-06
Cw	3,152E-06	3,152E-06	3,152E-06
Cg	0,0045	0,0045	0,0093
Soi	0,500	0,5	0,5
Sor	0,200	0,2	0,2
h (ft)	267	121	284
Cf	7,473E-06	7,473E-06	7,473E-06
C	7,531E-06	7,531E-06	6,558E-06
Ct	1,938E-05	1,938E-05	1,743E-05
Cs	0,1540	0,1913	0,1534
skin	2	2	2
Csd	2914,595	6431,38	3034,66
Twbs (hr)	30,06	82,43	37,28
Twbs (d)	1,25	3,43	1,55
r invs (ft)	279,47	462,79	285,17
r invs (m)	85,18	141,06	86,92

Source: Balceca O., 2019

The results obtained from the three candidate wells with the application of the transient pressure test (TPT) are presented below:

Well PGWELL1 – Results

Figure 7 shows pressures of 23.9 psia in the casing and 124.2 psia of BHP respectively at a depth of 2480 ft, also in figure 8 and 9 it was determined that the end of the test was premature, because the fluid column did not stabilize, this is verified with the pressure values (BHP) measured that are increasing.

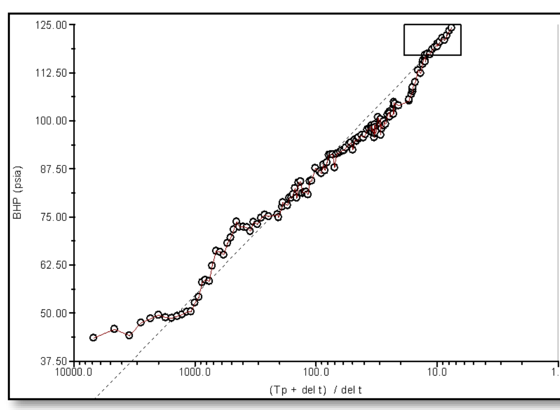

Fig. 4, Horner plot: BHP vs Time Variation
Source: TWM Software., 2019

Well PGWELL2 – Results

In Figure 10 it can be seen that the maximum casing pressure reached was 65.09 psig and the maximum bottomhole pressure (BHP) was 206.07 psia, at a depth of 2307 ft. In figure 12 with a mean slope (0,5) an infinite conductivity fracture is determined, on the other hand, in the MDH and Horner plots (figures 13 and 14), the beginning of pressure stabilization is observed, with this we found s = – 2.95 and P* = 225.6 psia.

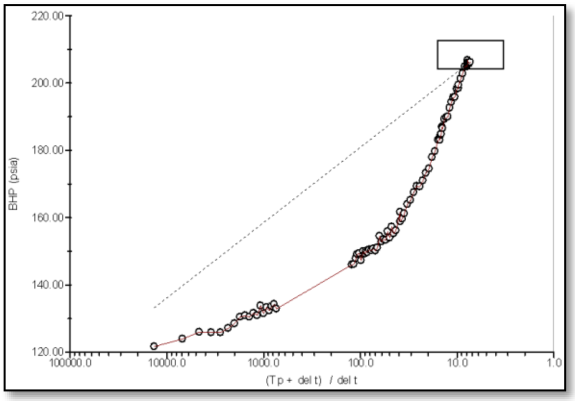

Fig. 5, Horner plot: BHP vs Time Variation
Source: TWM Software., 2019

Well PGWELL3 – Results

The results obtained can be seen in figure 15 with a casing pressure of 157 psi and a flowing bottomhole pressure of 283 psia. By means of the MDH and Horner methods (figures 17 and 18 respectively) the stabilization of the pressure is clearly appreciated, making it easy to determine the parameters of interest, so the formation damage is -3.365 on average and a reservoir pressure of 314.7 psi. It is important to mention that the real value of the storage coefficient (0.6917) can be determined, thus calculating the necessary time in which the reservoir pressure begins to stabilize (See Annexes, Table 4).

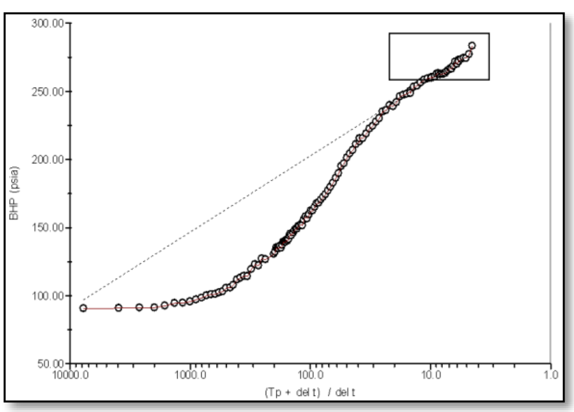

Fig. 6, Horner plot: BHP vs Time Variation
Source: TWM Software., 2019

V. CONCLUSIONS

According to the analysis performed with the echometer system in section 68 of the GGV oil field, it was obtained that for the three wells the current reservoir pressure varies between 220 to 314 psia and the pressure in 1963 was 440 psia, therefore, you can conclude that the initial pressure of the reservoir was relatively low and this pressure has not decreased much in this amount of time, this was also due to the low production that the well has had.

The skin factor obtained from this case study field varies between -3.5 to -2.5, this it can be concluded that the reservoir has no significant damage in the production formation.

It is essential that for mature field development it is necessary to optimize equipment, processes and logistics in order to reduce operational times and costs, thus optimizing the number of daily work stages.

VI. RECOMMENDATIONS

Carry out extensive build-up tests, greater than 6 days to get the storage phase and the pressure (BHP) to stabilize, to release a better understanding of the behavior of the well.

Obtain current data about production historical, fluid, and rock parameters to get realistic results.

Implement a schedule to apply transient pressure tests, according to the evaluation of the formation that has been most damaged.

VII. ACKNOWLEDGMENT

To Pacifpetrol for opening its doors to us do this research.

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ANNEXES

Table 4. Storage times before and after from Transient Pressure Test

	Theoretical calculation			TWM software calculation		
	SUCKER ROD PUMP	SWAB		SUCKER ROD PUMP	SWAB	
	SOUTH - ST	SOUTH - ST	SOUTH - ST	SOUTH - ST	SOUTH - ST	SOUTH - ST
	68	68	68	68	68	68
	PGWELL1	PGWELL3	PGWELL2	PGWELL1	PGWELL3	PGWELL2
Cs	2914.59	6431.38	3034.66	0	0.691763	0.644134
Twbs (hr)	31.67	86.85	39.28	0	298.04	156.55
Twbs (d)	1.32	3.62	1.64	0	12.42	6.52

Source: Balceca O., 2019

WELL PGWELL1

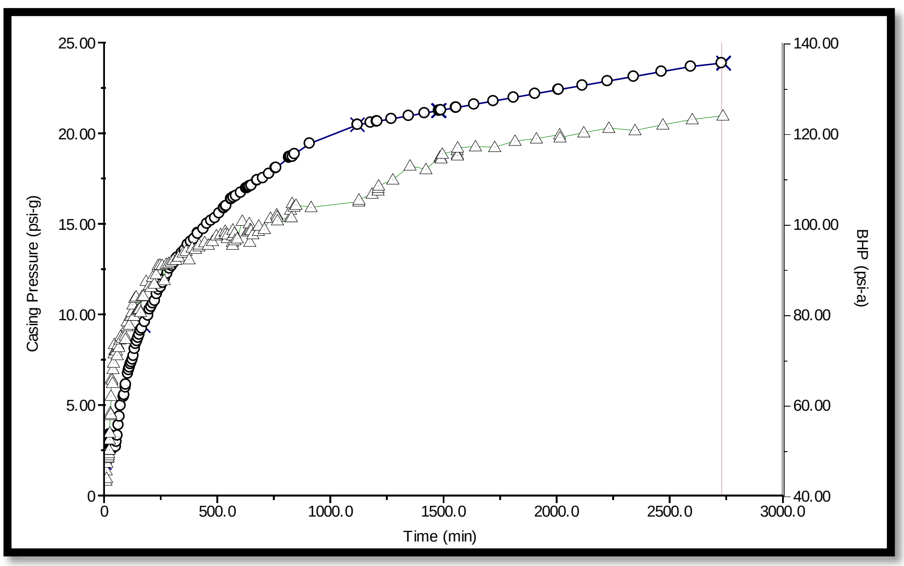

Fig. 7, Casing Pressure (circles) and BHP (triangles) vs Time
Source: TWM Software., 2019

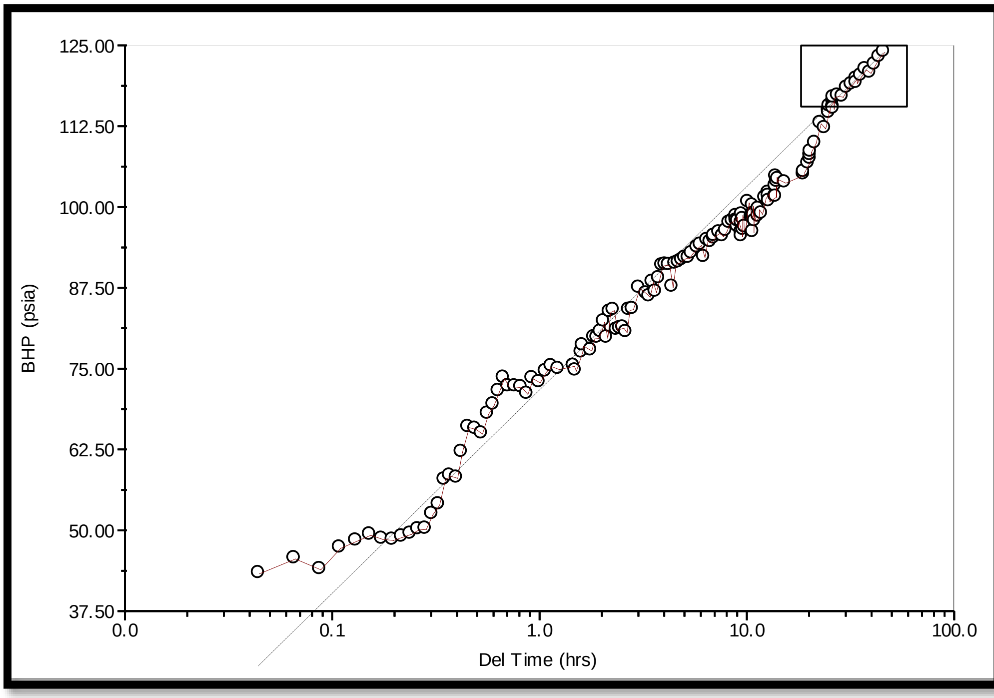

Fig. 8, MDH Plot: BHP vs Time Variation
Source: TWM Software., 2019

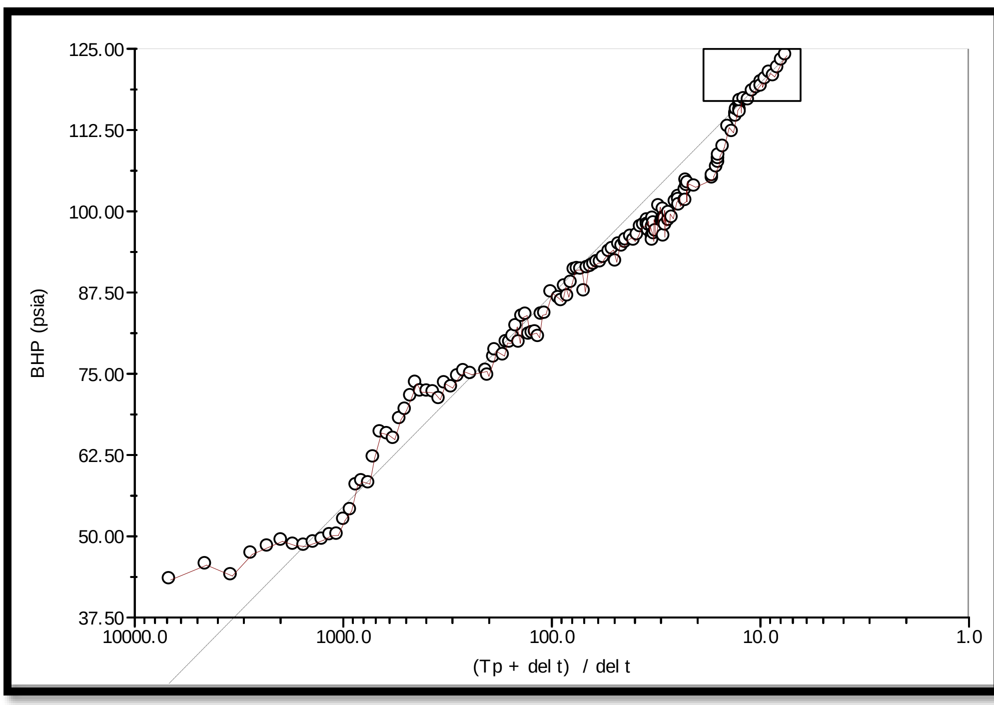

Fig. 9, Horner Plot: BHP vs Time Variation
Source: TWM Software., 2019

WELL PGWELL2

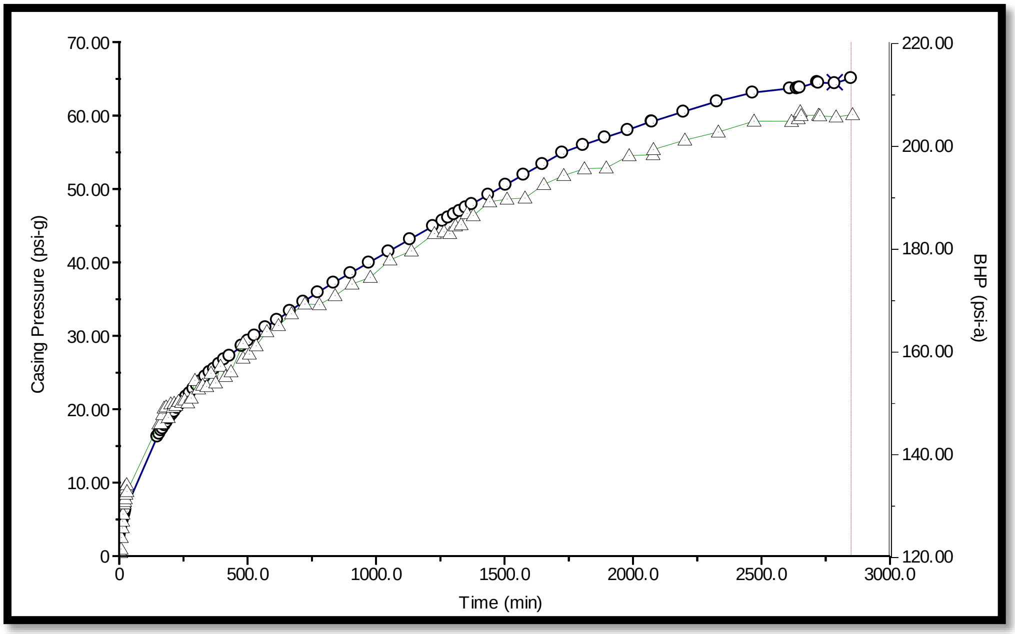

Fig. 10, Casing Pressure (circles) and BHP (triangles) vs Time
Source: TWM Software., 2019

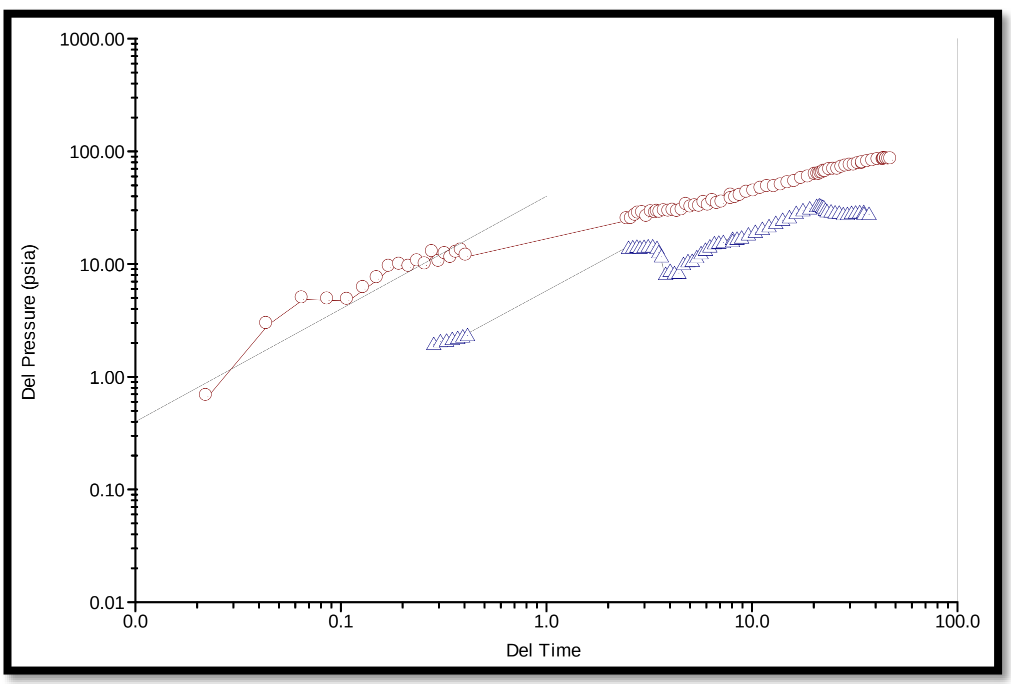

Fig. 11, Pressure Variation (circles) vs Time variation. Derived from pressure (triangles) vs Time variation
Source: TWM Software., 2019

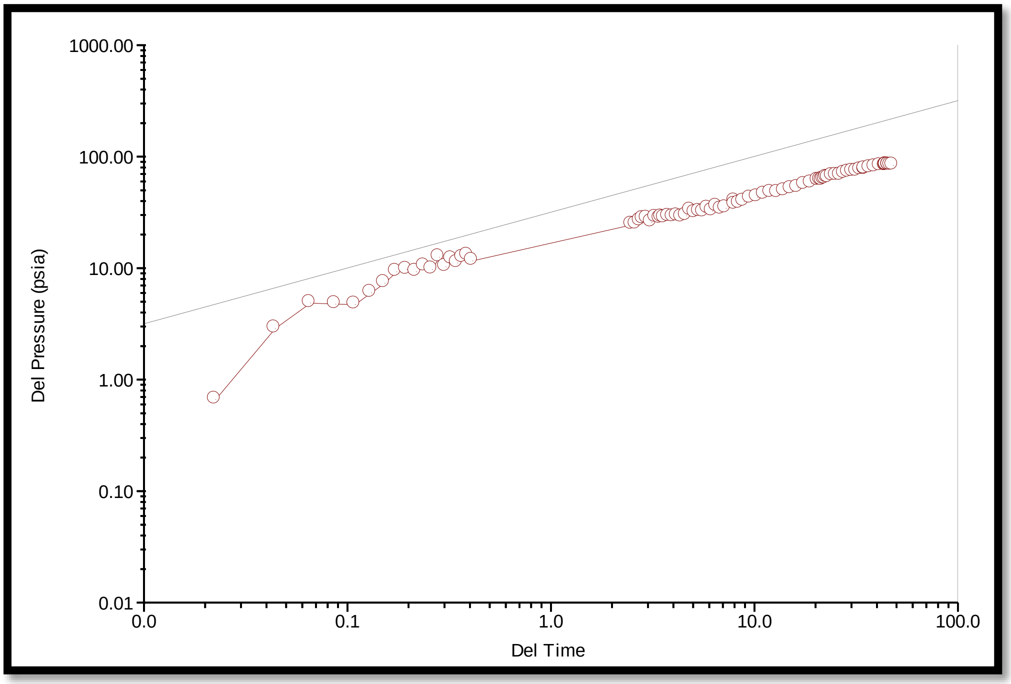

Fig. 12, Pressure Variation (circles) vs Time variation
Source: TWM Software., 2019

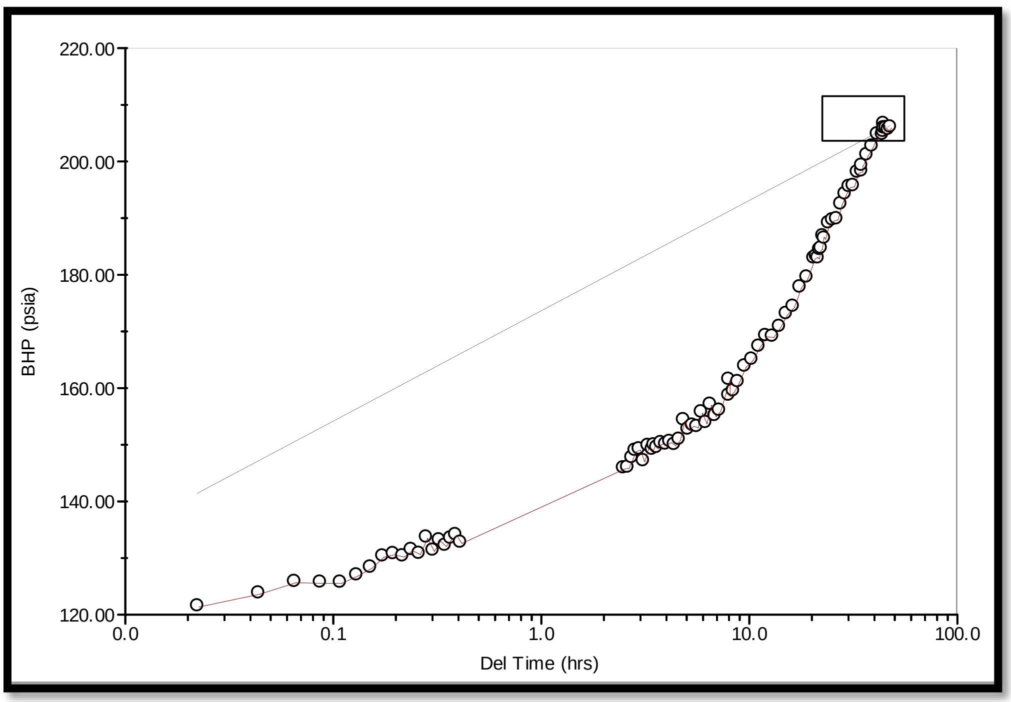

Fig. 13, MDH Plot: BHP vs Time Variation
Source: TWM Software., 2019

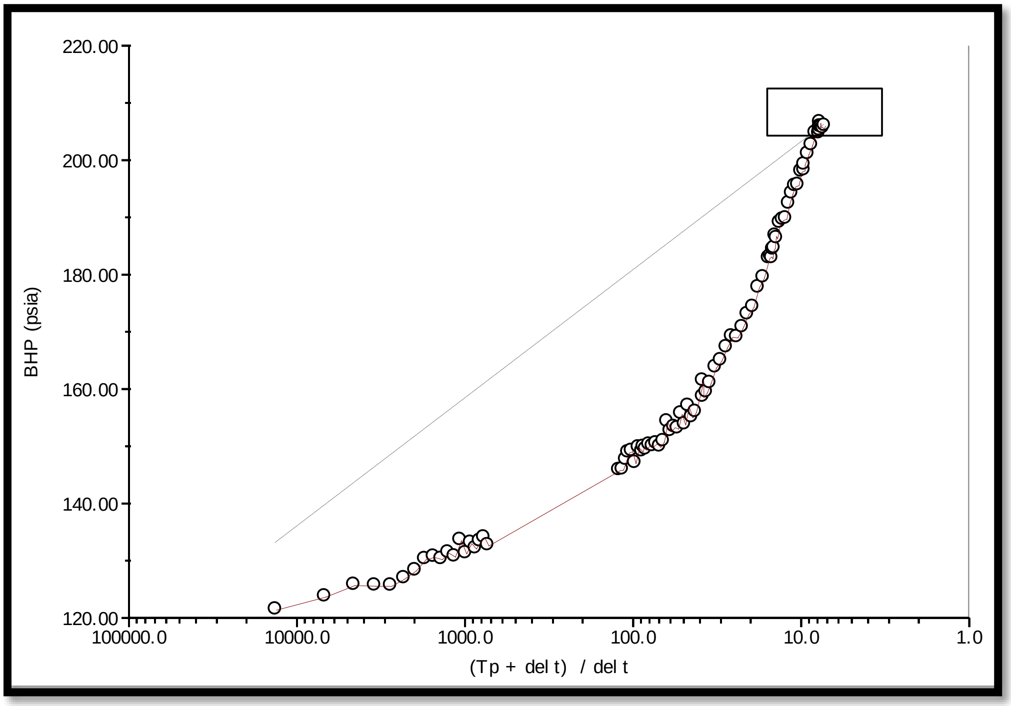

Fig. 14, BHP vs Time Variation
Source: TWM Software., 2019

WELL PGWELL3

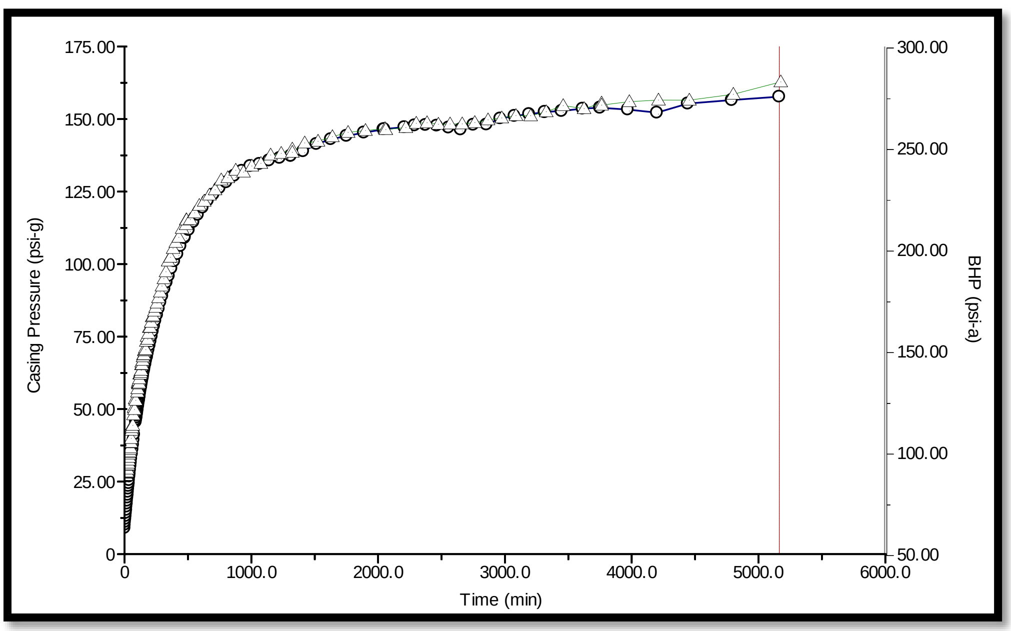

Fig. 15, Casing Pressure (circles) y BHP (triangles) vs Time
Source: TWM Software., 2019

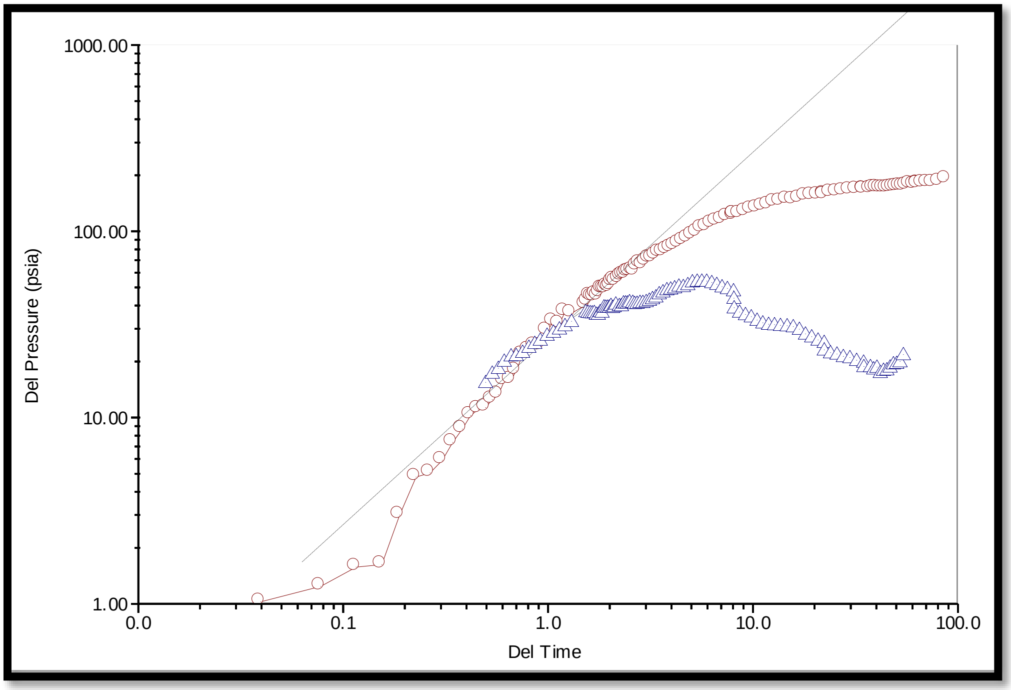

Fig. 16, Pressure Variation (circles) vs Time Variation: Slightly corrected. Derived from pressure (triangles) vs Time variation
Source: TWM Software., 2019

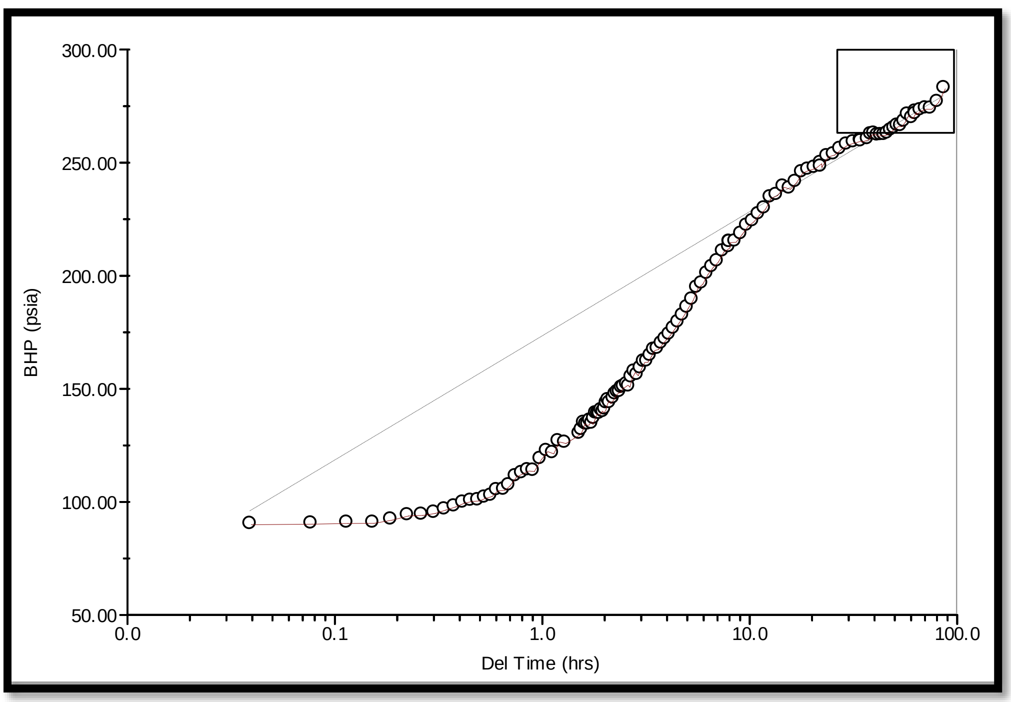

Fig. 17, MDH Plot: BHP vs Time Variation
Source: TWM Software., 2019

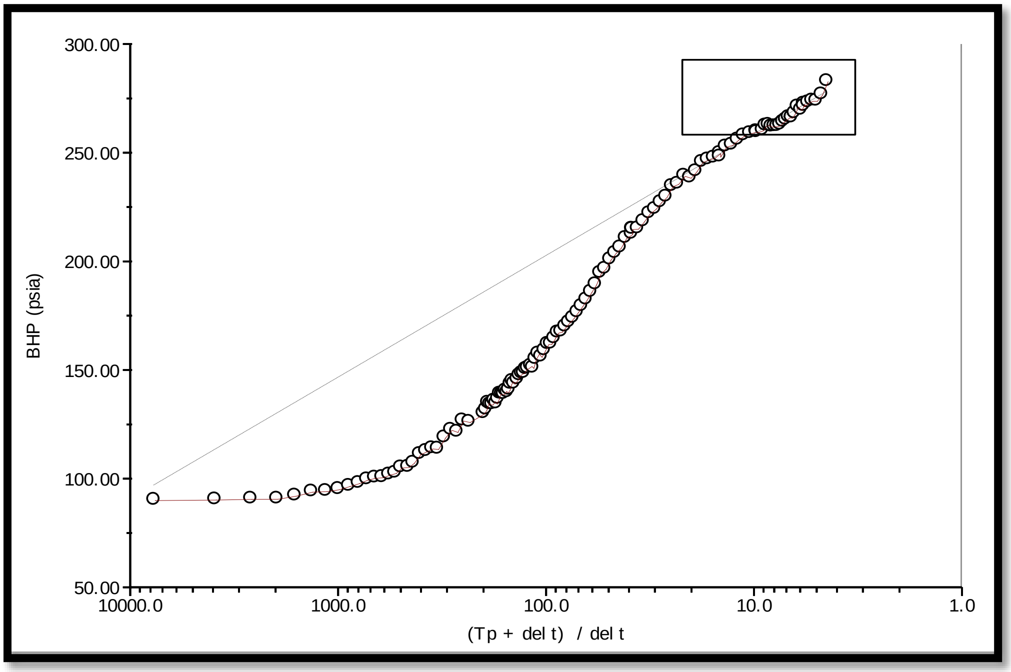

Fig. 18, Horner Plot: BHP vs Time Variation
Source: TWM Software., 2019